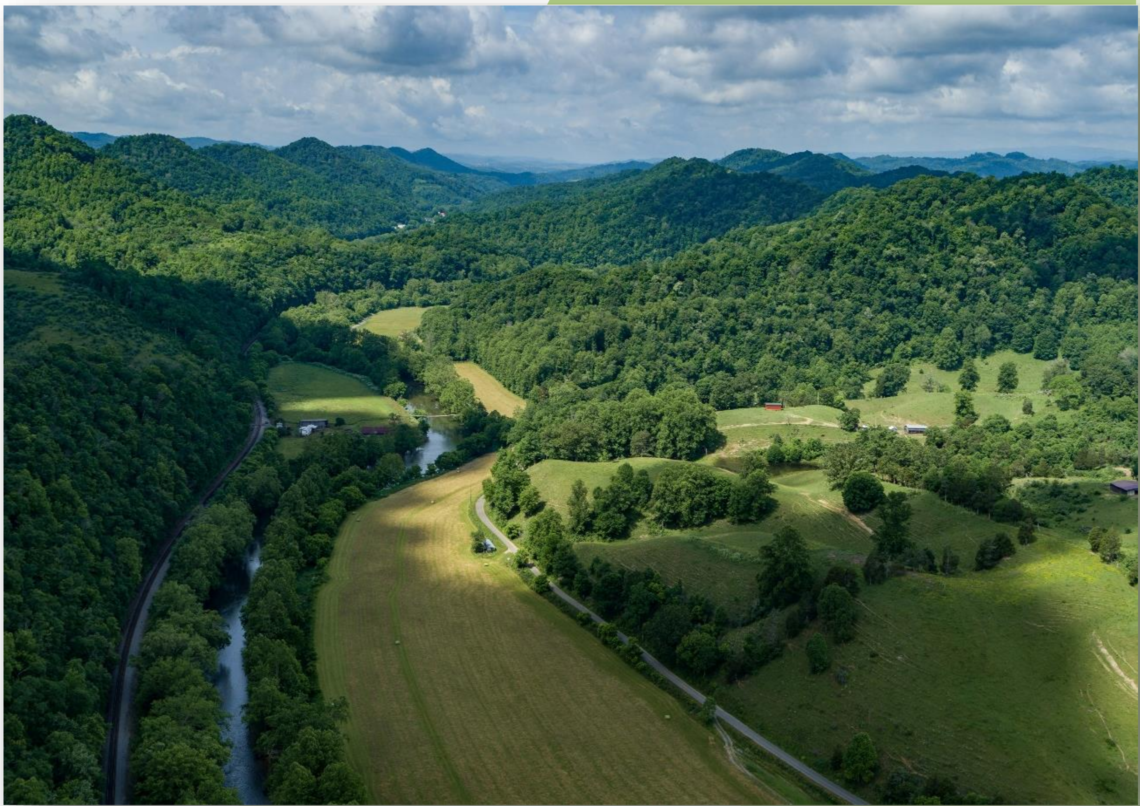
Conservation Status of Natural Habitats

in the Northeast

2023



Mark G. Anderson, Melissa Clark, Arlene Olivero

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For more information on CRCS and to access the report and data, visit: http://crcs.tnc.org

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About the Cover:

Photo Credit: © Cameron Davidson; Aerrial image of Clinch River near Artrip, Virginia with the rolling mountains of Central Appalachia in the background. The Cumberland Forest Project protects 253,000 acres of Appalachian forest in Tennessee, Kentucky, and Virginia and is one of TNC's largest-ever conservation efforts in the eastern United States.

3/2/2023

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Conservation Status of
Natural Habitats in the Northeast

Northeast Association of Fish & Wildlife Agencies

The Nature Conservancy

Executive Summary

The Northeast states share a long history of conservation and collaboration. The region's extensive forests, wetlands, rivers, and coastline cross state boundaries, and a tradition of working together to understand and conserve them has evolved. In 2008, the Northeast Association of Fish and Wildlife Agencies (NEAFWA) and its partners developed a multi-state monitoring framework to take stock of the condition and conservation of the species and habitats that characterize the region. In 2011, The Nature Conservancy (TNC), working with NEAFWA, produced the first regional application of the framework in the report: "*Conservation Status of Fish, Wildlife, and Natural Habitats in the Northeast*".

Synthesizing over 50 region-wide datasets, analyzing the underlying patterns, and assessing the indicators suggested by the monitoring framework, the 2011 status report presented a comprehensive and multidimensional picture of the state of the natural world across the 14-state NEAFWA Region: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Washington D.C.

This document is an update to the 2011 report. In it we focus on conservation progress and trends in the last decade (2012-2022). Original indicators were revisited where the source data had the resolution and detail to allow us to detect change. Additionally, we added new metrics or revised old ones, where improved data allowed us to backcast one or two decades to detect trends.

DATA HIGHLIGHTS

- A completely revised **conservation land dataset**, developed collaboratively with state offices, and with "date conserved" added for most records since 2011
- Remotely sensed **time-sequence data** on land cover change, forest turnover, and anthropogenic fragmentation
- New and computationally intensive **tools** for measuring local connectedness, regional connectivity, and stream integrated protection
- A revised **dam dataset** and detailed information on stream nutrient enrichment
- A **template** for exploring marsh migration and the conservation of migration space
- **Models** of climate resilience, connectivity, recognized biodiversity areas, and carbon stocks

This work was guided by a steering committee led by Jon Kart of Vermont Fish and Wildlife Department and representing eight states and the regional office. We gratefully acknowledge their help, guidance, and suggestions.

CENTER FOR RESILIENT CONSERVATION SCIENCE

Mark Anderson, Melissa Clark, Arlene Olivero. February, 2023

KEY FINDINGS

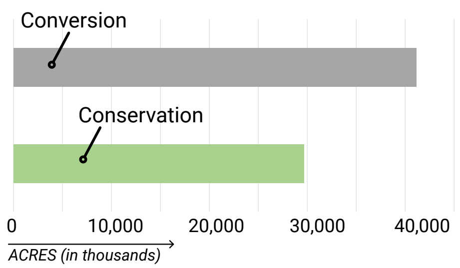
The following key findings are organized but the thematic chapters of the report. See the full chapter for detail on the methods and results.

CONSERVATION LANDS

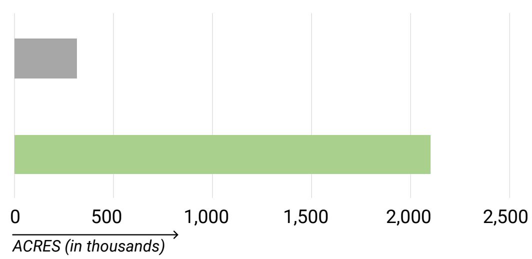
Historically, 26% of the region's natural land has been converted to development or agriculture, while 19% has been conserved for nature or multiple uses. This equals 1.4 acres converted for every acre conserved . **Over the last decade, this trend has reversed** with 6.7 acres *conserved* for every one acre converted since 2012.

The region now boasts 29 million acres of conservation land, with 2.1 million acres conserved in the last decade. Private conservation organizations accounted for half of the new conservation land, with 62% being easements and 38% fee acquisitions. Most of the new conservation lands (76%) were secured for multiple uses like recreation and forest management, while 24% were conserved primarily for nature.

ALL YEARS | 1800-2022



LAST 10 YEARS | 2012-2022

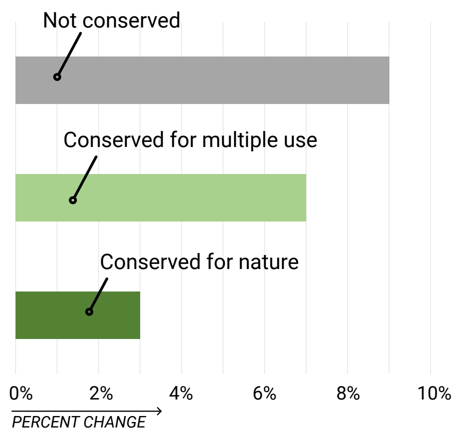


FORESTS

The region was once 91% forested but is now 61% forested with most of that permanently converted. Of the remaining forest, 24% is secured against further conversion, a ratio of 1.6 acres converted for every acre conserved.

Over the last 20 years, 8 million acres of forest have changed markedly: 57% have returned to forest after active turnover from logging or natural disturbances, 28% remains in other natural land cover, and 1% was converted to development or agriculture, a conversion rate of 35,000 acres per year. **Land conserved primarily for nature has seen much less forest change** (3%) than land conserved for multiple uses (7%) or unconserved land (9%).

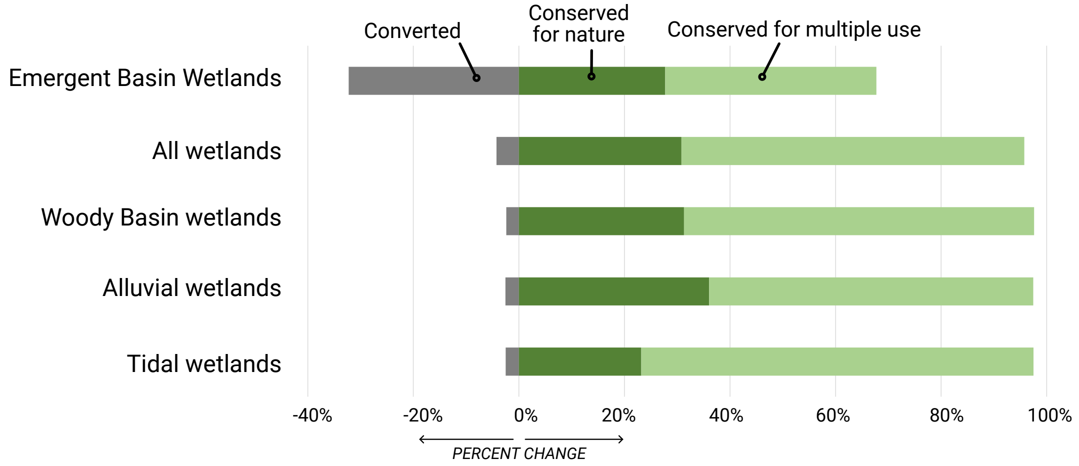
AMOUNT OF FOREST TURNOVER AND CHANGE | 2001-2022



WETLANDS

Twenty-one million acres of the region were once covered by swamp, peatlands, floodplain, and marsh supporting over 1,000 types of wetland dependent species. Now, 27% of that has been converted or drained, but 20% of the remaining wetlands are under conservation. In the last two decades regulations have further prevented wetland conversion. As a result, **wetland conservation in the last two decades surpassed conversion almost 25 to 1, reversing the historic trend**. Emergent marshes remain the wetland type most at risk.

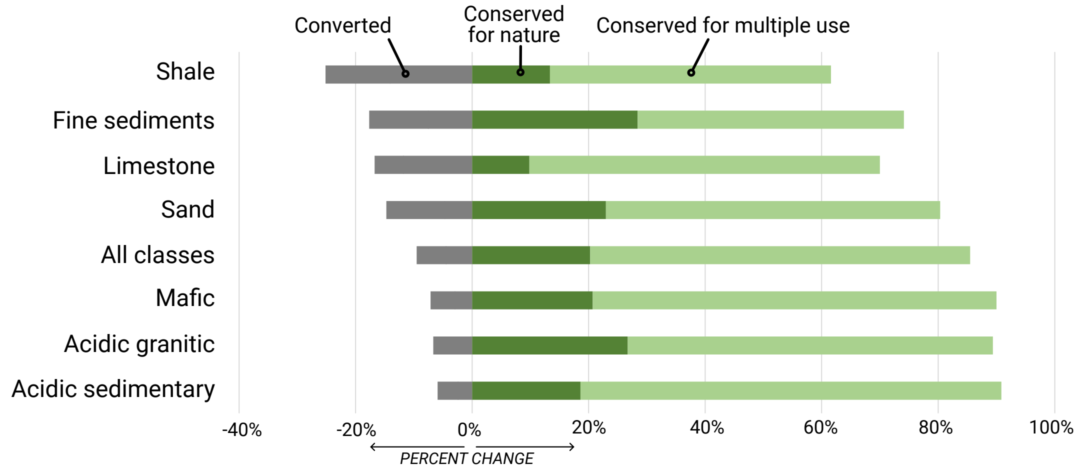
WETLAND CONSERVATION AND CONVERSION | 2001-2022



UNIQUE HABITATS

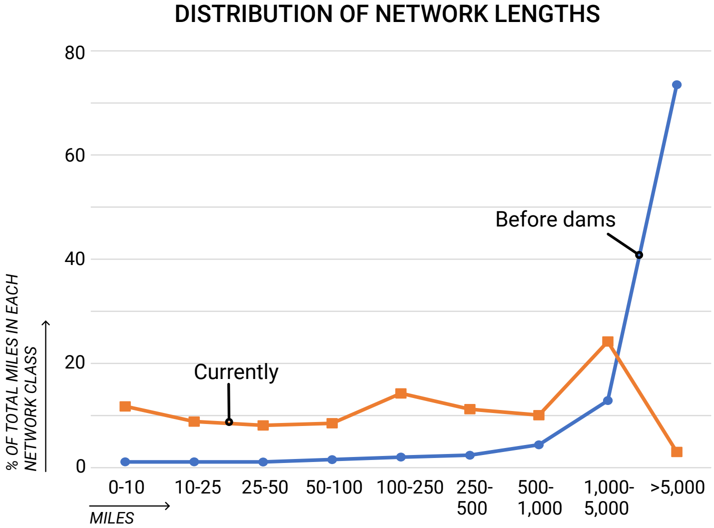
Conservation and conversion have not been distributed equally. In high elevation and granite bedrock areas conservation has exceeded conversion, but in low elevation regions with fertile soils derived from limestone or sand, conversion exceeds conservation eight to one. In the last decade this pattern has reversed with **conservation surpassing conversion across every soil type and elevation zone**. New conservation lands are a mix of multiple-use and nature focused reserves. Shale environments have had the most conversion.

CONSERVATION AND CONVERSION BY GEOLOGY CLASS | 2012-2022



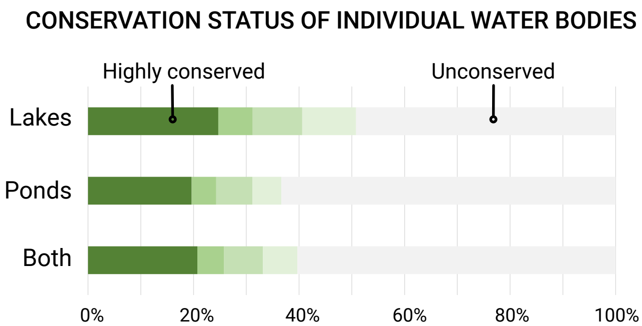
STREAMS AND RIVERS

The region's 200,000 miles of streams and rivers support thousands of species. In total, 23% of all stream miles are locally conserved, however, **only 6% have the upstream watershed conservation needed to achieve integrated protection**. Further, 14,000 dam's fragment the stream networks into segments averaging 7 dams per 100 miles. As a result, 86% of river miles are in networks less than a quarter of their pre-dam size, 21% are less than 25 miles long, and 48% are significantly altered in their hydrology. In the last decade, 346 dams were removed, opening at least 3,500 miles. This increases to over 5,000 miles of reconnected river and stream networks if we account for retrofitted or partially passable dams.



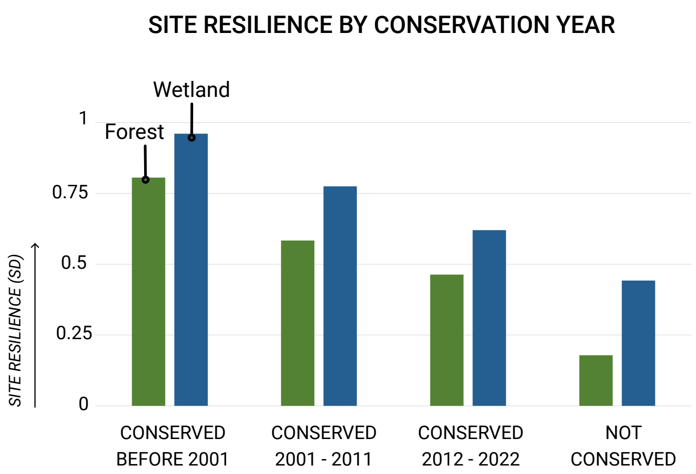
LAKES AND PONDS

Of the regions 35,000 lakes and ponds, **21% have most of their shoreline conserved**. Over the last decade, another 446 waterbodies have joined this group and another 800 have shown increased conservation of their shorelines.



CLIMATE RESILIENCE

Site resilience is a measure of a site's microclimatic buffering which help plants and wildlife persist under a changing climate. Quantitative scores for forest and wetlands on **conservation lands** suggest that they **are more resilient than their unconserved counterparts**, and that the resilience of older conservation lands is higher than the new conservation land. This likely reflects increasing levels of fragmentation across the whole region.



AMERICA THE BEAUTIFUL AND 30 BY 30

The global Convention on Biodiversity have targeted 30% of Earth to be formally protected by 2030. In the U.S., the Biden Administration's America the Beautiful initiative calls for us to work collaboratively to conserve and restore the lands, waters, and wildlife that support and sustain the nation, and to conserve 30 percent of US lands and waters by 2030.

The Nature Conservancy (TNC) has mapped a spatial blueprint for conservation that covers 34% and integrates the key principles of representation, resilience, connectivity, biodiversity, and carbon. TNC's Resilient and Connected Network (RCN) **provides an ecologically meaningful blueprint for how to distribute the conservation lands**. Collectively the **region is 19% conserved by *area*** if multi-use (GAP 3) conservation lands are included. The **RCN is 38% conserved, and averages 42% conserved by state**. Current conservation lands contain 25% of the region's forest carbon securing the stock from conversion and allowing further sequestration.

State	% Area GAP 1	% Area GAP 2	% Area GAP 3	% Area Conserved	% RCN Conserved	% Forest Carbon Conserved	Total Acres
CT	1%	4%	12%	17%	39%	20%	3,183,447
DC	0%	0%	20%	20%	100%	42%	39,988
DE	1%	4%	13%	18%	49%	30%	1,266,542
MA	3%	5%	16%	24%	46%	32%	5,200,573
MD	0%	2%	16%	18%	41%	30%	6,351,377
ME	2%	3%	16%	21%	28%	22%	20,824,982
NH	5%	8%	20%	33%	49%	36%	5,931,243
NJ	0%	13%	11%	24%	59%	37%	4,843,101
NY	9%	1%	9%	20%	46%	27%	31,055,902
PA	1%	1%	16%	18%	49%	26%	28,986,981
RI	1%	14%	5%	20%	38%	26%	697,220
VA	2%	3%	12%	17%	43%	26%	25,616,295
VT	3%	2%	16%	22%	36%	26%	6,153,095
WV	1%	2%	9%	11%	21%	13%	15,506,478
Region	3%	3%	13%	19%	38%	25%	**155,657,223**

To read and download the report, click HERE.

Please cite as: *Anderson, M.G., Clark, M. and A. Olivero. 2023. Conservation Status of Natural Habitats in the Northeast. The Nature Conservancy, Center for Resilient Conservation Science. Newburyport, MA.*

For more information on CRCS and to access the report and data, visit: http://crcs.tnc.org

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CHAPTER

Introduction

1

Understanding and Using the Report

Feb 2023

M.G. Anderson, A. Olivero and M Clark

The Northeast and Mid-Atlantic states share a long history of conservation and collaboration. The region's forests, wetlands, rivers, and coastline are extensive, but because they cross state boundaries, a tradition of working together to understand and conserve them has evolved. In 2008, the Northeast Association of Fish and Wildlife Agencies (NEAFWA) and its partners developed a multi-state monitoring framework to take stock of the condition and conservation of the species and habitats that characterize the region. The report was intended to inform decision makers and managers on how individual states were faring, as well as how the region was performing

- Monitoring the Conservation of Fish and Wildlife in the Northeast: A Report on the Monitoring and Performance Reporting Framework for the Northeast Association of Fish and Wildlife Agencies**.** *(*Tomajer et al. 2008)

In 2011, The Nature Conservancy, working with NEAFWA, produced the first regional application of the framework:

- Conservation Status of Fish, Wildlife, and Natural Habitats in the Northeast Landscape: Implementation of the Northeast Monitoring Framework. (Anderson and Olivero 2011)

Compiling region-wide data, analyzing the underlying patterns, and assessing the indicators suggested by the monitoring framework, this report presented a comprehensive and multidimensional picture of the state of the natural world in the Northeast. It was through the creation of that report we first became aware of several conservation challenges such as the fragmentation of our rivers, bird declines in forests, and the pervasive footprint of land conversion. At the same time, we became aware of the growth and reach of our collective land and water conservation network.

This report is an update to the 2011 Conservation Status report focused on progress and change in the last decade from 2012-2022. Not every indicator was revisited, only those where the source data had the resolution and detail to allow us to detect change, and that was the majority. Additionally, we added new metrics, or revised old ones, where we had better data that allowed us to backcast ten or twenty years to detect trends. Data highlights include:

- A completely revised conservation land dataset, developed collaboratively with state offices, and with "date conserved" added for most records since 2011
- Remotely sensed time-sequence data on land cover change, forest turnover, and anthropogenic fragmentation
- Computationally intensive tools for measuring local connectedness, regional connectivity, and stream integrated protection
- A revised dam dataset and detailed information on stream nutrient enrichment
- A template for exploring marsh migration and measuring the conservation of migration space
- Models of climate resilience, connectivity, recognized biodiversity areas, and carbon stocks

In addition to this written report, we have prepared excel spreadsheets to accompany each chapter and allow users to explore the data for their local geographies, or for the whole region.

The NEAFWA region includes Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, Washington D.C. and West Virginia. In these states, Fish and Wildlife agency members are responsible for managing species and their habitats in a diverse range of ecosystems that include terrestrial, freshwater, coastal, and marine systems, all set amongst one of the most densely populated regions of the country.

All thirteen states and DC have developed State Wildlife Action Plans (SWAPs) that represent a collective vision for the future of conservation. SWAPs are proactive plans that assess the condition of each state's wildlife, identify the problems they face, and prescribe actions to conserve wildlife and vital habitats before they become more rare and costly to protect. As SWAPs form the underlying basis of the monitoring framework, we hope the findings from this report, and the detailed state-by-state data tables will be useful to, and incorporated in, the next round of plans.

Methods and Approach

The monitoring framework intentionally focused on using existing data and information, rather than requiring new sets of data, to keep its recommendations simple and manageable, and allow for the type of decadal revisit that this plan represents. Nevertheless, implementing the recommendations required the compilation and management of over 50 datasets, and inevitably some needed thorough revision or had to be created anew from state sources for this report (e.g. conservation lands). Whenever possible we worked directly with the people who created and managed the source data to ensure that we were using it correctly. A few of the data originators, such as Matthew Neilson of U.S. Geological Survey Nonindigenous Aquatic Species (NAS) Program who extracted and summarized data for the northeast states and Erik Martin of The Nature Conservancy who assisted with compiling and updating dams in the northeast, merit our thanks and acknowledgment. We are grateful for the help and goodwill we received, and any errors in the analysis or interpretation are solely our own.

This report was completed over a shorter time frame than the original and we were guided by smaller but essential eight-state steering committee. The committee met bimonthly and reviewed our workplan, data summaries, and preliminary results. As the project moved fast, the steering committee was also where we reported problems, discuss alternative solutions, and approved decisions concerning scope and content.

We are indebted to the our Conservation Status 2.0 Steering Committee team including Jon Kart of Vermont Fish and Wildlife Department (lead), Cathy Haffner of the Pennsylvania Game Commission, Lisa Williams of Pennsylvania Game Commission, Gwen Brewer of Maryland Department of Natural Resources, John Herbert of Rhode Island Department of Environmental Management, Samantha Robinson of Delaware Department of Natural Resources and Environmental Control., Sandra Houghton of New Hampshire Fish and Game Department, Steve Walker of Maine Department of Inland Fisheries and Wildlife, Justin Schlawin of Maine Natural Areas Program, Dee Blanton of U.S. Fish and Wildlife Service, Elizabeth Crisfield of Strategic Stewardship Initiative, and Karen Terwilliger and Tracy Rice of Terwilliger Consulting Inc.

Organization of the Report

This report covers the proposed status measures for seven conservation targets:

- Conservation Lands
- Eastern Forests
- Freshwater Wetlands
- Unique Habitats
- Streams and Rivers
- Lakes and Ponds
- Climate Resilience

We did not revise the chapter on Regionally Significant Species of Greatest Conservation Need because we and the steering committee agreed that what was compiled in 2011 still stands, and it would take more effort than we had available to collect all new data and detect change over the last decade. The same is true for the bird trends we had embedded within each habitat chapter. The 2011 results are still relevant and recent summaries are available from USGS Breeding Bird Survey https://www.pwrc.usgs.gov/bbs/

As with the 2011 report we did not assess managed grassland or shrublands, or highly migratory species because good regional scale indicators have not yet been proposed by the monitoring team, nor did we find off-the-shelf usable datasets to detect trends in these systems. This is a good area for research.

We maintained the added chapter on conservation lands to highlight the overall and recent patterns of land conservation for the region, and clarify the concepts of securement, protection, management, and designation. These concepts are essential for understanding the area-based conservation that now underlies the Biden Administration's America the Beautiful initiative and the Global 30 by 30 movement. They are also essential to understanding the state and status of habitats in the Northeast, and our more important findings relate to how well the network of conservation land is working (or not working) with respect to certain targets.

Similarly, we added a new chapter on climate resilience, to assess how well the conservation land network has been able to encompass resilient land, connectivity, marsh migration space, and carbon. These topics were not in the 2008 monitoring framework but are relevant to conservation today.

The chapters are organized around the habitat types with a summary of findings on the first page. Each chapter begins with basic statistics on the target habitat, then looks at conversion and conservation rates across time, and across the last decade. Each of the various indicators is addressed, with an emphasis on identifying trends from the last decade or two. The results include charts, tables, maps, and accompanying excel data tables for detailed state-by-state information.

Compiling this report has been eye-opening both to the huge challenges we are facing and to the collective progress we have made on sustaining the region's habitats and wildlife. We hope this information will be useful to others who care about the natural world and we welcome comments, questions, suggestions, criticism, or other feedback.

CHAPTER

Conservation Lands 2

In the Northeast and Mid-Atlantic Feb 2023

A. Olivero, M. Clark, & M. Anderson

Covering 19% of the region, conservation lands represent a permanent commitment to nature and demonstrate what can be achieved through collective effort. They provide core protections for the region's outstanding habitats and threatened species and are increasingly understood as essential providers of ecosystem services and storehouses of the land's biological resources. Even as the region's ecology adjusts in response to a changing climate, conservation lands play a critical role in maintaining arenas for evolution and provide people with the opportunity and rewards of direct contact with nature.

Eastern Conservation Lands At-A- Glance	
Total Acres	29,669,493
Percent of the Region	19.06%
Number of Fee Owners	5,129
Average size of Ownership	4,393 Acres
Number of Easements	69,446
Average size of Easement	111 Acres
Number of Individual Tracts/Polygons	260,968

Definitions:

Conserved: Lands permanently secured against conversion to development = **GAP status 1 - 3**

Conserved for Nature: A secured area intended for biodiversity or nature conservation = **GAP status 1 or 2**

Conserved for Multiple Uses: A secured area intended for multiple uses such as forest management and recreation = **GAP status 3**

Conservation Land: Nineteen percent of the region is conserved against conversion to development with 6% of the land area protected explicitly for nature (GAP 1 & 2) and 13% for multiple use (GAP 3). Conservation lands are held by over 5,000 fee owners and 1,400 easement holders with state government (12 M ac.) being the largest fee owner, followed by the federal government (6 M ac.), county and local government (1.3 M ac.), and private non-profits (1.2 M ac.). Private non-profits hold the most easement land (3.6 M ac.) followed by state (3.1 M ac.), local (400 K ac.), and federal (200 K ac.).

Habitat Loss versus Conservation: In total, 26% of the region has been converted to development or agriculture, compared to the 19% conserved. Thus, 1.4 acres of natural habitat have been lost for every acre of land conserved.

Recent Trends (2012-2022): In the last decade, the collective efforts of over a hundred organizations and agencies have resulted in **2.1 million acres of new conservation land**. Easements accounted for 1.3 million acres and fee ownership for 780,000 acres. New conservation was achieved primarily by private NGOs (1.1 M ac), accounting for over half of the fee (406 K) and easement acreage (738 K).

For perhaps the first time, the area of **land conservation surpassed habitat loss by a ratio of 6 to 1.** For every one acre of land conserved, 0.15 acres of land were converted to agriculture or development. This pattern held true across almost every state. Three New England states had ratios over 15 to 1.

Background: Land and water permanently maintained in a natural state remains the most effective, long lasting, and essential tool for conserving species and habitats. By regulating the use of land and water within a network of places, conservation can sustain species populations and prevent habitat degradation at larger scales. Although most conservation lands are in a natural or semi-natural state, they are far from uniform. Individual places are governed by a variety of public and private fee owners and easement holders, with a wide range of management intents. As conservation has grown in sophistication, the tools for conserving land have greatly expanded in scope and versatility. Forever-wild reserves are but one end of a spectrum of conservation lands representing an array of restrictions, intents, designations, tenures, easements, interest holders, and ownership types.

The evolution of land and water protection to encompass a broad palette of uses and restrictions is one of the more interesting and practical advances in conservation. Ideally, it offers a credible pathway for creating natural infrastructure at a large scale with a diverse set of players. Moreover, it is a necessary response to the increasingly complex nature of the environmental crisis and the challenge of sustaining all the benefits and services provided by nature. However, monitoring is required to ensure that conservation land performs the functions we expect, with low quality or marginalized habitat unlikely to sustain the full spectrum of plants and wildlife.

In this section, we define the types of conservation land in a standardized way and then examine the general patterns of conservation across the region. In other chapters, conservation lands are examined in relation to natural features such as forests, wetlands, non-forested uplands, rivers, and lakes. Thus, the terms and data described in this chapter form the basis of understanding the other chapters in this report.

Definition of Conservation Land

In this report "**conservation land**" refers to land that is permanently secured against conversion to development. This definition was adopted by an international group of American and Canadian scientists to encompass a wide variety of public and private ownership and management types. It goes beyond the more restrictive IUCN definition of "protected areas" which refers to land with a government designation aimed at the conservation of nature. Our definition includes public land designated for conservation, but also includes land with no formal designation if the intent of the landowner or easement holder (public, private, or NGO) is for permanent conservation, and if there is a measurable capacity to fulfill the intent. For example, a permanent conservation easement held by an established land trust qualifies here as conservation land even though it is privately held and has no designation. Conversely, the definition excludes some formally designated areas, such as the Champlain-Adirondack Biosphere Reserve, if there is no conservation intent or means for sustaining permanent conservation.

The Nature Conservancy's Conserved Land Dataset

The Nature Conservancy (TNC) has been tracking and compiling information on conservation lands in the Northeast and Mid-Atlantic regions for over 20 years. TNC's Conserved Land Dataset is compiled bi-annually from over sixty state, federal, and private sources (CRCS 2022, Appendix 2.3). The foundation of the dataset is public land information maintained by each state, supplemented by federal land information from PAD-US (PAD-US 2022) and private conservation land information compiled by TNC's state field offices. State-based TNC staff compile the data for their state, assign a TNC/GAP status to each tract, and populate other standard attribute fields (Table 2.1). The completed state datasets are regionally compiled by TNC's Center for Resilient Conservation Science (CRCS), and quality checked for consistency and discrepancies. Importantly, TNC's dataset is focused on permanent conservation and only includes land where the intent of the owner or easement holder is conservation in perpetuity and there is some legal capacity to fulfill that intent. Thus, places with important temporary, volunteer, or one-time conservation activities are not included in the dataset. The requirement for permanent protection is not based on an ecological justification, it is simply beyond our capacity to track and maintain information on non-permanent ownerships that are constantly in flux.

During this project we made an extra effort to compile a thorough dataset and to populate the "date conserved" field with a focus on the last ten years. The final dataset will be posted for public use and submitted to the national Protected Areas Database US (PAD-US) and the National Conservation Easement Database (NCED) to become part of these national datasets of conservation lands.

<u>Conservation Lands and GAP Status</u>
Three factors - intent, duration, and potential to manage effectively - form what the Nature Conservancy internally calls a tract's Conservation Management Status (CMS), which is roughly synonymous to the U.S. Forest Service's **GAP status** (Crist et al. 1998). The relationship between the two classifications is straightforward in the United States because governments and land-owning organizations already meet standards for appropriate governance, and by definition, have the potential for effective long-term management. Further, as the TNC dataset is focused on permanent conservation, the duration is always permanent. Therefore, GAP status and CMS in this dataset are determined primarily by intent and degree of management. As GAP status is widely used in the U.S., we use it as our primary reporting standard in this document. The definitions of the GAP categories and their crosswalk to CMS (Box 1) are modified from Crist et al. (1998); original definitions are provided in Appendix 2.

In this report, we use the term "*conserved land*" to refer to the total amount of land secured against conversion, including both strict nature reserves (GAP 1 & 2) and multiple-use public lands and easements (GAP 3). We use "*conserved for nature*" to refer to GAP 1 & 2 lands only. These are lands where the primary intent is the conservation of nature such as breeding habitat for wildlife or places where forests can grow old and develop mature characteristics. We use "*conserved for multiple uses*" to refer to land secured against conversion, but for which the primary intent includes recreation and resource extraction, as well as conservation of nature. These lands vary greatly in their habitat quality depending on the individual, organization, or agency which owns and manages them.

Box 2.1. Definitions of GAP categories and their crosswalk to TNC's Conservation Management Status (CMS). CMS designations are bolded and italicized. Definitions are modified by TNC for ease of assignment, original GAP definitions are in Appendix 2.

Conserved**:** GAP Status 1, 2 and 3

Conserved for Nature: Conservation land where the primary intent is the conservation of nature.

- **GAP 1. Permanently Secured for Nature and Natural Processes**
  An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state where the area is allowed to "self-adjust" over time. Primary intention of the owner or easement holder is for biodiversity and nature protection. <u>Land and water managed through natural processes including disturbances with little or no human intervention.</u>
- **GAP 2. Permanently Secured for Nature with Management**
  An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state, but which receives hands-on management. Primary intention of the owner or easement holder is for biodiversity and nature protection. <u>Land and water managed with hands-on manipulation of processes, species composition, and disturbance.</u>

Conserved for Multiple Uses: Conservation land where the primary intent is multiple use.

- **GAP 3. Permanently Secured for Multiple Uses including extraction and recreation.**
  An area having permanent protection from conversion of natural land cover, but the <u>primary intention of the owner or easement holder is for **multiple uses**</u>, which may include biodiversity but also recreation and certain extractive uses. Extractive uses may include either a broad, low-intensity type (e.g., logging) or localized intense type (e.g., mining).

Conserved for Agriculture: Conservation land where the primary intent is the preservation of farmland.

- **GAP 39. Agricultural Easement**
  Land in a permanent agricultural easement or easement to maintain grass (e.g., vegetable farm with permanent easement to prevent development).

Not Conserved:

- **GAP 4. Unsecured**
  Temporary easement lands (e.g., CREP 5-year term, similar X-year term agreements with landowners) and/or municipal lands (school yards, golf courses, soccer fields, ball fields, town commons) where intention in management and use is not biodiversity protection.

Table 2.1. Description of fields in The Nature Conservancy's Conservation Land dataset.

2022 Conservation Land Field Name	Description of Fields in Conservation Land
STATE_PROV	Two-letter state/province postal abbreviation
AREA_NAME	Common name of secured area
FEE_OWNER	Name of the fee owner
FEE_ORGTYP	Organization type of the Fee Owner: FED: Federal, TRIB: Native American Lands, STAT: State, DIST :Regional Agency Special District, LOC: Local Government, NGO: Non-Governmental Organization, PVT: Private, JNT: Joint, UNK: Unknown, TERR: Territorial, DESG: Designation
INT_HOLDER	Name of entity holding additional interest in property
INT_ORGTYP	Organization type of Interest Owner: FED: Federal, TRIB: Native American Lands, STAT: State, DIST: Regional Agency Special District, LOC: Local Government, NGO: Non-Governmental Organization, PVT: Private, JNT: Joint, UNK: Unknown, TERR: Territorial, DESG: Designation
INT_TYPE	Type of Interest held by Interest Owner: Fee Ownership, Conservation Easement, Deed Restrictions, Deed Restrictions - Monitoring Required, Deed Restrictions - No Monitoring Required, Management Lease or Agreement, Timber Lease or Agreement, Grazing Lease, Grazing Permit, Life Estate, Right of Way Tract, Access Right of Way, Assist, Assist - Fee Ownership, Assist - Conservation Easement, Assist - Deed Restriction, Transfer, Transfer - Fee Ownership, Transfer - Conservation Easement, Transfer - Deed Restriction, Transfer - Life Estate, Transfer - Management Lease or Agreement, Transfer - Agreement, Other
ST_DESIG	The original designation as populated by the states. Could also be used to hold key information about other state types or coding.
DESIGNAT	Designation for management unit (state designations translated into generic categories for regional use): ACE- Area of Critical Environmental Concern; AGE - Agricultural Easement, CE - Conservation Easement, CRL-Crown Lands, EDU - Educational Lands (School, University), FL - Federal Land (including Military), HCA - Historic or Cultural Area, IRA-Inventoried Roadless Area, LCA-Local Conservation Area, MF - Municipal Forest, ML - Municipal Land, MP - Municipal Park, MPA - Marine Protected Area, NAT - Nature Reserve/ Preserve/ Sanctuary, NCA-National Conservation Area, NF - National Forest, NG-National Grassland, NM - National Monument, NP - National Park, NRA - National Recreation Area, NS - National Seashore, NWA - National Wilderness Area, NWR - National Wildlife Refuge, PCL - Private Conserved Land, RNA - Research Natural Area, SF - State Forest, SL - State Land, SP - State Park, TL - Tribal Land, WAT - Water, WMA - Wildlife Management Area, WSL - Water Supply Land, OTH - Other Land (use only if everything else does not apply), UNK - Unknown
GAP_STATUS	The final GAP code to use based on TNC review (matches GAP_TNC for reviewed parcels, matches GAP_ORIG for unreviewed parcels) and coding: 1 - Permanently Secured for Nature and Natural Processes 2 - Permanently Secured for Nature with Management, 3 - Permanently Secured for Multiple Uses and in natural cover, 39 - Permanently Secured and in agriculture or maintained grass cover, 4 - Unsecured (temporary easements lands and/or municipal lands that are already developed (schools, golf course, soccer fields, ball fields), 9 - Unknown
YEAR_CONSV	The Year (yyyy) the area was conserved via designation, decree, easement, or otherwise established.
PUB_ACCESS	Open Access, Limited Access, No Access, Unknown 'Open' requires no special requirements for public access to the property (may include regular hours of availability); 'Limited' requires a special permit from the owner for access, a registration permit on public land (e.g. self-permitting Wild and Scenic River, backcountry Wilderness registration) or has highly variable times when open to use; 'No Access' occurs where no public access is allowed (e.g. land bank property, special ecological study areas, military bases, many easements, etc.). 'Unknown' is assigned where information is not currently available.
GIS_ACRES	Acreage of property as calculated in ArcGIS: SHAPE_AREA x 0.0002471 or Calculate Geometry - Acres - US (ac)
SOURCE	Citation for the spatial data source dataset.
AUTHOR	Name of staff who prepared the data record
MOD_DATE	Date record was added to or updated; (Python 3 calculation: time.strftime('31/1/2000')

Distribution of Conservation Lands in the Northeast and Mid-Atlantic

Conservation efforts over the last century have resulted in over 29 million acres of conservation land distributed across the region, with over two million acres established in the last ten years. Who owns these lands? Do they add up to a larger conservation picture that represents the region's wildlife and plant diversity? Have we missed critical ecosystems or freshwater systems? In this report, we try to fit together the pieces of the conservation puzzle, take stock of our collective accomplishments, and identify where we need to put more effort. We begin by examining the overall patterns of conservation by acres, GAP status, and ownership type. In separate chapters we re-examine the secured lands with respect to the species, habitats, and natural features they were intended to conserve.

The conservation status of a parcel of land is not the same as the conservation status of a habitat or species. Conserving a habitat type, for example Northern Hardwood Forest, requires a network of conservation sites, preferably multiple viable examples of the forest, each large enough to sustain breeding populations of forest dependent species, and arranged in a configuration that sustains resilience and connectivity. Further, sustaining a species population or habitat type may also require restoration, improved management, or conservation outside the region to complement the area-based conservation documented here. We can begin to approximate the conservation status of a habitat by reviewing the set of conservation lands that contain the habitat and evaluating the distribution of their locations, sizes, and GAP status. Only in the last decade have we begun to unravel the complicated question of whether the collective set of tracts, together with other conservation strategies, accomplish the desired conservation outcomes.

<u>Basic Patterns of Land Securement</u>

Analysis of the 2022 Conservation Land Dataset (CRCS 2022, compiled and current through August 2022), revealed that the current network of conservation lands covered 29 million acres or 19% of the region (Map 2.1). Six percent was protected explicitly for nature (GAP 1 or 2) and 13% was secured for multiple uses (GAP 3). New England and New York had over four times the acreage of land conserved for nature, but the Mid-Atlantic had more multiple-use land (Table 2.2). Individual states also averaged 19% conservation land, and the total amount of state conservation land was highly correlated with the size of the state (r = 0.97). New Hampshire, Maine, and New York had more secured land than expected for their size (21% to 33% of the state). The amount of GAP 1 or 2 land conserved for nature, however, was far less correlated with a state's size, and New York, New Hampshire, New Jersey, and Virginia were all considerably above the average (Figure 2.1).

Table 2.2. Acres and percentages of conservation lands by GAP status.

Geographic Area	GAP 1		GAP 2		GAP 3		Acres: Unprotected	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
New England & New York	4,126,201	5.65%	1,962,866	2.69%	9,562,805	13.09%	57,394,590	78.57%
Mid-Atlantic	991,292	1.20%	2,240,386	2.71%	10,771,594	13.04%	68,607,490	83.05%
Region Total	5,117,493	3.29%	4,203,252	2.70%	20,334,399	13.06%	126,002,080	80.95%

Map 2.1. Conservation Lands by GAP status.

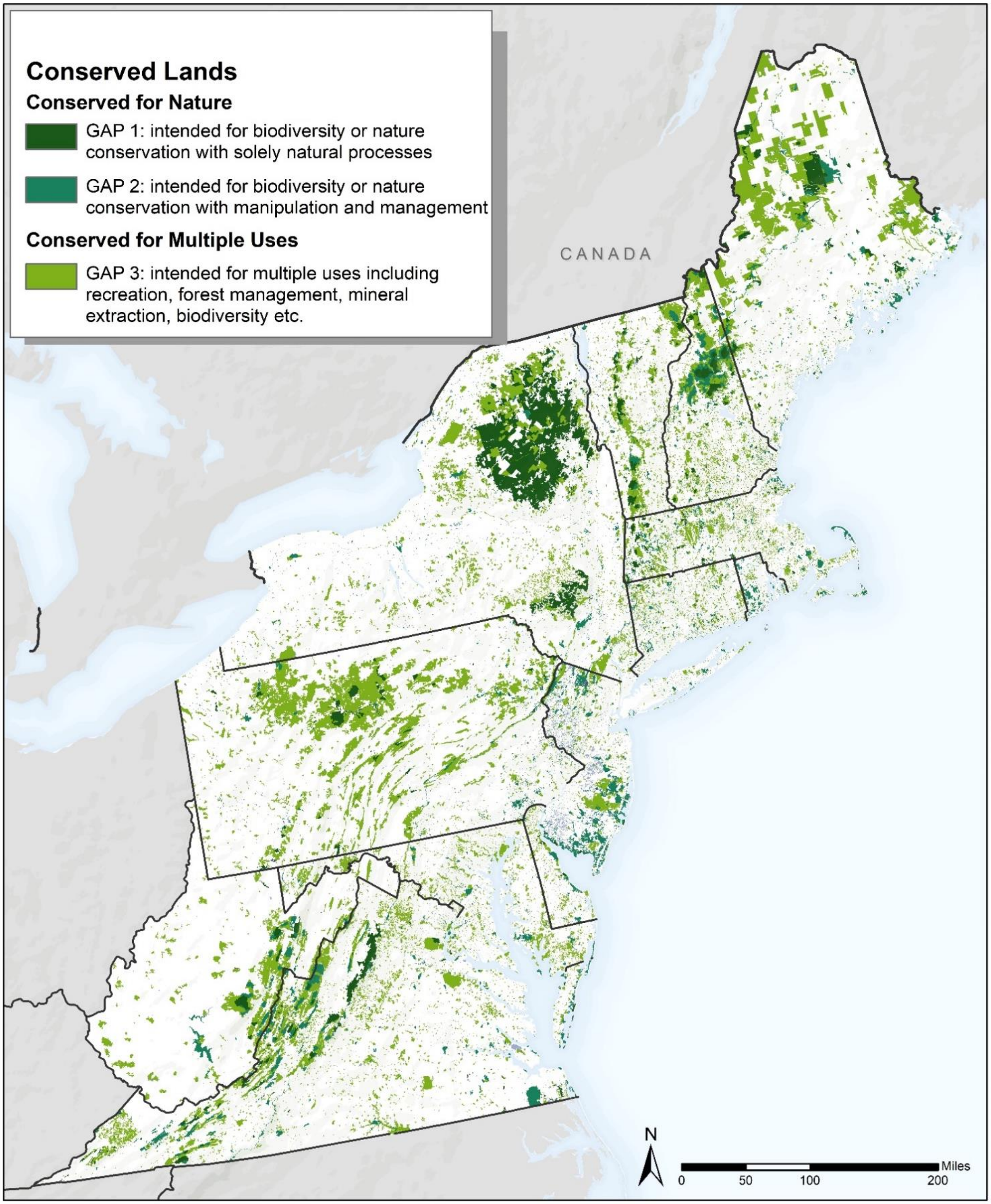
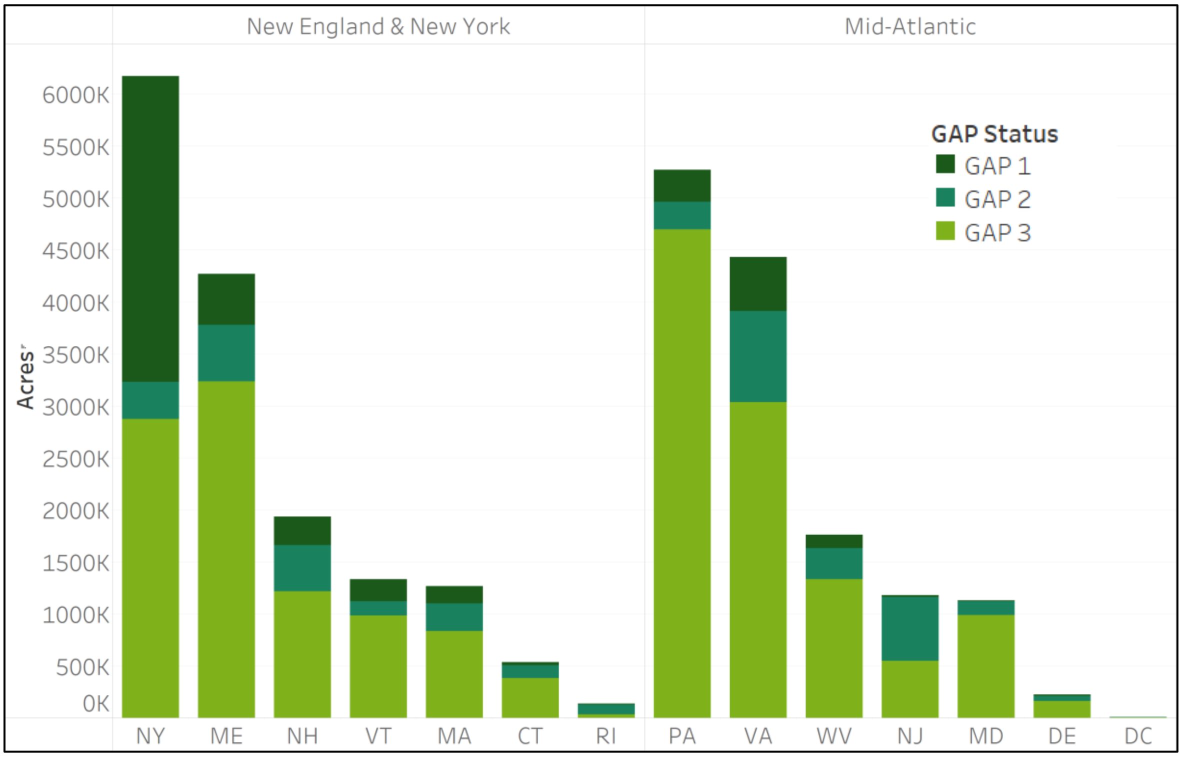


Figure 2.1. Conservation land by state, sub-region, and GAP status. The overall acreage was closely correlated with the size of the state (r=0.91).



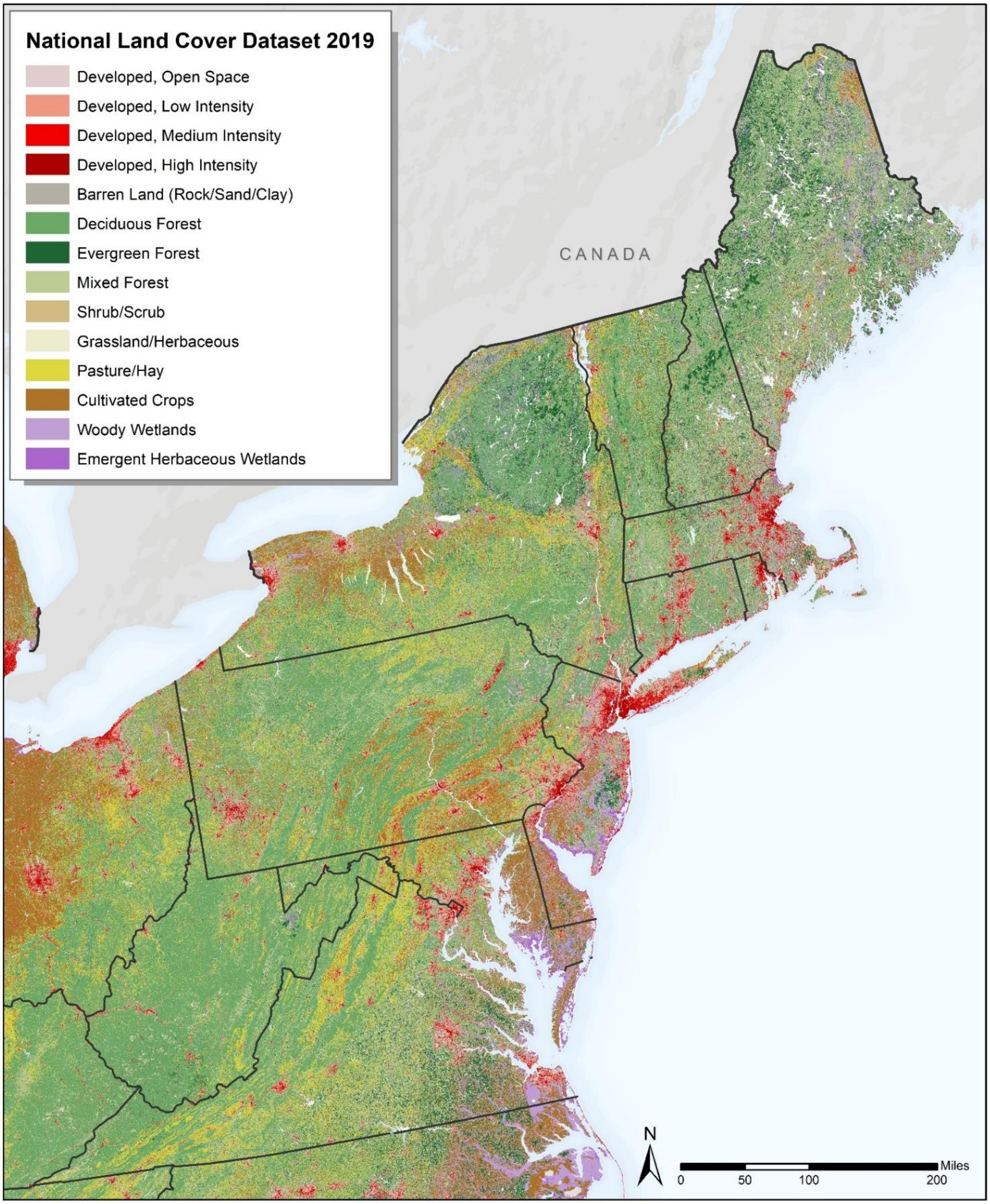
Habitat Loss versus Conservation

How much conservation do we need? One approach to answer this question is to compare the amount of land conservation with the amount of habitat loss due to conversion to development or agriculture. Hoekstra and others (2005) introduced a conservation risk index (CRI) as the ratio of conversion to conservation. We use this index, along with a stricture nature risk index (NRI) extensively in this report to understand the relative patterns of change. First, we examine the ratio at a variety of scales: from individual habitats to entire regions. For these comparisons we use the following definitions and labels.

- **CONSERVED** (CNM) This includes GAP 1-3 and encompasses both:
  - Conserved for Nature (CN) GAP 1-2 the primary intent is nature conservation
  - Conserved for Multiple Uses (CM) GAP 3, the primary intent is multiple use.
- **CONVERTED** (CV) includes conversion to development or agriculture, but not to other land cover types such as old fields that might recover to forest
- **CONSERVATION RISK INDEX** (CRI) = CV/CNM = converted / conserved
- **NATURE RISK INDEX** (NRI) = CV/CN = converted / conserved for nature

We used the 2019 National Land Cover dataset (NLCD, Dewitz and U.S. Geological Survey 2019, Map 2.2) to understand patterns of current and historic conversion. NLCD 2019 represents the most comprehensive land cover database ever produced by the USGS and was specifically developed to meet the rapidly growing demand for land cover change data. NLCD 2019 now offers consistently remapped land cover for years 2001, 2011, and 2019. We used the datasets to identify cells (30-m) that were mapped as natural in 2001 but switched to developed or row crop by 2019.

Map 2.2. National Land Cover Dataset (NLCD) 2019.



We considered land that was natural in 2001 or 2011 and currently mapped as development, at any intensity, or row crop to indicate habitat loss to conversion. Although row crops are potentially restorable, we expect food will continue to be needed and the habitat permanently degraded by fragmentation, disruption by mechanical disturbances, introduction of cultivated species, and elevated levels of nitrogen, phosphorus, and pesticides.

Using the 2019 NLCD (Map 2.2) in combination with the Conserved Lands dataset, we tabulated for every cell when it was converted from natural and to what is was converted. We also tabulate if, and when, the cell came under conservation and the GAP status, fee, or easement type and owner of the land. These two datasets allow us to compare spatial trends in habitat loss against spatial trends in land conservation.

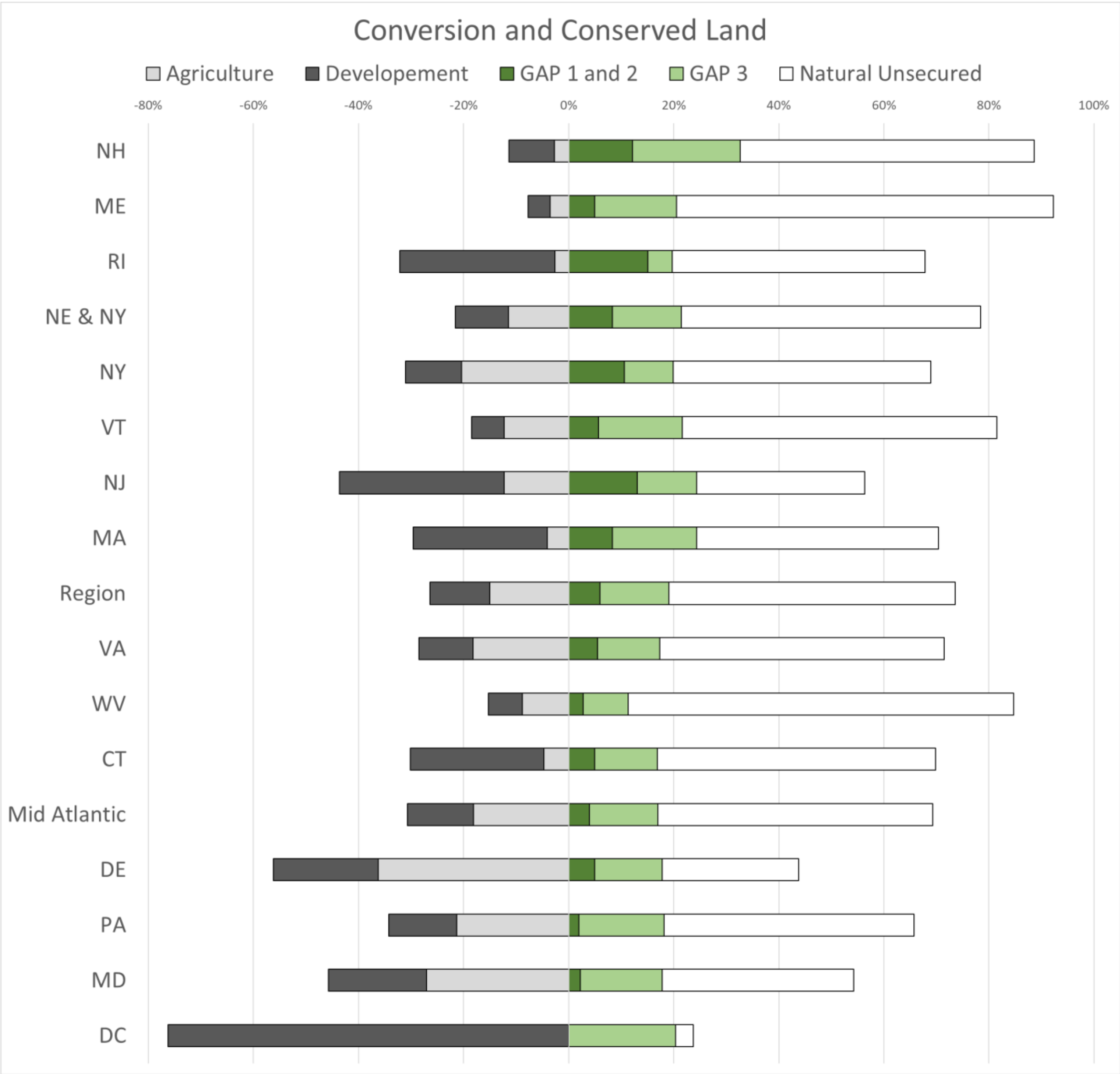
Results of our analysis show that, on average, land conservation has not offset habitat loss. For every acre of conservation land there is 1.4 acres of habitat conversion (CRI =1.4). Twenty-six percent of the land has been converted to development (11%) or agriculture (15%) compared to 19% conserved for nature (6%) or multiple uses (13%) (Figure 2.2, Table 3). Risk is slightly higher in the Mid Atlantic (CRI = 1.8) than in New England and New York where conversion equals conservation (CRI = 1.01). Maine, New Hampshire, and Vermont all have more land conserved than converted to development or agriculture.

The statistics in the previous paragraph include multiple-use lands. Focusing only on GAP1-2 land conserved for nature reveals a higher risk for the region (NRI = 4.1), with the Mid-Atlantic (NRI =7.8) having more risk than New England and New York (NRI = 2.6). New Hampshire is the only state that has more land conserved explicitly for nature than lost to conversion (NRI = 0.98).

Table 2.3. The amount of land converted and conserved by state, region, and GAP status.

		Development		Agriculture		GAP 1 & 2		GAP 3		Unsecured Natural		Total Secured		Total Converted			
		Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	NRI	CRI
New England and New York	NY	3,318,852	11%	6,319,981	20%	3,294,343	11%	2,875,551	9%	15,247,175	49%	6,169,894	20%	9,638,833	31%	2.93	1.56
	ME	880,376	4%	735,919	4%	1,032,797	5%	3,236,891	16%	14,938,998	72%	4,269,688	21%	1,616,295	8%	1.56	0.38
	NH	515,241	9%	158,550	3%	720,962	12%	1,215,293	20%	3,321,197	56%	1,936,255	33%	673,791	11%	0.93	0.35
	VT	377,695	6%	756,910	12%	348,963	6%	984,140	16%	3,685,387	60%	1,333,103	22%	1,134,605	18%	3.25	0.85
	MA	1,325,504	25%	213,882	4%	430,807	8%	836,789	16%	2,393,591	46%	1,267,596	24%	1,539,386	30%	3.57	1.21
	CT	809,279	25%	151,117	5%	156,401	5%	381,320	12%	1,685,330	53%	537,721	17%	960,396	30%	6.14	1.79
	RI	205,719	30%	18,490	3%	104,794	15%	32,819	5%	335,398	48%	137,613	20%	224,209	32%	2.14	1.63
	Total	7,432,664	10%	8,354,850	11%	6,089,067	8%	9,562,805	13%	41,607,075	57%	15,651,872	21%	15,787,514	22%	2.59	1.01
Mid Atlantic	PA	3,755,014	13%	6,162,355	21%	571,297	2%	4,696,905	16%	13,801,410	48%	5,268,202	18%	9,917,369	34%	17.36	1.88
	VA	2,630,070	10%	4,664,179	18%	1,396,981	5%	3,035,222	12%	13,889,844	54%	4,432,203	17%	7,294,249	28%	5.22	1.65
	WV	1,006,546	6%	1,370,085	9%	427,075	3%	1,333,222	9%	11,369,551	73%	1,760,297	11%	2,376,631	15%	5.56	1.35
	NJ	1,515,213	31%	596,429	12%	633,409	13%	547,855	11%	1,550,195	32%	1,181,264	24%	2,111,642	44%	3.33	1.79
	MD	1,187,892	19%	1,717,404	27%	140,329	2%	987,374	16%	2,318,378	37%	1,127,703	18%	2,905,296	46%	20.70	2.58
	DE	253,014	20%	458,649	36%	62,586	5%	162,873	13%	329,420	26%	225,459	18%	711,663	56%	11.37	3.16
	DC	30,477	76%	16	0%	1	0%	8,145	20%	1,349	3%	8,146	20%	30,493	76%	0.00	3.74
	Total	10,378,226	13%	14,969,118	18%	3,231,678	4%	10,771,594	13%	43,260,146	52%	14,003,272	17%	25,347,344	31%	7.84	1.81
Region Total		17,810,890	11%	23,323,968	15%	9,320,745	6%	20,334,399	13%	84,867,221	55%	29,655,144	19%	41,134,858	26%	4.41	1.39

Figure 2.2. Distribution of habitat conversion and land conservation by state, sub-region, and region. In this chart, each bar represents the total area of land in the geographic area. Land to the left of the center bar has been converted to development or agriculture; land to the right of the center bar remains unconverted. Unconverted land is apportioned by securement status and the percent unsecured.



Ownership and Designation

Ownership

According to our data, the 2022 conservation land network was owned by 10,088 different entities. Most fee-owned acres were held by state agencies (50%), followed by almost equal amounts of federal (25%) and private ownerships (21%). Private Non-Profits was the fastest growing sector and now accounts for over one million acres of fee owned land and over three million acres of conservation easements (Tables 4 & 5, Map 2.3), much of that acquired in the last 20 years. Land trusts, and other non-profit organizations, held the interest on most of the private easements, and reflect a growing involvement of private landowners in the long-term conservation of land (Figure 2.3).

Table 2.4. Conservation ownership. This table is organized by fee ownership types and shows both the average size of the ownership as well as the average tract or parcel size.

Organization Type	Total Acres	Number of owners	Average Acres per Owner	Max acres of Owner	Owner of Maximum	Average Tract Size	Max Tract Size
State	12,862,099	163	80,344	3,970,874	NYS Department of Environmental Conservation	206	283,137
Federal	6,349,244	27	236,890	4,424,552	USDA Forest Service	446	440,093
Local	1,427,995	3,575	400	182,871	New York City Department of Enviromental Protection	18	8,235
Private Non Profit	1,229,608	1,017	1,252	459,504	The Nature Conservancy	47	81,227
Private for Profit	335,751	336	721	4,997	Appalachian Power Company	146	4,997
District	21,748	69	312	6,356	Connecticut Metropolitan District Commission	24	1,772
Unknown	11,574					55	3,672
Tribal	155	1			Cheroenhaka Indian Tribal Heritage Foundation		
Grand total	22,238,174	5,188	53,320			135	117,591

Table 2.5. Conservation easements. This table is organized by conservation easement holder and shows both the average size of the easements as well as the average tract or parcel size.

CONSERVATION EASEMENT HOLDER					
Organization Type	Total Acres	Number of easement holders	Average Acres per Easement Holder	Max acres per Owner	Holder of Maximum
Private Non Profit	3,618,035	514	7,139	1,138,185	New England Forestry Foundation
State	3,139,308	78	43,435	1,223,602	NY Department of Environmental Conservation
Local	408,732	655	585	54,519	New York City Department of Enviromental Protection
Federal	210,917	13	16,990	72,791	USDA Natural Resource Conservation Service
Unknown	39,133				
District	845	7	22	327	Rockingham County Conservation District
Grand total	7,416,970	753	15,258		

Figure 2.3. The distribution of conservation easements. This chart shows the distribution of easements among types of interest holders. By area, most easements are held by private non-profit entities and state government. Local government has the largest number of individual tracts, followed by Private Non-Profit organizations.

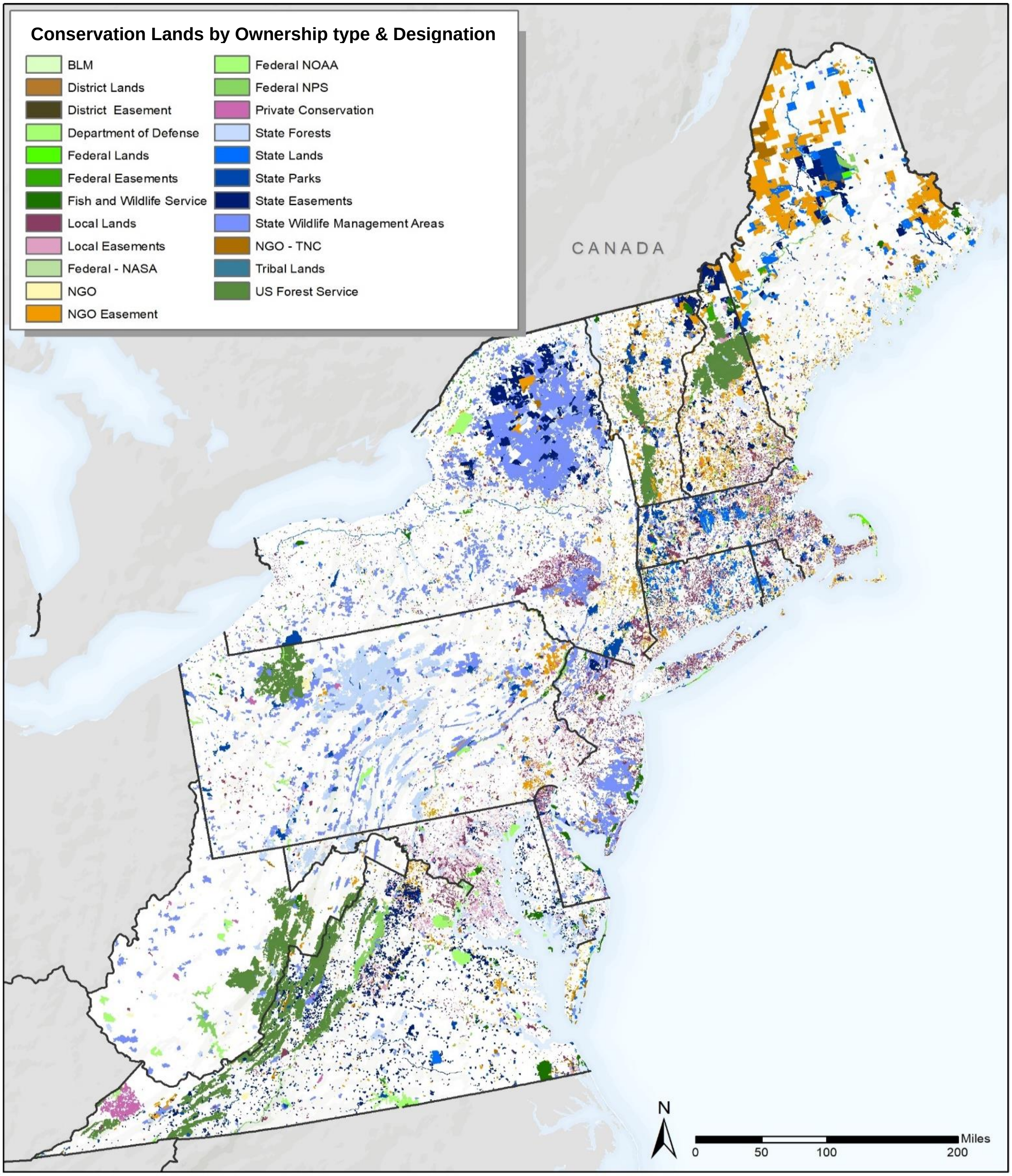


Table 2.6. Conservation lands by ownership/interest holder. State wildlife management areas comprise the conservation designation with the most land, but their intent and management varies greatly from state to state. Private Non-Profit organizations own the most land under easements, accounting for 15% of conservation land.

Fee Owner or Interest Holder	GAP 1 & 2	% G 1 - 2	GAP 3	% G3	GAP 1 - 3	% G1-3
State Wildlife Management Area	3,554,785	36.1%	3,526,989	17.3%	7,081,774	23.9%
US Forest Service	1,536,520	15.6%	2,881,848	14.2%	4,418,368	14.9%
Private Non-Profit Easement	513,765	5.2%	3,068,137	15.1%	3,581,902	12.1%
State Easement	174,304	1.8%	2,965,003	14.6%	3,139,308	10.6%
State Forest	454,068	4.6%	2,621,615	12.9%	3,075,683	10.4%
State Park	484,777	4.9%	1,009,305	5.0%	1,494,082	5.0%
Local Lands	112,560	1.1%	1,315,435	6.5%	1,427,995	4.8%
State Land	296,372	3.0%	953,211	4.7%	1,249,583	4.2%
Private Non-Profit	852,372	8.7%	377,236	1.9%	1,229,608	4.1%
National Park Service	575,520	5.8%	116,507	0.6%	692,027	2.3%
Department of Defense	7,937	0.1%	666,552	3.3%	674,489	2.3%
Fish and Wildlife Service	468,977	4.8%	7,157	0.0%	476,134	1.6%
Local Easement	20,478	0.2%	387,001	1.9%	407,479	1.4%
Private Conservation	395,317	4.0%	247,834	1.2%	335,751	1.1%
Federal Easement	94,535	1.0%	114,751	0.6%	209,285	0.7%
Federal Lands	288,249	2.9%	17,250	0.1%	81,355	0.3%
Easement Unknown Holder	17,836	0.2%	21,290	0.1%	39,126	0.1%
District Lands	404	0.0%	21,344	0.1%	21,748	0.1%
Unknown	2,556	0.0%	9,018	0.0%	11,574	0.0%
Federal - NASA	0	0.0%	6,283	0.0%	6,283	0.0%
District Easement	212	0.0%	633	0.0%	845	0.0%
BLM	519	0.0%	0	0.0%	519	0.0%
Tribal	155	0.0%	0	0.0%	155	0.0%
Federal - NOAA	310	0.0%	0	0.0%	69	0.0%
Grand Total	9,852,530		20,334,399		29,655,144	

Recent Conservation Trends

The key to tracking conservation status in the Northeast is accurate spatial data, and in the last 10 years, the TNC Conserved Land dataset has significantly improved, thanks to extensive contributions by state agency and TNC field office staff. The dataset is maintained by over 60 organizations, who are constantly making improvements to the data and creating a better database for tracking, managing, and accurately mapping conservation information.

The northeast region has seven states with the highest number of non-profit land conservation organizations in the country (PAD-US, 2021). This accounts for much conservation progress, but the large number of entities engaged in land conservation makes it particularly complex to track all the work.

Since our 2011 report (based on the 2009 dataset), the number of records grew from 136,000 to 260,000, reflecting both an increase in the number of non-profit and local conservation lands as well as detail in record keeping. Easements grew 30-fold from 2,400 to over 69,000 records, and the footprint of conservation land increased by over five million acres, raising the proportion of land in conservation from 16% to 19% of the region.

Although there was an apparent five-million-acre difference in the amount of conservation land from the 2009 to the 2022 dataset, we could only confirm that two million of those acres were due to new land acquisitions or easements. The other three million acres of land were missing from the 2009 dataset, but their "date conserved" attribute was empty and we strongly suspect they reflect error or missing data in the older dataset and not true additions (Table 2.7). Spot checking of the dataset supported this assumption. We investigated 10 large conservation parcels over 10,000 acres in this group, for example, West Canada Lake (est. 1972) in the Adirondacks, and found them to be public lands established long before 2009.

Table 2.7: Completeness of the "Year Conserved" field by number of tracts. The "No Date" columns indicate the number or percent of tracts missing date information.

State	No Date Conserved	% No Date Conserved	Before 2001	% Before 2001	Between 2001 and 2011	% Between 2001 and 2011	Between 2012 and 2022	%Between 2012 and 2022	Grand Total
MD	1,677	5.2%	5,526	17.3%	14,098	44.1%	10,664	33.4%	31,965
VT	1,321	13.6%	5,062	52.0%	1,548	15.9%	1,797	18.5%	9,728
RI	793	15.7%	2,927	57.9%	1,233	24.4%	105	2.1%	5,058
VA	2,061	18.1%	3,539	31.2%	3,650	32.1%	2,108	18.6%	11,358
PA	1,863	24.9%	2,838	37.9%	1,686	22.5%	1,105	14.7%	7,492
WV	267	30.4%	426	48.5%	147	16.7%	39	4.4%	879
CT	5,764	32.1%	9,744	54.3%	2198	12.2%	244	1.4%	17,950
MA	14,285	34.6%	16,396	39.8%	6,735	16.3%	3,828	9.3%	41,244
NH	4,790	37.7%	3,970	31.3%	3,039	23.9%	892	7.0%	12,691
ME	3,590	39.4%	3,162	34.7%	1,355	14.9%	1,015	11.1%	9,122
NJ	38,573	53.0%	18,844	25.9%	11,801	16.2%	3,527	4.8%	72,745
DC	453	55.3%	366	44.7%	0	0.0%	0	0.0%	819
NY	24,623	77.2%	3,351	10.5%	3,483	10.9%	425	1.3%	31,882
DE	7,366	91.7%	376	4.7%	233	2.9%	60	0.7%	8,035
Grand Total	107,426	0.4%	107,426	0.4%	51,206	0.2%	25,809	0.1%	29,655,144

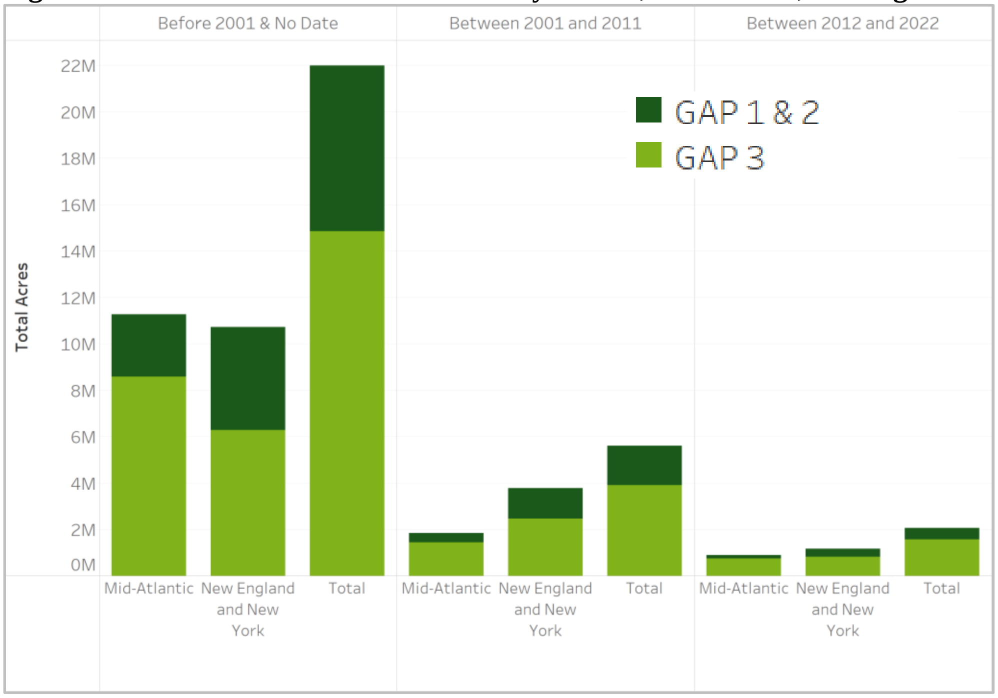
For the reasons described above, our analysis of new land conserved between 2012-2022 is based solely on the two million acres we could confirm (Table 2.8). This reflects a multi-year effort to get the "date conserved" field completed in the dataset by state data stewards. The effort was augmented by cross checking with the Conservation Almanac, PAD-US, NCED, phone calls to the steward or conservation organizations, and Google searches. Nevertheless, it is probably an underestimate of the actual acres as there is a wide variety of the completeness of the "date conserved" field across the region, with Maryland, Vermont, Maine, Rhode Island, Virginia, and Pennsylvania having the most complete records (Table 2.8).

Over the decade from 2011 to 2022, our results show that the collective efforts of over a hundred organizations and agencies **resulted in 2.1 million acres of new conservation land.** Easements accounted for 1.3 million acres and fee ownership for 780,000 acres (Table 2.8). Overall, this appeared to be slightly less conservation land than was acquired in the previous decade (Figure 2.4).

Table 2.8: Acres of Conservation Land by decade conserved. Due to missing data information as described in the text, we only counted recent acres (2012-2022) that we could confirm. Unknown dates were considered pre-2001.

State	Before 2001 (includes no Date)	% Before 2001 (includes no Date)	Between 2001 and 2011	% Between 2001 and 2011	Between 2012 and 2022	%Between 2012 and 2022	Grand Total	% of total State Area
ME	2,206,515	10.6%	1,316,898	6.3%	746,275	3.6%	4,269,688	20.5%
VA	3,024,917	11.8%	799,389	3.1%	607,896	2.4%	4,432,202	17.3%
PA	4,879,658	16.8%	214,636	0.7%	173,908	0.6%	5,268,202	18.2%
NH	1,367,566	23.1%	423,339	7.1%	145,350	2.5%	1,936,255	32.6%
MA	976,032	18.8%	185,698	3.6%	105,866	2.0%	1,267,596	24.4%
VT	1,098,007	17.8%	134,519	2.2%	100,577	1.6%	1,333,103	21.7%
NJ	980,230	20.2%	144693	3.0%	56342	1.2%	1,181,265	24.4%
NY	4,524,436	14.6%	1,591,628	5.1%	53,830	0.2%	6,169,894	19.9%
MD	470,578	7.4%	609,792	9.6%	47,333	0.7%	1,127,703	17.8%
WV	1,701,460	11.0%	47,437	0.3%	11,400	0.1%	1,760,297	11.4%
CT	433,675	13.6%	93,709	2.9%	10,337	0.3%	537,721	16.9%
RI	105,253	15.1%	26,198	3.8%	6,162	0.9%	137,613	19.7%
DE	200,882	15.9%	21,619	1.7%	2,958	0.2%	225,459	17.8%
DC	8,145	20.4%	0	0.0%	0	0.0%	8,145	20.4%
Grand Total	21,977,354	14.1%	5,609,555	3.6%	2,068,234	1.3%	29,655,144	19.1%

Figure 2.4. Amount of conservation land by decade, GAP status, and region.



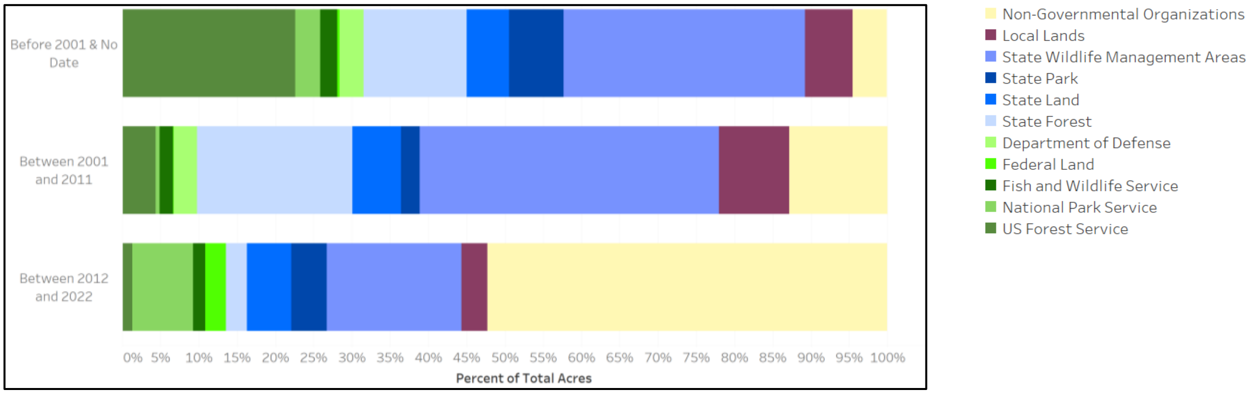
New conservation was achieved primarily by private NGOs and individuals (1.1 M ac), accounting for over half of the fee (406 K ac.) and easement acreage (738 K ac, Figure 2.5). Maine and Virginia had the largest increases in conservation land with both states adding over 600,000 acres (2% of each state). A list of the larger projects (Appendix 1) highlights major projects in many states including:

- Moosehead Forest Easement: 350,000 acres, Forest Society of Maine, ME
- Cumberland Forest (CF) Project: 154,576 acres, CF Highlands LLC (w The Nature Conservancy), VA
- Clarion Forest Junction: 25,591 acres, The Conservation Fund, PA
- Mahoosuc Gateway: 23,733 acres, NH DRED, NHDF, Conservation Fund, NH
- Elk Lake Conservation Easement: 20,440 acres, NY DEC, Adirondack Nature Conservancy, NY
- Woodbury Mountain Wilderness Preserve: 5,947 acres, Northeast Wilderness Trust, VT

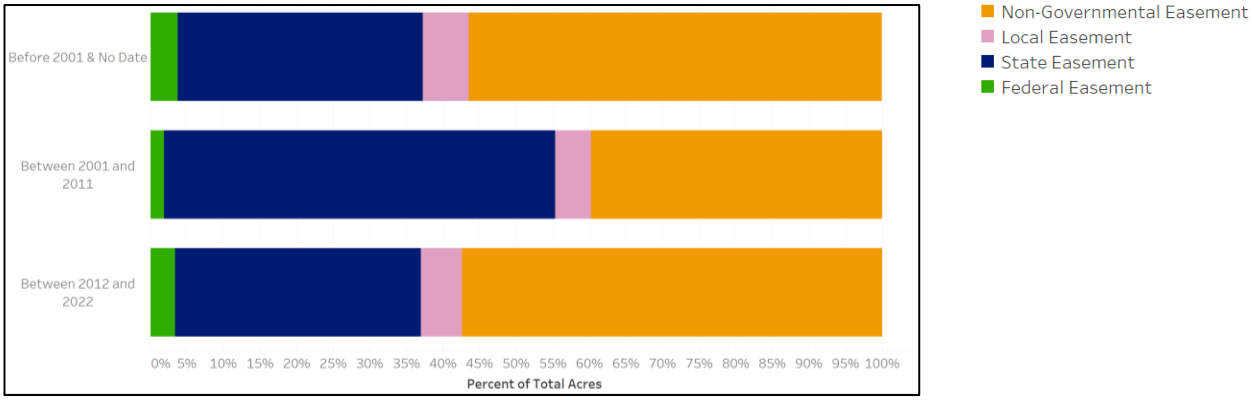
All these projects were completed with partnerships, often between state agencies and private organizations. The Cumberland Forest project formed a new organization to hold and manage the land.

Figure 2.5: Date conserved by fee organization or easement holder. The charts show the relative distribution of fee and easement land by type of organization. Colors of the organizations match Map 2.3.

FEE



EASEMENTS



There were also over 100,000 acres of new or expanded federal projects, and over 200,000 acres of state projects (Table 2.9 and Appendix 2.1), often involving private non-profit organizations as fund raisers, easement holders, or initial buyers who later transferred the properties to the state. Federal highlights include:

- Katahdin Woods and Water National Monument: 88,104 acres, US National Park Service, ME
- Umbagog National Wildlife Refuge: 7,500 acres, USFW, as part of the Androscoggin Headwaters Fee and Easements project. 28,372 acres, NH DRED, NHFG, Trust for Public Land, NH
- Cherry Valley National Wildlife Refuge: 4,213 acres, USFW, PA
- George Washington and Jefferson National Forests: 4,592 acres, USFS, Open Space Institute, Chesapeake Conservancy, VA

Harder to track, but equally important, were small expansions to many existing lands and refuges. For example, there were smaller expansions at Forsythe NWR, Cape May NWR, Great Dismal Swamp NWR, Rappahannock River Valley NWR, and Canaan Valley NWR. Funding for the NWR projects include Migratory Bird Conservation Fund Returns and Land and Water Conservation Fund Returns.

Table 2.9: Conservation fee and easements by decade, ownership type, and GAP status.

Conservation Projects	Pre 2001			2001-2011			2012-2022			Total
Fee Owner	GAP 1 & 2	GAP 3	Total Conserved	GAP 1 & 2	GAP 3	Total Conserved	GAP 1 & 2	GAP 3	Total Conserved	All Years
FEE PROTECTION - FEE OWNER										
Bureau of Land Management (BLM)	0	0	0	519	0	519	0	0	0	519
Department of Defense (DOD)	7902	593,574	601,476	36	72,978	73,014	0	0	0	674,490
Federal Lands (FED)	41,819	15,606	57,425	977	1,643	2,620	21,309	0	21,309	81,354
Fish and Wildlife Service (FWS)	414,617	7,012	421,629	42,217	138	42,355	12,143	7	12,150	476,134
National Aeronautics and Space Administration (NASA)	0	6,283	6,283	0	0	0	0	0	0	6,283
National Oceanic and Atmospheric Administration (NOAA)	69	0	69	0	0	0	0	0	0	69
National Park Service (NPS)	509,246	108,951	618,197	6,914	5,024	11,938	59,359	2,532	61,891	692,026
US Forest Service (USFS)	1,465,652	2,838,684	4,304,336	70,312	33,701	104,013	555	9,463	10,018	4,418,367
Tribal (TRIB)	0	0	0	0	0	0	155	0	155	155
State Forests (SF)	338,002	2,229,977	2,567,979	113,533	372,472	486,005	2,383	18,879	21,262	3,075,246
State Lands (SL)	268,857	781,987	1,050,844	23,002	129,824	152,826	4,945	40,259	45,204	1,248,874
State Parks (SP)	438,215	923,239	1,361,454	31,162	27,460	58,622	15,397	20,731	36,128	1,456,204
State Wildlife Management Areas (SWMA)	2,686,652	3,321,641	6,008,293	796,162	140,567	936,729	71,971	64,781	136,752	7,081,774
Local Lands (LOC)	76,806	1,104,559	1,181,365	31,517	188,587	220,104	4,238	22,288	26,526	1,427,995
District Land (DIST)	97	20,285	20,382		850	850	307	209	516	21,748
Private Protection (PVT)	46,515	48,803	95,318	23,402	23,939	47,341	18,000	20,516	38516	181,175
Non-governmental Organizations (NGO)	499,832	256,078	755,910	208,392	51,860	260,252	144,148	223,874	368,022	1,384,184
Unknown (UNK)	1,698	2,151	3,849	231	6,593	6,824	627	274	901	11,574
Total Acres Fee	6,795,981	12,258,831	19,054,812	1,348,375	1,055,637	2,404,012	355,537	423,814	779,351	22,238,174
EASEMENT PROTECTION - EASEMENT HOLDER										
Federal Easement	44,530	62,952	107,482	34,051	25,710	59,761	16,034	27,639	43,673	210,916
State Easement	80,887	911,759	992,646	67,724	1,646,095	1,713,819	25,693	407,149	432,842	3,139,307
Local Easement	8,103	171,814	179,917	7,457	149,070	156,527	4,752	67,537	72,289	408,733
District Easement	83	343	426	123	280	403	6	10	16	845
Non-governmental Organizations Easement	182,807	1,427,378	1,610,185	242,087	1,027,727	1,269,814	88,679	649,357	738,036	3,618,035
Unknown	14,752	17,135	31,887	1,623	3,596	5,219	1,461	566	2,027	39,133
Total Acres Easement	331,162	2,591,381	2,922,543	353,065	2,852,478	3,205,543	136,625	1,152,258	1,288,883	7,416,969

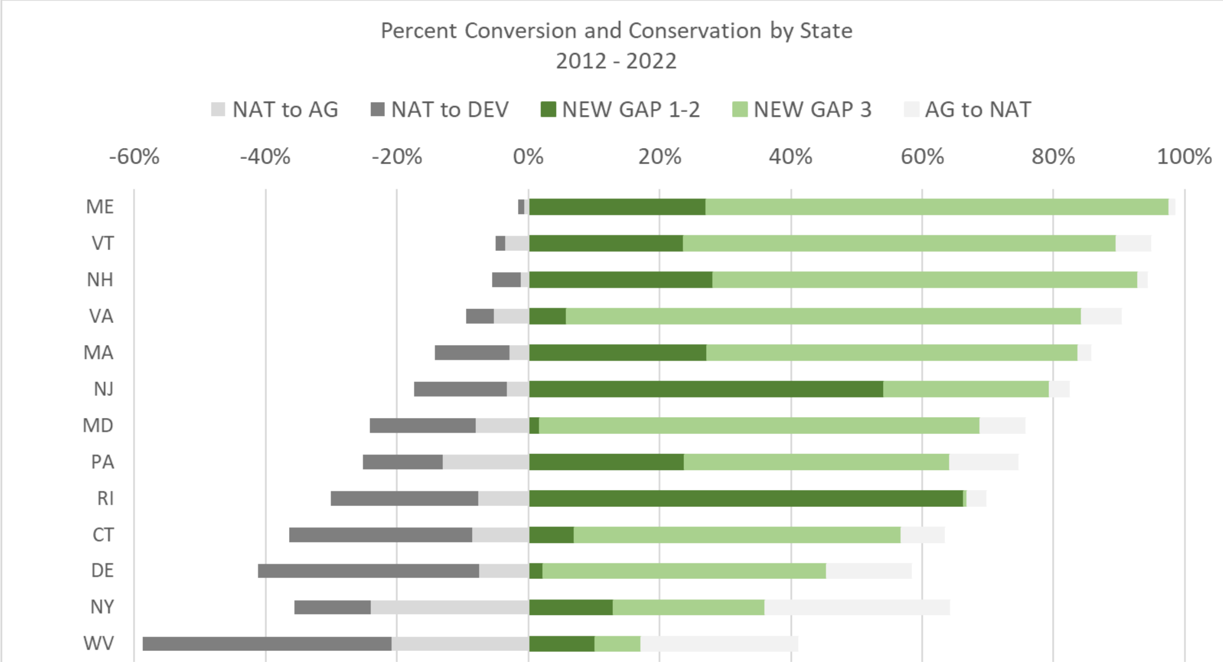
Habitat Loss versus Land Conservation (2012-2022)

To sustain the region's wildlife and plants, the big questions are whether the new conservation lands are in critical places that represent the full spectrum of biodiversity, and whether the amount of conservation land is enough to offset habitat loss. The first question is explored in detail in this report's chapters on forest, wetland, natural communities, rivers, and lakes. Here were explore the latter question of land conversion versus conservation progress.

Using the methods and terminology described previously, we calculated the conservation risk index (CRI) and nature risk index (NRI) for the last decade (2012-2022) to determine if the extent of conservation was offsetting the extent of habitat loss due to conversion.

Results show that over the last decade **land conservation surpassed habitat loss by a ratio of 6 to 1.** For every one acre of land conserved, 0.15 acres of land were converted to agriculture or development (CRI=0.15). This was true across every state except West Virginia, and for Maine, New Hampshire, and Vermont the amount of conservation was over 15 times higher than conversion (Figure 2.6).

Figure 2.6. Percent habitat conversion versus land conservation by state. The table shows the percent of historic and current acres converted, the percent secured as GAP 1-3 or protected as GAP 1-2, and the ratio of conversion to securement (CRI) or conversion to protection (NRI).

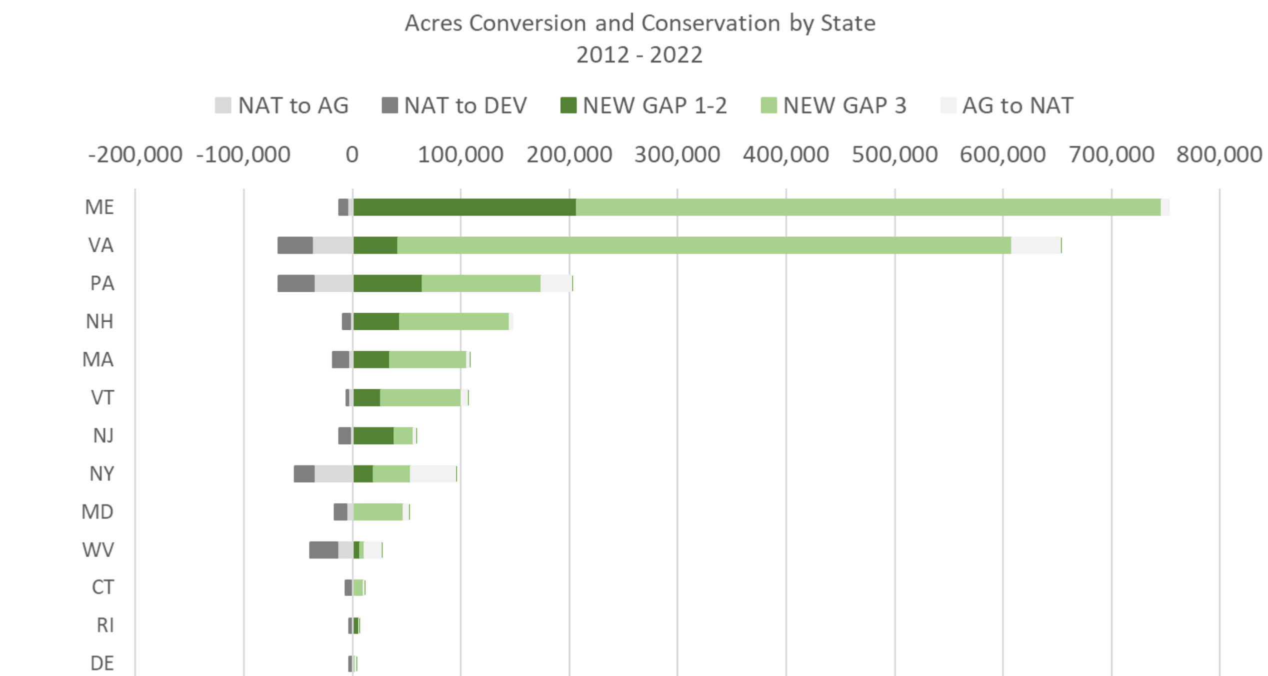


	WV	NY	DE	CT	RI	PA	MD	NJ	MA	VA	NH	VT	ME
NAT to AG	-13,725	-35,772	-487	-1,553	-696	-35,217	-5,478	-2,283	-3,563	-37,604	-1,720	-3,915	-4,250
NAT to DEV	-25,031	-17,267	-2,182	-5,071	-2,068	-32,969	-11,069	-10,078	-14,325	-30,626	-6,903	-1,618	-7,475
NEW GAP 1-2	6,723	19,392	149	1,294	6,110	64,640	1,255	38,527	34,435	42,131	44,064	26,597	206,929
NEW GAP 3	4,677	34,455	2,808	9,043	52	109,379	46,089	17,822	71,444	565,807	101,286	73,981	539,414
AG to NAT	15,882	42,117	848	1,221	282	28,550	4,824	2,292	2,524	45,314	2,602	6,078	6,385
CRI	3.40	0.99	0.90	0.64	0.45	0.39	0.35	0.22	0.17	0.11	0.06	0.06	0.02
NRI	5.76	2.74	17.86	5.12	0.45	1.05	13.19	0.32	0.52	1.62	0.20	0.21	0.06

The amount of GAP1-2 conservation for nature was considerably less than GAP 3 multiple-use conservation land, but six states had more conservation for nature than habitat conversion (NRI <1): Maine, New Hampshire, Vermont, New Jersey, Rhode Island, and Massachusetts. Two states, Pennsylvania and Virginia, had roughly equal amounts (Figure 2.7). This trend indicates substantial progress for conservation.

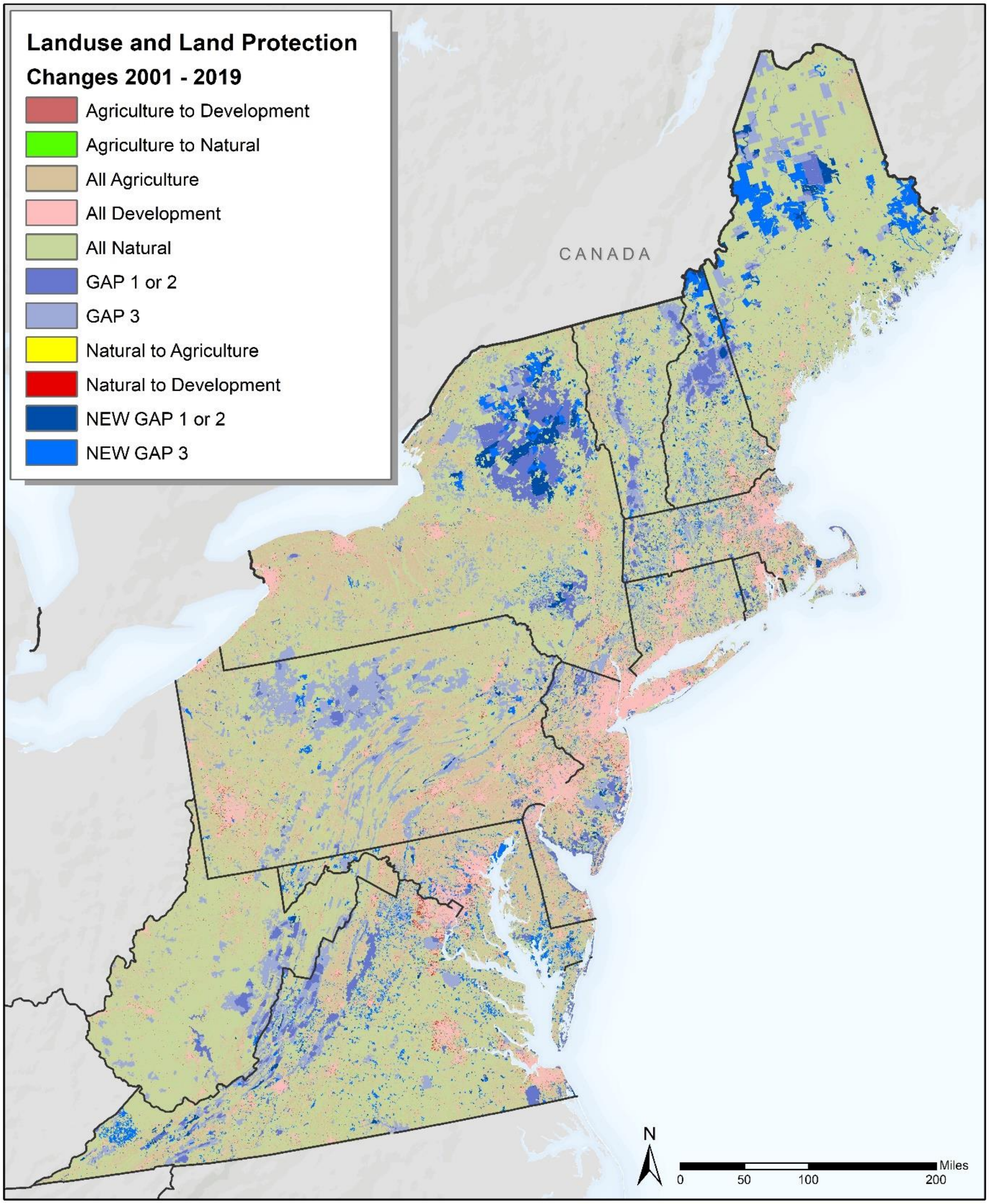
States differ dramatically in size, and the actual amount of conservation and conversion is closely related to the size of the state, with Maine, Virginia, and Pennsylvania being the three states with the largest amount of new conservation land established in the last decade (Figure 2.7). The acreage reflects the large private-public projects discussed above and listed with more detail in Appendix 2.1, and visible at the scale of the whole region (Map 2.4)

Figure 2.7. Acres of Habitat Conversion and Conservation by State. The table shows the percent of historic and current acres converted, the percent secured as GAP 1-3 or protected as GAP 1-2, and the ratio of conversion to securement (CRI) or conversion to protection (NRI).



	DE	RI	CT	WV	MD	NY	NJ	VT	MA	NH	PA	VA	ME
NAT to AG	-487	-696	-1,553	-13,725	-5,478	-35,772	-2,283	-3,915	-3,563	-1,720	-35,217	-37,604	-4,250
NAT to DEV	-2,182	-2,068	-5,071	-25,031	-11,069	-17,267	-10,078	-1,618	-14,325	-6,903	-32,969	-30,626	-7,475
NEW GAP 1-2	149	6,110	1,294	6,723	1,255	19,392	38,527	26,597	34,435	44,064	64,640	42,131	206,929
NEW GAP 3	2,808	52	9,043	4,677	46,089	34,455	17,822	73,981	71,444	101,286	109,379	565,807	539,414
AG to NAT	848	282	1,221	15,882	4,824	42,117	2,292	6,078	2,524	2,602	28,550	45,314	6,385
CRI	0.90	0.45	0.64	3.40	0.35	0.99	0.22	0.06	0.17	0.06	0.39	0.11	0.02
NRI	17.86	0.45	5.12	5.76	13.19	2.74	0.32	0.21	0.52	0.20	1.05	1.62	0.06

Map 2.4. Conservation progress and land use change between 2001 and 2019. Bright blue indicates new conservation land, while yellow and red indicate losses to conversion.



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Appendix 2.1. Highlights of Conservation Projects occurring between 2012-2022 in the Northeast

The Northeast has made significant progress on conservation over the last 10 years. Over two million acres of conservation land is verified new conservation. Below is a summary of large conservation projects that have been accomplished since 2011.

Non-Governmental Organization Fee

Over 1,380,000 acres of fee-based conservation have been added to the conservation lands dataset since 2011. The dataset has over 287 different non-governmental organizations owning land since 2011. The largest fee owners include The Nature Conservancy, The Conservation fund, Northeast Wilderness Trust, and New England Forestry Foundation, all owning over 10,000 acres since 2011.

Non-Governmental Easements

Over 3,600,000 acres of easements were added to the conservation lands dataset since 2011. The dataset shows over 500 different non-governmental easement holders. New England Forestry Foundation, Forest Society of Maine, The Nature Conservancy, and Vermont Land Trust all have over 100,000 acres of easements since 2011.

Conservation projects over 5,000 acres

The following projects are conservation projects in the region that are over 5,000 acres:

Moosehead Forest Easement:

Easement Holder: Forest Society of Maine
Partners: Forest Society of Maine (FSM), The Nature Conservancy, and the Appalachian Mountain Club
GIS Acres: 357,216
Year: 2019
State: Maine

The Moosehead Region Conservation Easement is the result of a Maine state-approved concept plan for Plum Creek Timber Company's lands around Moosehead Lake and a partnership effort between Forest Society of Maine (FSM), The Nature Conservancy, and the Appalachian Mountain Club. This is the largest conservation easement held by FSM and one of the largest nationally. The easement lands are near 20 existing state-owned conservation properties on and around Moosehead Lake, creating one of the largest groupings of recreational lands in the nation. This network of conserved lands provides remarkable opportunities for nearby communities to grow their natural resource-based economies, including tourism.

Cumberlands Forest Highlands:

Fee Owner: CF Highlands LLC (The Nature Conservancy)
GIS Acres: 154,576
Year: 2019
State: Virginia
At 253,000 acres, the Cumberland Forest Project, one of TNC's largest-ever conservation efforts in the eastern United States, protects sweeping forest landscapes across two parcels, one in Southwest Virginia

and one along the Kentucky and Tennessee border. Safeguarding this vast stretch of forest tackles climate change on two fronts: by storing millions of tons of carbon dioxide and by connecting a migratory corridor that scientists believe could be one of North America's most important "escape routes" as plant and animal species shift their ranges to cooler climates.

Androscoggin Headwaters-:

Androscoggin Easement Holder: NH Department of Resources & Economic Development
Umbagog National Wildlife Refuge: Fee Owner: US Fish and Wildlife Service
Greenough Ponds Wildlife Management Area: Fee Owner: NH Fish and Game Department
Partner: Trust for Public Land
GIS Acres: 28,372
Year: 2014
State: New Hampshire
The jewels of the Androscoggin Headwaters property are Greenough Pond and Little Greenough Pond, two of only three ponds in New Hampshire that sustain native, non-stocked brook trout populations. Development around these two ponds would have degraded some of the best cold-water fisheries in the eastern United States. The Trust for Public Land and partners obtained $16.7 million from federal, state and private sources to conserve this property. Approximately 7,500 acres was added to the Umbagog National Wildlife Refuge and 934 acres was conveyed to New Hampshire Department of Fish and Game for fisheries conservation. The remaining 23,000 acres of productive forestland are protected by a state-held conservation easement that allows for continued sustainable timber production.

Reed Forest:

Fee Owner: The Conservation Fund
Interest Holder: Forest Society of Maine
Partners: The Conservation Fund, Forest Society of Maine, Apple
GIS Acres: 32,462
Year: 2016
State: Maine
In November 2016, with support from Apple, The Conservation Fund donated a conservation easement at Reed to the Forest Society of Maine.

Clarion Forest Junction:

Fee Owner: The Conservation Fund
GIS Acres: 25,591
Year: 2018
State: Pennsylvania
The Conservation Fund is stepping up to quickly acquire large, threatened working forests across the country, including in Pennsylvania, where it recently acquired 32,598 acres of sustainable timberland surrounding the city of Johnsonburg. Located within the "Pennsylvania Wilds" region, the property provides a bridge between Pennsylvania Game Commission lands and the Allegheny National Forest. The Conservation Fund's purchase will maintain clean water and productive fishing streams, securing the

confluence of the East and West branches of the Clarion River and 100 miles of high-quality cold water fisheries, six miles of which hold the state's highest designation of Exceptional Value.

Mahoosuc Gateway:

Interest Holder: NH Department of Natural Resources and Economic Development
GIS Acres: 23,733
Year: 2018
State: New Hampshire
A private-public partnership was formed between the New Hampshire Division of Forests and The Conservation Fund to secure a 24,000-acre landscape of working forestland in Coos County near the Appalachian National Scenic Trail in the Mahoosuc Mountains.

Elk Lake Conservation Easement:

Easement Holder: NY Department of Environmental Conservation
GIS Acres: 20,440
Year: 2012
State: New York
In 2013, The Nature Conservancy announced that a private landowner had donated a conservation easement protecting all 12,000 acres around Elk Lake.

Fish River Chain of Lakes:

Interest Holder: Forest Society of Maine
Partners: The Conservation Fund, Forest Society of Maine, Apple
GIS Acres: 16,921
Year: 2021
State: Maine
The Fish River Conservation Easement conserves permanent working forestland on nearly 17,000 acres adjacent to Mud Lake, Cross Lake, Carry Pond, Little California Pond, and Square Lake in Aroostook County. The easement ensures unique natural habitats are conserved and wildlife habitat is maintained so that these lands can continue to be sustainably managed forests and creates a permanent right of pedestrian public access across these lands. These lakes are popular with fishermen, boaters, and other recreationists. The Fish River Conservation Easement was developed during a public process as part of the Fish River Chain of Lakes Concept Plan developed by Irving Woodlands and approved in late 2019 by the Land Use Planning Commission (LUPC).

Grafton Forest:

Fee Owner: Northeast Wilderness Trust
Easement Holder: Forest Society of Maine
GIS Acres: 15,198 easement, 5,947 Fee
Year: 2022
State: Maine
The Grafton Forest Project ensures a legacy of wildness in Western Maine. These mountains, also known as the Mountains of the Dawn in honor of the Wabanaki of Maine, or the People of the Dawnland, are

some of the first mountains to greet the rising sun as day breaks over this continent. The Western Maine Mountains are of high conservation importance, and the Wilderness Trust has turned its attention to protecting more land in this eco-region in recent years. Grafton Forest is a keystone area linking a vast public Ecological Preserve and a 15,000-acre, well-managed woodland conserved by The Forest Society of Maine. From the Preserve, a few days' hike north on the A.T. brings one to the outskirts of Northeast Wilderness Trust's Lone Mountain and Redington Wilderness Sanctuaries, which cumulatively protect 4,455 forever-wild acres near Bigelow Preserve.

West Grand Lake:

Fee Owner: Downeast Lakes Land Trust
Easement Holder: Maine Bureau of Parks and Land
GIS Acres: 14,819
Year: 2012
State: Maine
With the help of funding from the Land for Maine's Future program, the Maine Department of Agriculture, Conservation, and Forestry purchased a conservation easement on 21,870 acres of forestland. It was aided by the Downeast Lakes Land Trust, who went on to purchase the parcel in 2016 and convert it into a community forest. With charming lakes, pristine wooded areas, diverse wildlife, and bountiful recreational opportunities, the West Grand Lake Forest offers excellent examples of so much that makes Maine's nature extraordinary. It is located within a network of more than 1.4 million acres of preserved land that extends all the way into Canada. It shares a border with Farm Cove Community Forest, and the two preserves combine to form the largest community forest in the United States.

Spring River Preserve:

Fee Owner: The Nature Conservancy
GIS Acres: 13,455
Year: 2021
State: Maine
This 13,500-acre property in Downeast Maine was protected in 2021 by The Nature Conservancy. Conservation of this property will help maintain a forested connection between the Downeast coast and Maine's north woods, protecting habitat for wide-ranging wildlife and allowing species to move in response to a changing climate. The property includes 3.75 miles of shoreline on Narraguagus Lake, nearly completing conservation of the shoreline of the headwater lake for Spring River, as well as two miles of frontage on the north side of Spring River, seven miles of frontage on the West Branch of the Narraguagus River, and 46 miles of interior tributary streams. This land is important as a buffer for high-value aquatic habitat that that supports native brook trout fisheries and contributes to important Atlantic salmon habitat.

Crooked River Headwaters:

Interest Holder: Mahoosuc Land Trust
GIS Acres: 12,267
Year: 2021
State: Maine

A coalition of conservation-minded groups, federal agencies, and private landowners permanently protected 12,000 acres of forestland in Oxford County with a conservation easement. More than half of the lands filter water into Sebago Lake, the public drinking water supply for much of southern Maine. The project is considered a significant milestone to protect water quality, wildlife, and recreation.

Crocker Mountain:

Fee: Maine Bureau of Parks and Lands
Partner: Trust for Public Land
GIS Acres: 11,888
Year: 2013
State: Maine
Protected in 2013, 12,046-acre Crocker Mountain includes three of Maine's tallest mountains and some of the best opportunities for high mountain recreation including a 10-mile segment of the Appalachian Trail. Now part of the State of Maine's system of public reserve lands, the property will be open to hiking, hunting, fishing, and snowmobiling. The intact subalpine forest of Crocker's peaks also holds incredible ecological importance. Picturesque glacial cirques capture the eye, high elevation areas are home to the Northeast's most imperiled songbird, the Bicknells Thrush, and the cold-water streams host the endangered Roaring Brook Mayfly. The protection of Crocker Mountain is the latest in a notable list of conservation investments in Maine's Northern Forest by the federal Forest Legacy Program, Land for Maine's Future Program, private foundations, and individual donors. It is also a cornerstone success in a pattern of landscape conservation that links the Mahoosuc Mountains and Maine's High Peaks under the nationally recognized banner of the White Mountains to Moosehead Lake Initiative.

Boundary Mountains Preserve:

Fee Owner: The Nature Conservancy
GIS Acres: 9,527
Year: 2020
State: Maine
Boundary Mountains Preserve, at almost 10,000 acres protected by The Nature Conservancy, is an important link in a large swath of contiguous forest located adjacent to over 22,000 acres of public lands in Quebec. The preserve extends a corridor of permanently conserved lands northward to a total of over 260,000 acres, representing a key link in a major pathway of ecological connection from the White Mountains in New Hampshire through the western Maine Mountains and Quebec borderlands and beyond. The preserve includes a healthy, mature mountain forest, featuring 3,648-foot Caribou Mountain, 3,333-foot Merrill Mountain, and a dozen other peaks over 2,700 feet in elevation. It is important headwater habitat for the Kennebec River as well as headwater streams that feed into the nearby Moose River, providing great habitat for wild brook trout.

DeHart Property:

Fee Owner: Capital Region Water
Interest Holder: The Nature Conservancy
GIS Acres: 8,193
Year: 2016

State: Pennsylvania
In 2016, Capital Region Water's Board of Directors approved an agreement to conserve its 8,200-acre DeHart Property in Dauphin County by easement in partnership with The Ward Burton Wildlife Foundation, The Nature Conservancy, and Fort Indiantown Gap. The 8,200-acre DeHart Property located in northern Dauphin County is the primary source of drinking water for Capital Region Water's 60,000 plus customers. The DeHart Property includes the five-mile long and six-billion-gallon DeHart Reservoir and 7,500 acres of forestland. This pristine reservoir and forestland are the foundation to Capital Region Water's award-winning drinking water.

Sterling Run Conservation Easement:

Fee Owner: Pennsylvania Department of Conservation and Natural Resources
GIS Acres: 9,132
Year: 2018
State: Maine
Protected in 2018, the DCNR's Bureau of Forestry is applying a new approach to conserving forest land and expanding forest recreation opportunities in Pennsylvania. This new approach involves partnering with private landowners and employing a tool known as working forest conservation easements. The DCNR partnered with the Lyme Timber Company to conserve the first of these lands near Sterling Run, in Cameron County. This more than 9,000-acre tract is owned by an affiliate of The Lyme Timber Company, with DCNR holding a conservation easement for the public access and recreation rights as well as landowner requirements for conservation and sustainable forest management. Public access will be managed by the Bureau of Forestry as part of Elk State Forest.

USN Ursa Major:

Easement Holder: US Navy
Partner: Trust for Public Land
GIS Acres: 8,492
Year: 2020
State: Maine
Protecting this land ensured permanent public access in a part of Maine where many communities are looking for more places to get outside in all four seasons. This project also maintained one of the most scenic views from the Appalachian Trail, conserved an intact working forest, and protected habitat for the endangered Atlantic salmon and Bicknell's Thrush, a state species of concern. Through a unique partnership, the project also helped the Navy meet their military readiness goals by buffering the SERE School, a remote training facility.

Cold Stream Forest:

Fee Owner: Maine Bureau of Parks and Lands
Partner: Trust for Public Land
GIS Acres: 8,157
Year: 2016

State: Maine
The Trust for Public Land helped protect 8,000 acres known as Cold Stream Forest in 2016—a refuge for the wild native brook trout, threatened Canada lynx, and dwindling northern Maine deer herd that have attracted generations of hunters, naturalists, and fly fishermen. The trout pond populations on this property alone are larger than those found in Massachusetts, New Hampshire, and Vermont combined.

Gulf Hagas - White Cap:

Fee Owner: Maine Bureau of Parks and Lands
Partner: Forest Society of Maine
GIS Acres: 8,401
Year: 2016
State: Maine
This 10,000-acre property protected in 2016 by The Forest Society of Maine, the Gulf Hagas – Whitecap conserved lands maintain productive forestland to help forest products businesses; provide an important buffer to 11 miles of the Appalachian Trail corridor; preserve and enhance public access to numerous campsites, hiking trails, Gulf Hagas, and a segment of the popular Interconnected Trail System for snowmobiles; and protects Eastern brook trout habitat and supports Atlantic salmon restoration.

Leuthold Forest Preserve:

Fee Owner: The Nature Conservancy
Partner: Forest Society of Maine
GIS Acres: 6,566
Year: 2015
In 2015, there was a 6,500-acre addition to the Leuthhold Forest TNC preserve in Maine, which features a unique Fir-Heart Leaved Birch Alpine Forest and the fourth largest contiguous Spruce-Fir/Northern Hardwood Forest in Maine. The complete shorelines of seven ponds are also protected within the preserve. Among the wildlife species that thrive here are pine marten, gray jay, boreal chickadee, Blackburnian warbler, and blackpoll warbler.

Upper St John River Watershed:

Fee Owner: The Nature Conservancy
Partner: Forest Society of Maine
GIS Acres: 6,364
Year: 2014
This GAP 1 forest reserve owned by The Nature Conservancy, with an easement by the Forest Society of Maine in 2014, this property connects to the larger Upper St John River Forest in northwestern Maine.

Albany Water Board Conservation Easement:

Easement Holder: Mohawk Hudson Land Conservancy
GIS Acres: 6,343
Year: 2019
State: New York

The City of Albany's drinking water reservoirs are surrounded by about 5,000 acres of forest that work to filter surface and groundwater and improve water quality. To protect these lands, in 2019, the Albany Water Board joined The Nature Conservancy's Working Woodlands Program, a program that preserves forest land and generates revenue by marketing carbon credits to a voluntary carbon market. Through this program, the city will improve forest health, protect water resources, and create new revenue to maintain these benefits for people and nature into the future.

Redington Easement:

Easement Holder: US Department of the Navy, Maine Appalachian Trail Land Trust
GIS Acres: 6,335
Year: 2019
State: New York
Protected in 2018, this easement is co-held by the US Navy and Maine Appalachian Trail Land Trust.

East Grand Lake:

Fee Owner: Maine Bureau of Parks and Lands
Partner: The Conservation Fund, US Forest Service Forest Legacy
GIS Acres: 6,070
Year: 2016
State: Maine
In 2016, The Conservation Fund secured 7,486 acres of working forestland in the town of Orient. Located along the international border of eastern Maine and New Brunswick, Canada, the newly conserved land will continue to be sustainably harvested for timber while securing the largest white-tail deer wintering area in the region and protecting key waterfowl habitat along North Lake and Monument Brook, both of which are essential to the local recreation economy. Made possible in part with funding from the U.S. Forest Service's Forest Legacy Program, through the Land and Water Conservation Fund (LWCF), The Conservation Fund conveyed 5,992 acres and a conservation easement on 1,494 acres to the Maine Bureau of Parks and Lands in late March 2016.

Woodbury Mountain Wilderness Preserve:

Fee Owner: Northeast Wilderness Trust
GIS Acres: 5,947
Year: 2021
State: Vermont
This preserve, purchased in 2021 by the Northeast Wilderness Trust, is the largest non-governmental wilderness area in the state of Vermont. Woodbury Mountain Wilderness Preserve includes headwater streams of the Lamoille and Winooski Rivers. It protects regional wildlife connections, and includes stunning northern hardwood forests, a diversity of wetlands, and 39 miles of headwater streams.

Orbeton Stream:

Easement Holder: Maine Bureau of Parks and Lands
GIS Acres: 5,778
Year: 2012

State: Maine
The Orbeton Stream conservation easement was completed in 2014 by a coalition of partners that included The Trust for Public Land, Maine Appalachian Trail Land Trust, High Peaks Alliance, and others. The Land for Maine's Future program allocated $150,000 to the project and other funding came from the Open Space Institute, Wildlife Conservation Society, Fields Pond Foundation, Hopwood Charitable Trust, John Sage Foundation, and many private donors. The easement is held by the Maine Bureau of Parks and Lands, over land owned by Linkletter Timberlands, LLC. The land contains 5,495 acres of working forest with trail access for both motorized and non-motorized activities. The Appalachian Trail runs along the western edge of the property and the Orbeton Stream, which is the site of Atlantic Salmon breeding grounds and some spectacular waterfalls, runs through the middle of the property.

Seboeis:

Fee Owner: Maine Bureau of Parks and Lands
Partner: Trust for Public Land
GIS Acres: 5,749
Year: 2012
State: Maine
The 5,741-acre Lake View Plantation parcel was added in 2012 to the roughly 15,600-acre Seboeis Public Reserved Lands Unit, which is managed by the Maine Bureau of Parks and Lands for timber harvesting, outdoor recreation, and wildlife. The Trust for Public Land, a national land conservation organization, worked with the state to arrange the acquisition from Bigelow Timber Corp. of Madison.

Bald Eagle Mountains:

Easement Holder: The Nature Conservancy
GIS Acres: 5,296
Year: 2013
State: Pennsylvania
In 2013, Lock Haven City in Pennsylvania worked with The Nature Conservancy to protect 5,200 acres in a conservation easement. Lock Haven City Authority, as a partner in The Nature Conservancy's Working Woodlands Program, agreed to forever protect and sustainably manage its forest and freshwater resources.

George Washington and Jefferson National Forests:

Fee Owner: US Forest Service
Partners: The Open Space Institute, and the Chesapeake Conservancy
GIS Acres: 4,592 (in total 7676 acres protected over the last 10 years in George Washington and Jefferson National Forests)
Year: 2019
State: Virginia
In 2019, the US Forest Service, the Open Space Institute, and the Chesapeake Conservancy announced a Land and Water Conservation Fund success in protecting a significant property within the George Washington and Jefferson National Forests. The purchase of the 4,664.5-acre property in Botetourt County, Virginia will preserve a local historic asset, enhance recreation access, and protect the water

quality of Craig Creek, a tributary to the James River and the Chesapeake Bay. The property is one of the largest tracts to be acquired for conservation purposes in Virginia in decades.

Charlotte State Forest:

Fee Owner: VA Department of Forestry
GIS Acres: 5003
Year: 2020 and 2021
State: VA
The Charlotte State Forest is 5,005 acres (2,531 acres acquired in late 2020 as phase 1 and 2,474 acres acquired in 2021 as phase 2) in Charlotte County. It is managed for sustainable timber production, demonstration of scientific forest management, applied forest research, diverse wildlife habitat, watershed protection, biological diversity, and passive outdoor recreation.

New Federal National Monument:

Katahdin Woods and Waters National Monument:

Fee Owner: US National Park Service / US Department of the Interior
GIS Acres: 88,104
Year: 2016
State: Maine
The 413th national park, Katahdin Woods and Waters, is part of Maine's famed North Woods, offering recreation opportunities for all. Comprised of 87,500 acres in Penobscot County, Maine, the Katahdin region is a popular destination for outdoor recreation and home to a wide diversity of wildlife, and contains spectacular mountains, important historical resources, and areas of great cultural significance. The area contains opportunities for hiking, camping, mountain biking, fishing, hunting, and snowmobiling. These uses are fully protected and enhanced under the President's national monument designation signed on August 24, 2016.

National Wildlife Refuges:

Over the last 10 years, more than 13,542 acres were added to the National Wildlife Refuges. The largest addition was to Umbagog National Wildlife Refuge (4,500 Acres) as a part of the Androscoggin Headwaters Fee and Easements project. The other large acquisition was Cherry Valley National Wildlife Refuge in Pennsylvania (4,213 Acres). Other smaller acquisitions include Forsythe NWR, Cape May NWR, Great Dismal Swamp NWR, Rappahannock River Valley NWR, and Canaan Valley NWR. Funding for the NWR acquisitions and easements include Migratory Bird Conservation Fund Returns and Land and Water Conservation Fund Returns.

State Easement Programs:

Several states have coordinated easement acquisition programs that we were able to identify in the database. These coordinated easement programs protected around 330,000 acres in the region. The largest of these programs is Virginia Outdoors Foundation with 235,510 acres in easements. Established by the Virginia General Assembly in 1997 and administered by the Virginia Outdoors Foundation (VOF), the Open-Space Lands Preservation Trust Fund (PTF) provides grants for acquisitions, easements, rights of way, and other methods of protecting open space for farming, forestry, recreation, wildlife, water quality, and more. They currently have 1.8 million in funding available for the second half of 2023. Virginia established Land Preservation Tax Credits in 2000 to encourage private landowners to limit development of rural open spaces and keep the land available for farming, forestry, recreation, and other traditional rural uses. About 83% of all the land that VOF has protected since it was established in 1966 has been protected since 2000. Maryland's Forest Conservation Act Easements have protected 21,909 Acres since 2011. Massachusetts has several state easement programs which include easements held by DCR Parks and Rec, DCR Division of Water Supply Protection WPR easements, and MA Department of Fish and Game.

State Fee Programs:

Mass Division of Fisheries and Wildlife: actively protects lands. In FY 2022 they completed 11 projects and protected 937 acres. These projects were completed using bond funds, Land Stamp funds, and cooperative partnerships with land trusts.

PA State Wildlife Management Additions (29,000 acres). Some examples of new State Game Land Acquisition include State Game Land 042, State Game Land 332, State Game land 334, and State Game land 333. Recently in 2022, nearly 1,000 acres were added on various properties. PA Game Commission acquisitions are funded primarily by hunting and furtaker license sales; State Game Lands timber, mineral, and oil/gas revenues; and a federal excise tax on sporting arms and ammunition (Pittman-Robertson Act). The Commission is almost entirely supported by hunters and trappers, or assets that have been procured with license dollars. Some of these PGC acquisitions are "matched" with other state acquisition money from the Dept of Conservation and Natural Resources C2P2 Grant program or other private funds, e.g., PGC will pay for half and TNC (or other land trusts) might raise the other 50% through private (donors, OSI, ATC) and other state grant programs.

New Jersey Green Acres Program Fee (40,500 acres) is one of the first state land acquisition programs, founded in 1961. It is funded through the Garden State Preservation Trust act and Preserve New Jersey Act. Over the past sixty years, Green Acres has passionately strived to accomplish the ambitious goals of the State's early conservation efforts. As of March 2021, Green Acres has funded the preservation of 714,558 acres of parkland through state, local, and nonprofit acquisitions, adding them to the system of protected public open space in the state and preserving the environmental and recreational resources within them.

Appendix 2.2: Shortened wording for definitions of GAP status

GAP 1: Permanent protection for biodiversity. Examples: Nature reserves, research natural areas, wilderness areas, and Forever-Wild easements.

GAP 2: Permanent protection to maintain a primarily natural state. Examples: National Wildlife Refuges, many state parks, and high use National Parks.

GAP 3: Permanent protection for multiple uses, typically retaining natural cover but often subject to extractive uses such as logging. Examples: State or Town forest or Crown lands in Canada managed for timber; land protected from development by forest easements. GAP 3x refers to permanent protection where natural cover is removed (permanent farm easements, city parks).

GAP 4: Temporarily protected lands, or lands with no securement. If there is no practical way to contact each manager of every protected area to determine management practices, these assignments based on the designation can be used as a starting point, after first determining if the area has permanent protection or is not already developed.

Status 1: National Park, National Monument, Wilderness Area, Nature Reserve/Preserve, Research Natural Area, Heritage areas

Status 2: State Parks, State Recreation Areas, National Wildlife Refuge, National Recreation Area, Area of Critical Environmental Concern, Wilderness Study Area, Forever-Wild Conservation Easement, National Seashore

Status 3: BLM Holdings, Military Reservations, National Forests, State Forest, Wildlife Management Areas, Game and Fish Preserves, State Commemorative Area, Access Area, National Grassland, ACOE Holding. Private Land with Conservation Easement

Status 4: Private Land with no easements, Tribal Land, City Park, Undesignated State Land, County Land, City Land, Fish Hatcheries

Dichotomous key for assigning GAP protection status codes

A-1:

If the management intent can be determined through agency or institutional

documentation GO TO A-2, if not, GO TO A-5

A-2:

If the land unit is subject to statutory or legally enforceable protection from conversion to

anthropogenic use of all or selected biological features by state or federal legislation, regulation, private deed restriction, or conservation easement intended for permanent status, GO TO B-1; if not, GO TO A-3

A-3:

If ecological protection is not legally enforceable, temporary, or lacking but managed by a plan intended for permanent status, GO TO A-4; if not, GO TO A-5

A-4:

Management to benefit biological diversity is provided by a written plan in place or in process under an institutional policy requiring such management - Status 3

A-5:

Not subject to an adopted management plan or regulation that promotes biological diversity, or management intent is unknown - Status 4

B-1:

If the total system in the land unit is conserved for natural ecological function with no more than 5% of the land unit in anthropogenic use, GO TO B-4; if conservation provisions apply only to selected features or species, GO TO B-2

B-2:

If management emphasizes natural processes including allowing or mimicking natural ecological disturbance events, but also allows low anthropogenic disturbance, renewable resource use, or high levels of human visitation on more than 5% of the land unit - Status 2; if not, GO TO B-3

B-3:

Management allows intensive, anthropogenic disturbance such as resource extraction, military exercises, or developed or motorized recreation on more than 5% of the land unit, but includes ecological management for select features - Status 3

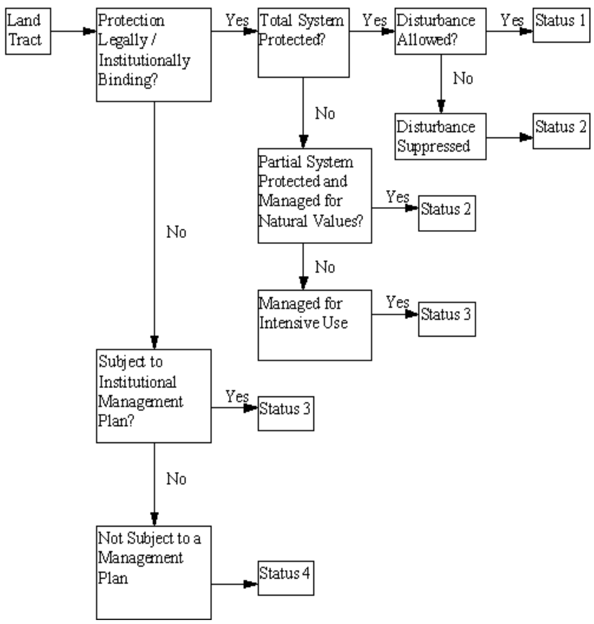
B-4:

If management strives for natural processes including allowing or mimicking natural ecological disturbance events - Status 1; if not, GO TO B-5

B-5:

Managed for natural processes, but some or all disturbance events are suppressed or modified - Status 2

Dichotomous key for assigning GAP protection status codes



Appendix 2.3.The Nature Conservancy's 2022 Secured Lands Data Sources

The 2022 Northeast Conservation Lands dataset used in this report was compiled from multiple sources. These include state, federal, and other non-profit and land trust data. The primarily datasets are listed below. TNC reviewed the source data for spatial accuracy and assigned GAP status along with other attributes in our standard conservation lands database attribute template as possible. Please contact the primary TNC State GIS analysts for additional detailed information on the input sources within their states, GAP coding rules, and other questions within states.

CONNECTICUT
Overview: This Connecticut Conservation Lands dataset was based on an update of the existing 2018 Secured Lands dataset compiled by TNC which had its roots in 1) the 2005 Protected Open Space Phase 1 dataset which mapped parcels designated as permanently protected open space by the Connecticut Department of Environmental Protection, 2) a Municipal and Private Open Space data layer from the Connecticut Office of Policy and Management DEP which mapped property owned by Connecticut municipalities and private organizations for the purpose of preserving open space including land conservation trust property, town open space, parks, school playgrounds, campgrounds, golf courses, club/association recreational property, and cemeteries, and 3) a DEP Property dataset which included state owned property such as natural area preserves, state forests, state parks, state park scenic reserves, state park trails, wildlife areas, and wildlife sanctuaries. This dataset was augmented in summer 2022 with updated TNC lands, Harvard Forest Wildlands 6/2022 parcels, Northeast Wilderness Trust properties, and a newly available protected open space dataset for eastern Connecticut from efforts of the CT Land Conservation Council/The Last Green Valley Protected Open Space Mapping Project (5/2/2022 Brian Hall, Hunter Brawley, Amy Patterson, Lois Bruinooge).
Contact Information: Anna Ormiston anna.ormiston@TNC.ORG, The Nature Conservancy of New Hampshire
Last Updated: September 2022

DELWARE
Secured lands are present in Delaware via their FirstMap online service, under their Preserved Lands Network 2.0 layer. Additionally, Drexel University was able to provide more data on secured lands throughout the Delaware River Basin. A similar process to that descried for Delaware was used to crosswalk between the fields in this dataset and the secured areas schema Sources: FirstMap Delaware, Drexel, The Nature Conservancy, PAD-US 3.0
Contact Information: Melissa Clark, melissa_clark@tnc.org, The Center for Resilient Conservation Science, The Nature Conservancy
Last Updated: December 2022

MAINE
Overview: The Maine Conservation Lands Geodatabase is maintained and updated by the Maine Chapter of The Nature Conservancy in cooperation with Justin Schlawin, Maine Department of Agriculture, Conservation, and Forestry. It includes most of the state, federal, and larger private conservation lands with legal protection in the state of Maine. TNC in Maine is working with both state agencies and land trusts to improve comprehensive updating and the overall content of this dataset. The spatial data is compiled from over 300 different data sources and are from a variety of scales, ranging from 1:100,000 scale to high-accuracy digital surveys.
Contact Information: Dan Coker dcoker@TNC.ORG, The Nature Conservancy of Maine.
Last Updated: May 2022

MARYLAND
Overview: The Maryland Conservation Lands dataset is based on a compilation of multiple sources, with most data coming from the https://imap.maryland.gov/, data downloaded Feb 2022. The iMAP data sources included DNR Owned and Conservation Easements, MD Environmental Trust Easements, Protected Federal Lands, Coastal Estuarine Land Conservation Progam, Rural Legacy Properties, Private Conservation Lands, Local Protected Lands, MALPF Easements, Transfer Purchased Development, and Forest Conservation Act Easements. Additional sources include NRCS Geospatial Data Gateway Agricultural Conservation Easement Program Wetlands Reserve Easements, military lands from the previous 2018 MD Secured Areas dataset, and updated TNC lands.
Contact Information: Michelle Canick mcanick@TNC.ORG, The Nature Conservancy of Maryland
Last Updated: June 2022

MASSACHUSETTS
Overview: The Massachusetts Conservation Lands layer is based primarily on the Protected and Recreational Open Space, MassGIS. Link to Data Version April 2022, from the Executive Office of Energy and Environmental Affairs, Office of Geographic and Environmental Information (MassGIS). This layer contains the boundaries of conservation lands and outdoor recreational facilities in Massachusetts. The associated database contains relevant information about each parcel, including ownership, level of protection, public accessibility, assessor's map and lot numbers, and related legal interests held on the land, including conservation restrictions. Additional parcels and attributes were added from TNC_Interests Version March 2022, DCR Landscape Designations Version 2012, and Harvard Forest Wildlands June 2022 datasets.
Contact Information: Jessica Dietrich jessica.dietrich@TNC.ORG, The Nature Conservancy of Massachusetts
Last Updated: October 2022

NEW HAMPSHIRE
Overview: The New Hampshire Conservation Lands dataset was based primarily on NH GRANIT data as of July 2022. The New Hampshire Geographically Referenced Analysis and Information Transfer System (NH GRANIT) https://www.nhgeodata.unh.edu/ maintains and updates the statewide conservation lands dataset through extensive outreach to federal and state agencies, municipalities, land trusts and private land owners. TNC worked to integrate additional land trust lands compiled by TNC in cooperation with GRANIT but which had not been integrated into the latest GRANIT posted conservation lands dataset, additional properties from the Harvard Forest Wildlands project, and management zones from the US Forest Service land in the White Mountains of New Hampshire using the US Forest Service Management Areas.
Contact Information: Anna Ormiston anna.ormiston@TNC.ORG, The Nature Conservancy of New Hampshire **Last Updated:** September 2022

NEW JERSEY
Overview: The New Jersey Conservation Lands dataset was based primarily on the New Jersey Department of Environmental Protection (NJDEP), Green Acres Program state-local-and-nonprofit-open-space layer (version 20220810) which includes Green Acres encumbered and unencumbered protected open space and recreation areas. The Green Acres encumbered lands are owned in fee simple interest by either the state, county, municipality, or a nonprofit agency and have either received funding through the Green Acres State or Local Assistance Program or are listed on a Green Acres approved Recreation and Open Space Inventory (ROSI). The unencumbered open space lands do not fall under Green Acres rules and regulations and therefore have a lesser level of protection. Types of open space property in this data layer include parks, conservation areas, preserves, historic sites, recreational fields, beaches, etc. The data was derived from a variety of mapped sources which vary in scale and level of accuracy. This dataset was

augmented with additional Federal conservation land from USGS Protected Areas Database 2.1, TNC lands as of September 2022, and the Farmland Preservation File http://www.state.nj.us/agriculture/sadc/farmprogress.htm .
Contact Information: Mike Shanahan mshanahan@TNC.ORG, The Nature Conservancy of New Jersey
Last Updated: September 2022

NEW YORK
Overview: The New York Conservation Lands dataset used in this report is based primarily on the draft New York Protected Areas Database (NYPADv20) obtained for use in this project 5/2022 from New York Natural Heritage Program Department of Environmental Conservation. This data layer represents a new effort to update and combines the most current known parcels of land in New York state that have some level of protection including state, federal, local, municipal, and non-profit lands and easements. Given the draft nature of this dataset, NY NHP asked the digital data not be further re-distributed but only used in statistics and static maps developed as part of this NEAFWA Conservation Status report. Upon study and comparison of the draft NY PAD to the 2018 New York Secured Areas dataset previously compiled by TNC, the draft NYPAD was found to be missing various non-profit lands and easements and in some cases other local conservation lands and military ownership lands. These missing GAP 1-3 lands were added from the 2018 New York Secured Areas dataset and updated TNC lands were also added into the resultant New York Conservation Lands dataset used in this analysis.
Contact Information: David Richardson david.richardson@TNC.ORG, The Nature Conservancy of New York
Last Updated: September 2022

PENNSYLVANIA
Overview: The Pennsylvania Conservation Lands dataset was derived from the WeConservePA dataset which maintains and regularly updates a comprehensive, statewide series of datasets mapping conserved Federal, State, Local, LandTrust, and Easement lands. A most current version of these datasets was obtained from Irina Beale at WeConservePA as of 9/1/2022. Some additional management zones within larger state or federal forests were added based on PAD-US 3.0.
Contact Information: Tamara Gagnolet tgagnolet@TNC.ORG, Jacob Leizear jacob.leizear@TNC.ORG The Nature Conservancy of Pennsylvania
Last Updated: December 2022

RHODE ISLAND
Overview: The Rhode Island Conservation Lands dataset is based on a compilation of state, federal, local and NGO datasets. It builds upon the 2018 Secured Areas dataset compiled by TNC. The primary source dataset is the State Conservation and Park Lands layer from The State of Rhode Island Department of Environmental Management which contains approximate edges of conservation lands protected by the State of Rhode Island through Fee Title Ownership, Conservation Easement, or Deed Restriction. Additional local and NGO lands were added from the State DEM local conservation lands dataset, TNC lands, and other land trusts as available.
Contact Information: Kevin Ruddock kruddock@tnc.org, The Nature Conservancy of Rhode Island
Last Updated: September 2022

VERMONT
Overview: The Vermont Conservation Lands Database was developed using multiple sources. It included the Vermont Protected Areas Database as of 8/28/2022 from VT Center for Geographic Information which incorporates revisions from Cooperating Technical Partners (Vermont Agency of Natural Resources, Vermont Land Trust, Green Mountain National Forest, Upper Valley Land Trust, Vermont Housing and Conservation Board, Green Mountain Club, The Nature Conservancy). Substantial further

improvements were made in the summer and fall of 2022 by TNC including effort to remove duplicates, overlaps, and add new data from Northeast Wilderness Trust, Protected Areas Database US Version 2.1, State of Vermont Forest Legacy Program, Stowe Land Trust, Upper Valley Land Trust, Vermont Agency of Natural Resources, VT DEC River Corridor Easements, Vermont Land Trust and Vermont River Conservancy, Harvard Forest Wildlands, and updated TNC lands.
Contact Information: Ann Ingerson ann.ingerson@TNC.ORG, The Nature Conservancy of Vermont
Last Updated: November 2022

VIRGINIA
Overview: The Virginia Conservation Lands dataset was developed primarily from Virginia Department of Conservation and Recreation data, TNC lands, and USGS Protected Areas Database 2.1 The primary source was the Virginia Conservation Lands Database that is continually maintained and updated by the state Department of Conservation & Recreation. It includes all state and federal lands and many local and private conservation lands. A current version of which was obtained from David Boyd at DCR. This dataset includes TNC lands, however to ensure the most up-to-date and accurate TNC lands data were included in the secured areas data, TNC lands were removed from the DCR data before starting. TNC assigned GAP status using information in the source data and also attemped to eliminate the many overlapping polygons (>20 acres in size) present in the DCR data, due to multiple designations (e.g., national forest and wilderness area) or conservation easements co-held by multiple organizations.
Contact Information: Chris Bruce cbruce@TNC.ORG, (David.Boyd@dcr.virginia.gov)
Last Updated: September 2022.

WEST VIRGINIA
Overview: The West Virginia Conservation Lands dataset was based on the WV protected lands data that was submitted to PAD-US by Maneesh Sharma, of the West Virginia GIS Technical Center. It was later determined that this dataset did not include certain Federal lands, so additional Federal lands were added from the USA Federal Lands data published by Esri in the Living Atlas and from USFWS ownership data. Agricultural and some other easements were also not included so these were obtained from the WV Farmland Protection Program and incorporated. Upon the release of PAD-US 3.0, some edits were made based on these data. Finally, updated TNC Lands data were incorporated. GAP status and other fields in the dataset were populated by TNC as possible given available source information.
Contact Information: Chris Bruce cbruce@TNC.ORG, The Nature Conservancy of Virginia
Last Updated: September 2022.

Additional Data Sources

U.S. Geological Survey (USGS) Gap Analysis Project (GAP), 2022, Protected Areas Database of the United States (PAD-US) 3.0: U.S. Geological Survey data release, https://doi.org/10.5066/P9Q9LQ4B.

National Conservation Easement Database (NCED_06232022.gdb) https://www.conservationeasement.us/# The NCED is an initiative of the U.S. Endowment for Forestry and Communities.

Harvard Forest Wildlands (Wildlands_06062022.shp). Compiled for the project Wildlands in New England. Past, Present and Future. Foster, David R. drfoster@fas.harvard.edu Hall, Brian R. <brhall@fas.harvard.edu>

Northeast Wilderness Trust Properties, September 2022

The Trust for Public Land, *Conservation Almanac*, 2022, www.conservationalmanac.org.

CHAPTER

Forests 3

Condition and Conservation Status

Feb 2023

M. Clark, M. G. Anderson, & A. Olivero

Forests define the eastern landscape, but although forests give a feel of permanence to the land they have been in continual change for centuries. In this chapter we examine the state of our forests, and take stock of their conservation, turnover, historic and recent conversion, fragmentation, and connectedness.

Historic Loss and Conservation: Ninety-one percent of the region was once covered by forest, now forest covers 61% with the rest converted to converted to agriculture (15%), development (12%) or other natural systems (3%). Of the remaining forest, conservation efforts have secured 24% against conversion including 8% explicitly for nature and 17% for multiple use. Thus, for every acre of forest conserved, 1.6 acres have been lost to conversion. Boreal Upland Forest is considerably more conserved (39%) than Northern Hardwood Forest (25%) or Central Oak Pine Forest (22%).

Recent Trends in Turnover and Loss: Eight million acres (8%) of eastern forests have changed markedly over the last twenty-years (2001-2021). Forest turnover accounts for 57% of the change reflecting active logging and natural disturbances followed by regrowth back to forest. Another 28% transformed to other natural land cover reflecting recent turnover that may return to forest or changing climate regimes. Less than 1% was converted to development (0.6%) or industrial agriculture (0.2%) an annual loss 35,500 acres per year.

Recent Trends in Conservation: Across the last two decades (2001-2021) conservation greatly surpassed conversion reversing the historic trend for all forest types: Boreal Upland (89:1), Northern Hardwood (7:1) Central Oak Pine (5:1), an average of 7.6 acres conserved for every acre converted. Land conserved explicitly for nature showed markedly less forest turnover and change (3%) than land conserved for multiple uses (7%) or unconserved land (9%). Recent easements have focused on forest with high levels of turnover and change.

Forest Connectivity: Forests in the region are highly fragmented by permanent roads, powerlines, and fields. Boreal Upland was the only forest type to score markedly above the regional mean for local connectedness (1.3 SD). This likely reflected the large amount of conservation land. Land conserved for nature (1.25 SD) and land conserved for multiple uses (0.79 SD) both had average connectedness values far above the regional mean. Losses in connectedness over the last decade were localized but pervasive across the region.

Forest Types

Ecologists recognize four major forest types in this region and 30 to 40 variations related to latitude, soil, elevation and distance to the coast. We used a simplified version of TNC's Terrestrial Habitat map (Ferree and Anderson 2013) augmented with current land use (NLCD 2019) and forest extent (GFC 2022) to map existing vegetation to quantify the abundance of each type.

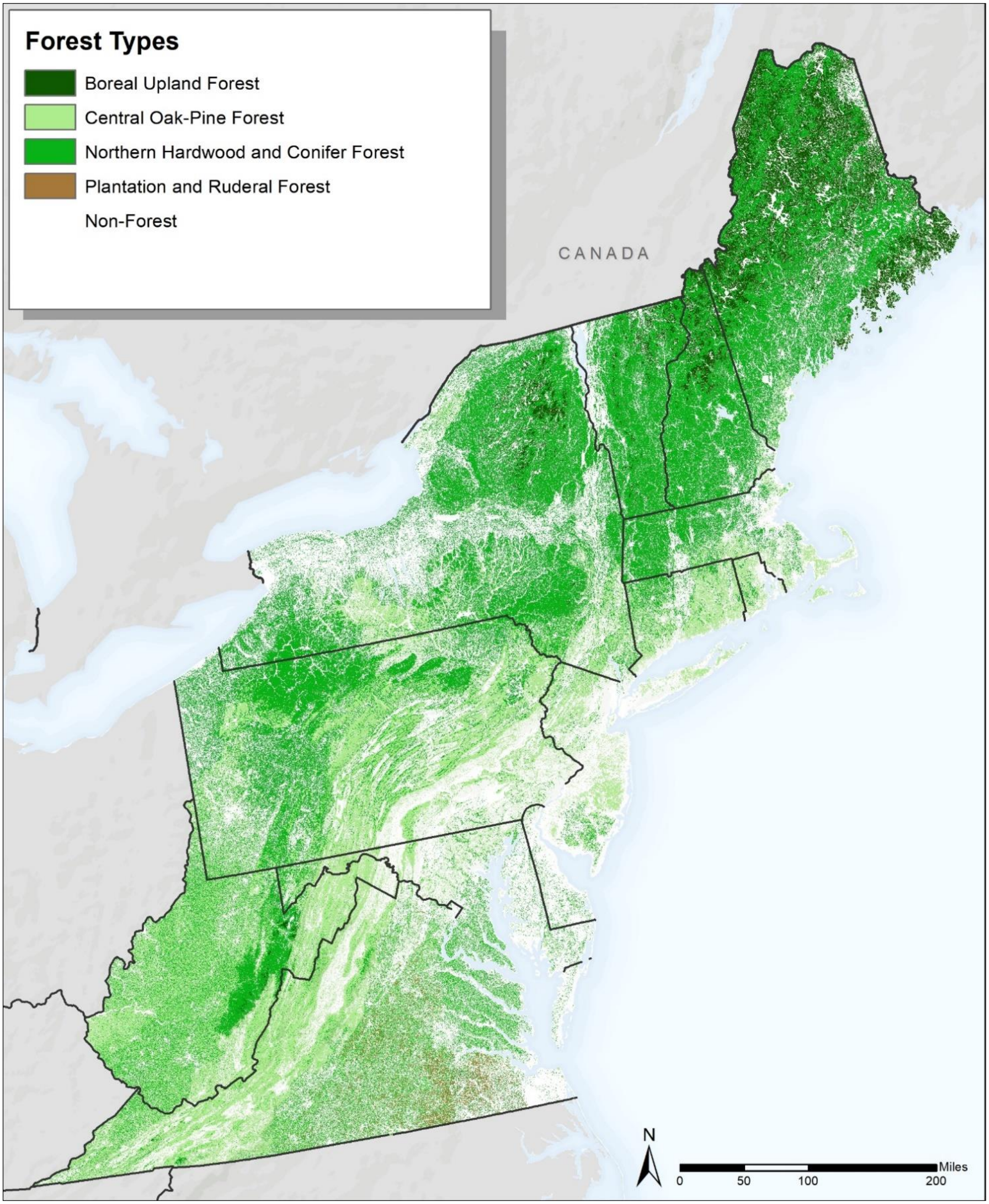
Northern Hardwood and Conifer Forest: This heterogeneous forest type typical of mesic settings covered 54% of the region (50.5 million acres) and occurred throughout at higher elevation or northern latitudes (Map 1). It is a deciduous or mixed forest dominated by sugar maple, American beech, and yellow birch (i.e. hardwoods other than oaks and hickories). Conifers, when present, include white pine, eastern hemlock, or red spruce. Other deciduous associates include red maple, white ash, paper birch, red oak, American basswood, and tulip tree. Mixed forests are often dominated by some combination of hemlock with sugar maple and tend to occur in moist ravines or north slopes. In the southern portion of the region, examples in coves or protected settings may include the characteristic trees: cucumber-tree, mountain magnolia, umbrella-tree, yellow buckeye, and mountain silverbell, and a diverse herb layer with blue cohosh, black bugbane, American ginseng, and northern maidenhair.

Central Oak-Pine Forest: This forest type was most common in the southern portion of the region, covering 35% of the region's forests (32.4 million acres, Map 1). Oaks and pines dominate these dry forests that typically have a well-developed understory and a full or discontinuous canopy. Characteristic trees include eastern white pine, pitch pine, or red pine with chestnut oak, northern red oak, and/or bear oak. Early-successional examples are often more strongly pine-dominated with oaks and hickories increasing over time. Sometimes the pines are absent and oaks, hop hornbeam, or sugar maple dominate. Chestnut oak often prevails on dry exposed ridges and plateaus, usually with an understory of heathy shrubs. On more mesic sites a mix of oaks (northern red oak, white oak, black oak, scarlet oak) and hickories (mockernut hickory, shagbark hickory, red hickory) are common associates.

Boreal Upland Forest: This forest type makes up 8% of the region's forests (7.7 million acres) and was largely restricted to the northern states or high elevation settings (Map 1). Spruce and fir are characteristic trees, with conifer cover generally exceeding deciduous. In mountain settings, yellow birch may share the canopy over an understory of mountain-ash and other montane species. Red spruce, balsam fir and jack pine tend to dominate in valley settings with hardwood associates such as yellow birch, paper birch, or American beech. Black spruce is characteristic of imperfectly drained flat soils.

Ruderal and Plantation Forest: This is a forest type dominated by early-successional trees such as red maple, paper birch, loblolly pine, Virginia pine, bigtooth aspen, or quaking aspen without a strong component of oak, hickory or other hardwoods. It is a forest is comprised of short-lived, light-requiring trees that develops quickly on land reverting from being cleared, plowed, or grazed. Plantations are identified by trees apparently in row or having other evidence of intentional planting by humans. Ruderal forest comprised 2.4 % of the region's forests (2.3 million acres, Map 1).

Map 3.1. Major Forest Types of the Northeast Region.



Distribution, Loss, and Protection Status

Forest currently covers 61% of the region's land area (93 million acres) and is composed of three major forest types: northern hardwood (54%), central oak-pine (35%), boreal upland (8%), plus a small component of ruderal forest that is always in flux (3%, Map 3.1). The northern region differs substantially in composition from the south. New England and New York forests are 72% northern hardwoods, 17% boreal forest, and 11% central oak-pine (Figure 3.1). In contrast, Mid-Atlantic forests are 57% central oak pine, 39% northern hardwoods and 4% ruderal forest, with a small amount of boreal forest occurring in the extreme mountainous areas.

<u>Historic Loss:</u> The region has a long history of forest clearing and conversion. To quantify forest conversion, we overlaid the most recent National Land Cover Data (2019) on the LANDFIRE map of biophysical settings (BpS, LANDFIRE 2016) which represents the vegetation system that may have been dominant on the landscape prior to Euro-American settlement. We calculated the difference between the historic distribution and the current distribution by subtracting all the current non-forest cells (30-m) that fall within historic forest distribution and quantifying the land use type of each. The results indicate that 36.5 million acres, or 27% of all historic forest, have been permanently converted to agriculture (15%) or development (12%). A larger percentage of forest in the Mid-Atlantic has been converted than in New England/New York mostly to agriculture (Figure 3.1A).

<u>Conservation:</u> The region also has a long history of public and private conservation. To measure the amount of conserved forest in the region, we overlaid the 2022 TNC conserved lands dataset (described in the Conservation Lands chapter) on the map of existing forest types (Map 3.2). The results show that 25% of the remain forest is now under conservation (Figure 3.1 &3.2, Table 3.2), including 7 million acres of forest conserved for nature (GAP 1-2) and 15 million acres conserved for multiple uses (GAP 3). Boreal forests had the highest proportion of conservation land with 38% (2.8 million acres) conserved including 8% explicitly for nature. Central Oak-Pine was proportionally the least conserved forest (22%, 5.3 million acres) and had the least conservation for nature (5%). Northern Hardwood forests were intermediate with 23% conserved including 8% conserved for nature and 15% for multiple uses.

Conservation Land Terminology

Conserved (GAP 1-3): The land is permanently secured against conversion to development.

Conserved for Nature (GAP 1): The land is conserved for nature and natural processes.

Conserved for Nature (GAP 2): The land is conserved for nature with management.

Conserved for Multiple Uses (GAP 3): The land is secured AND the intent of the management is for multiple uses, including forest management. This land may provide implicit conservation value such as connectivity or providing stream buffers.

CRI = Conservation Risk Index = %Conv / %GAP1-3

NRI = Nature Risk Index = % Conv / %GAP 1-2

Map 3.2. Conservation Land and Major Forest Types.

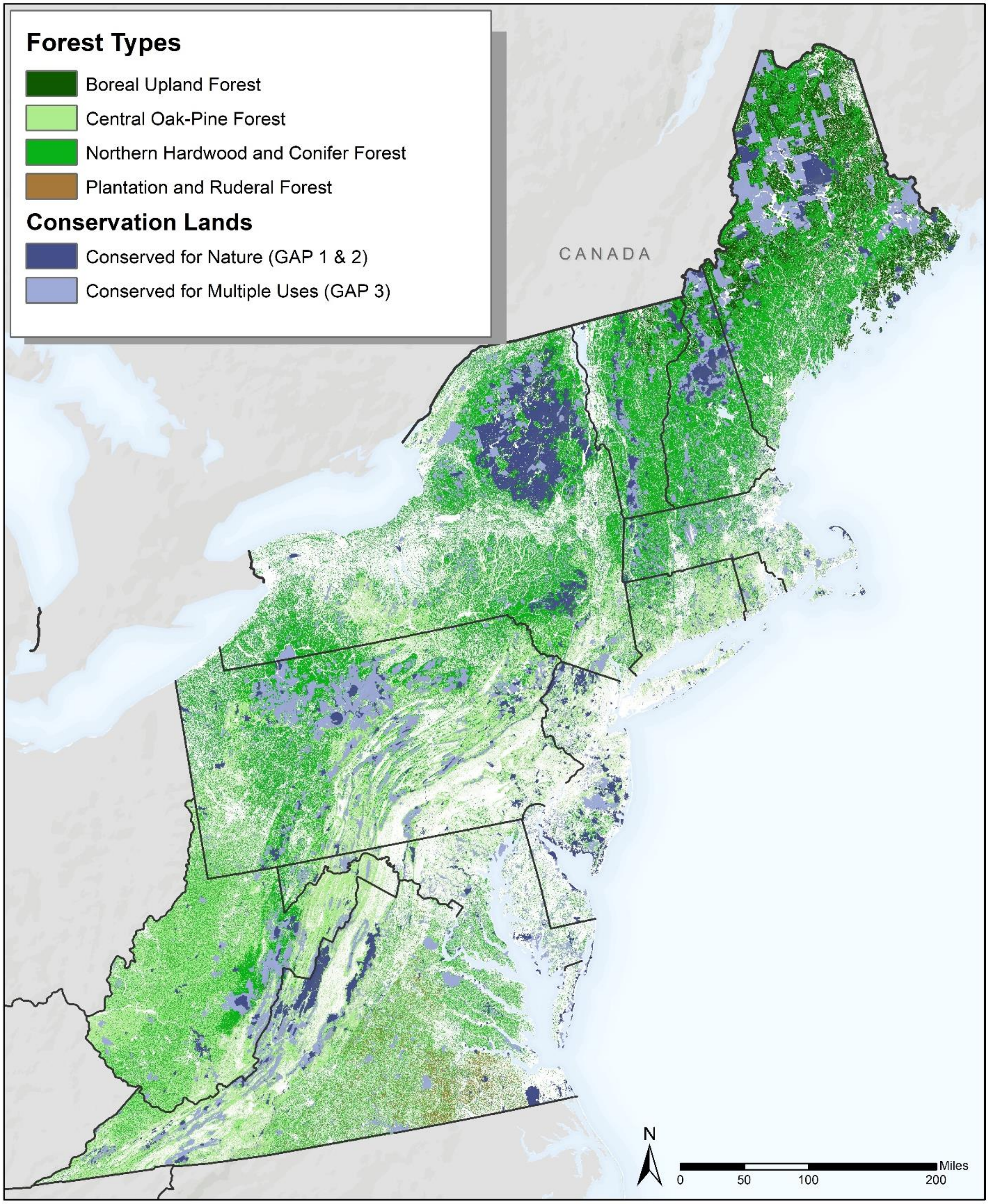


Figure 3.1. Forest Conversion compared with Conservation. Figure A is by subregion. Figure B is by forest type. Each bar represents 100% of the historic forest area. Conservation is land permanently secured against conversion to agriculture or development and either protected for nature conservation (GAP 1-2, dark blue) or intended for multiple uses (GAP 3, light blue). Red and Orange represent conversion to agriculture or development. Purple and green represent transitions to other land cover.

A

B

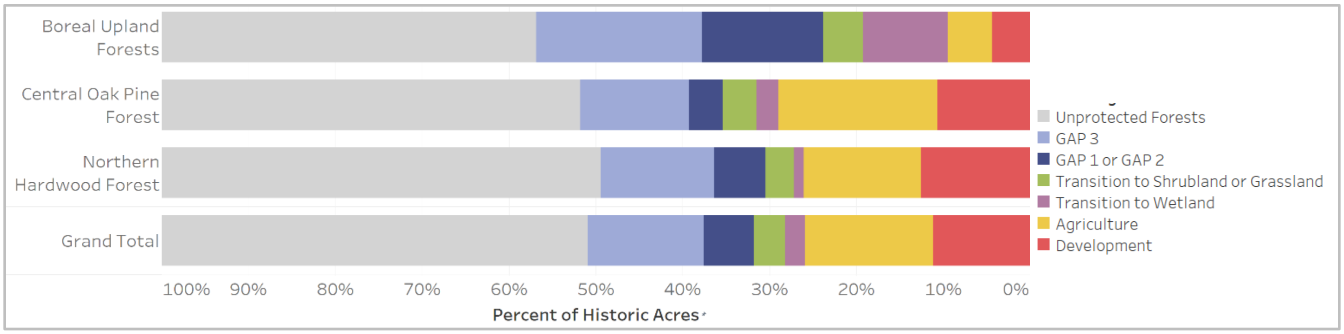


Figure 3.2. Percent of forest acres conserved by forest type. The bar represents the current distribution of each forest type. Of the three major forest types, boreal upland forests are the most conserved and central oak-pine the least, the differences mostly due to the amount of GAP1-2 land conserved for nature.

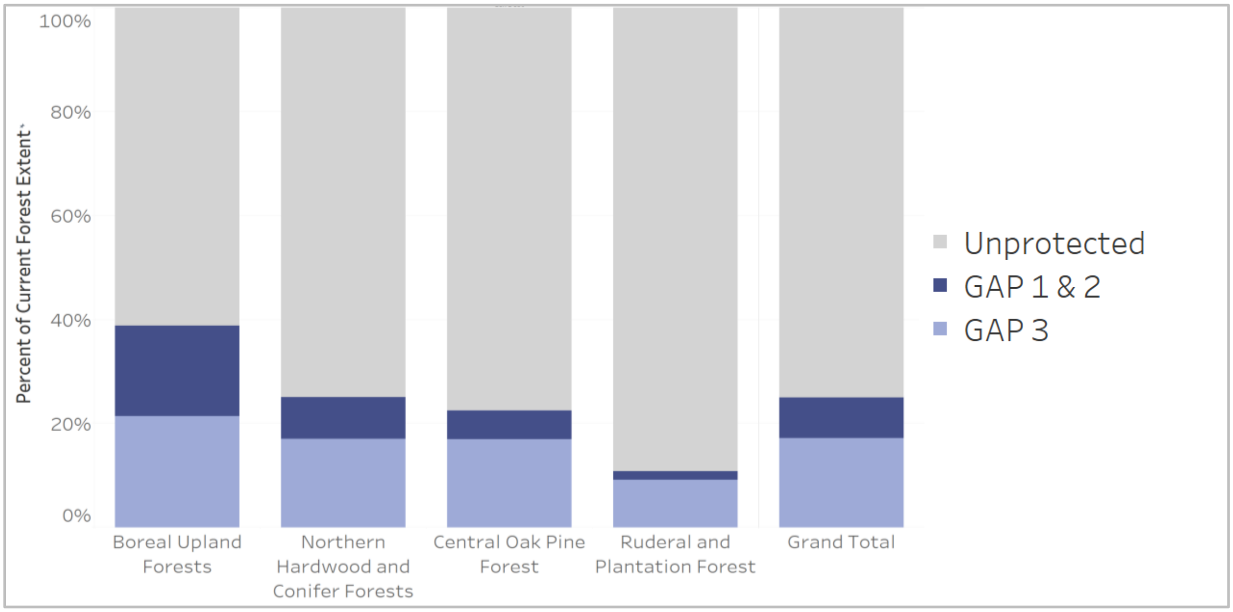


Table 3.1. Acres of forest by secured land status, forest type and sub-region. In this table, %L is the percent forest lost through conversion to development or agriculture and %C is the percent conserved (GAP1-3). CRI is the ratio of forest loss to conserved (%L/%C). NRI is the ratio of loss to conservation explicitly for nature (%L/%GAP 1-2) and is always larger than CRI.

REGION		GAP 1-2	GAP 3	UNPROTECTED	TOTAL ACRES	% L	%C	CRI	NRI
MID-ATLANTIC									
	Boreal Upland Forests	32,422	22,824	6,906	62,153	8%	89%	0.1	0.2
	Northern Hardwood and Conifer Forests	710,363	3,266,600	14,358,268	18,335,231	46%	22%	3.9	21.6
	Central Oak Pine Forest	1,477,178	4,839,806	20,930,870	27,247,853	20%	23%	1.1	4.6
MID-ATLANTIC TOTAL		2,219,962	8,129,230	35,296,045	45,645,237	33%	23%	2.1	10.0
NEW ENGLAND AND NEW YORK									
	Boreal Upland Forests	1,256,338	1,562,593	4,521,322	7,340,253	12%	38%	0.4	0.8
	Northern Hardwood and Conifer Forests	3,286,749	5,149,488	22,686,979	31,123,217	11%	27%	0.4	1.1
	Central Oak Pine Forest	286,803	578,041	3,837,707	4,702,550	63%	18%	9.3	27.9
NEW ENGLAND AND NEW YORK TOTAL		4,829,891	7,290,122	31,046,008	43,166,020	23%	28%	1.1	2.6
REGION									
	Boreal Upland Forests	1,288,760	1,585,417	4,528,228	7,402,406	12%	39%	0.3	0.8
	Northern Hardwood and Conifer Forests	3,997,112	8,416,088	37,045,247	49,458,448	28%	25%	1.5	4.8
	Central Oak Pine Forest	1,763,981	5,417,847	24,768,577	31,950,403	32%	22%	2.1	8.4
REGION TOTAL		7,049,853	15,419,352	66,342,053	88,811,258	28%	25%	1.6	5.0

Recent Trends in Forest Turnover and Loss.

In addition to analyzing historic patterns of forest loss, we also examined trends in forest turnover and loss over the last 20 years. To explore this, we used the global forest change dataset (Hansen et al. 2021) which uses real-time remotely sensed imagery to measure forest loss and gain between 2001-2021 at a 30-meter scale. We analyzed areas of forest loss detected by Hansen et al. (2021) and compared them to the land use changes and current values in the National Landcover Dataset (NLCD 2019).

Results show that 8 million acres (8%) of our forests changed over the last 20 years (Map 3.3, Figure 3.3). Forest turnover accounted for most of change (57%). We defined turnover as areas (30 m cell) of forest in 2001 that initially changed to another natural landcover and then changed back to forest by 2022 suggesting disturbance and regrowth. Change to another natural landcover accounted for another 28% most of this was to shrubland or grassland and could represent potential turnover that has not converted back to forest. Less than 1% (709, 985 acres) converted to development (0.6%) or industrial agriculture (0.2%). This suggests an annual rate of 35,500 acres lost to conversion each year. The two subregions had similar amounts of turnover.

Map 3.3. Extent of Forest Change (Loss and Turnover) in the last 20 years.

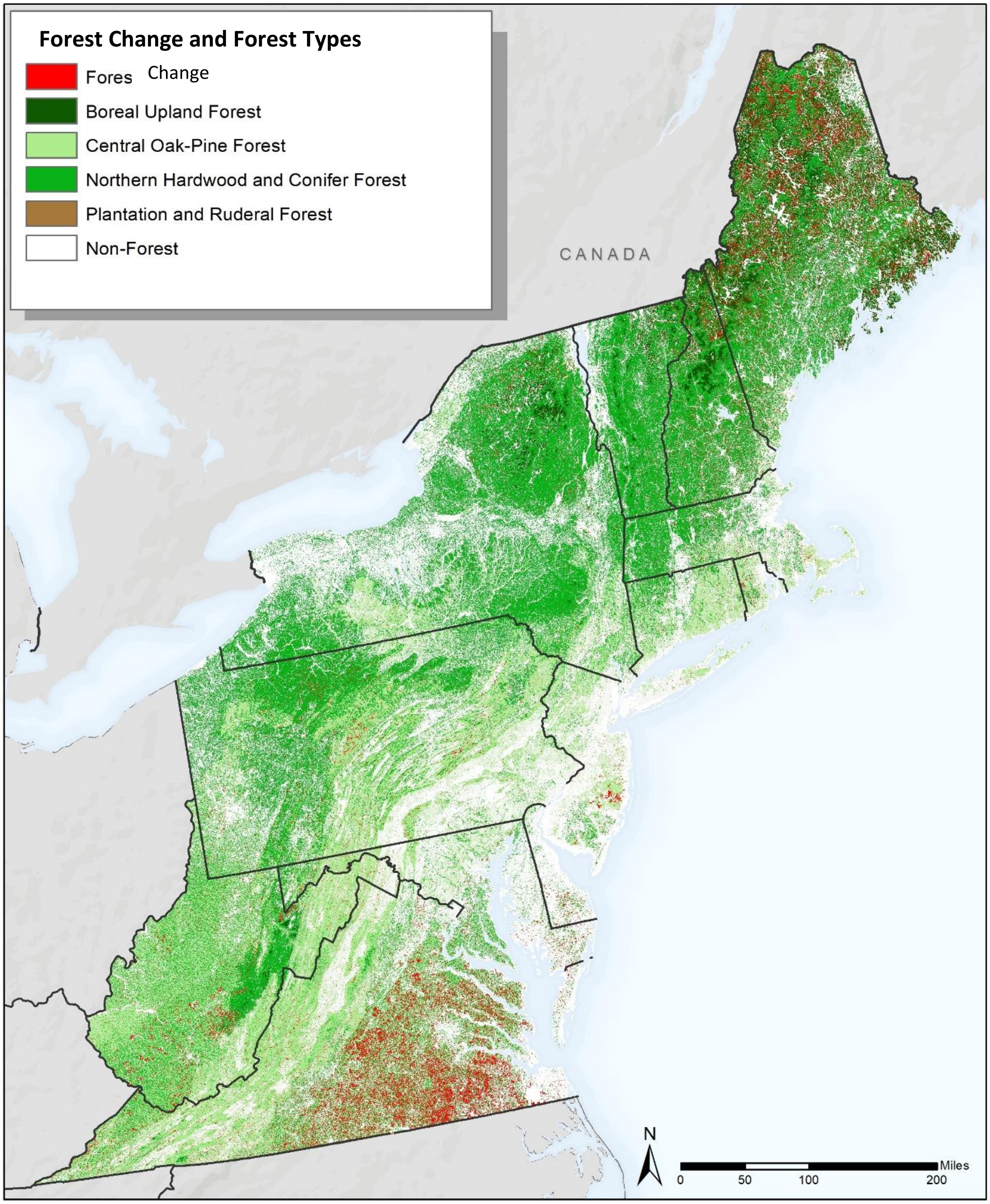
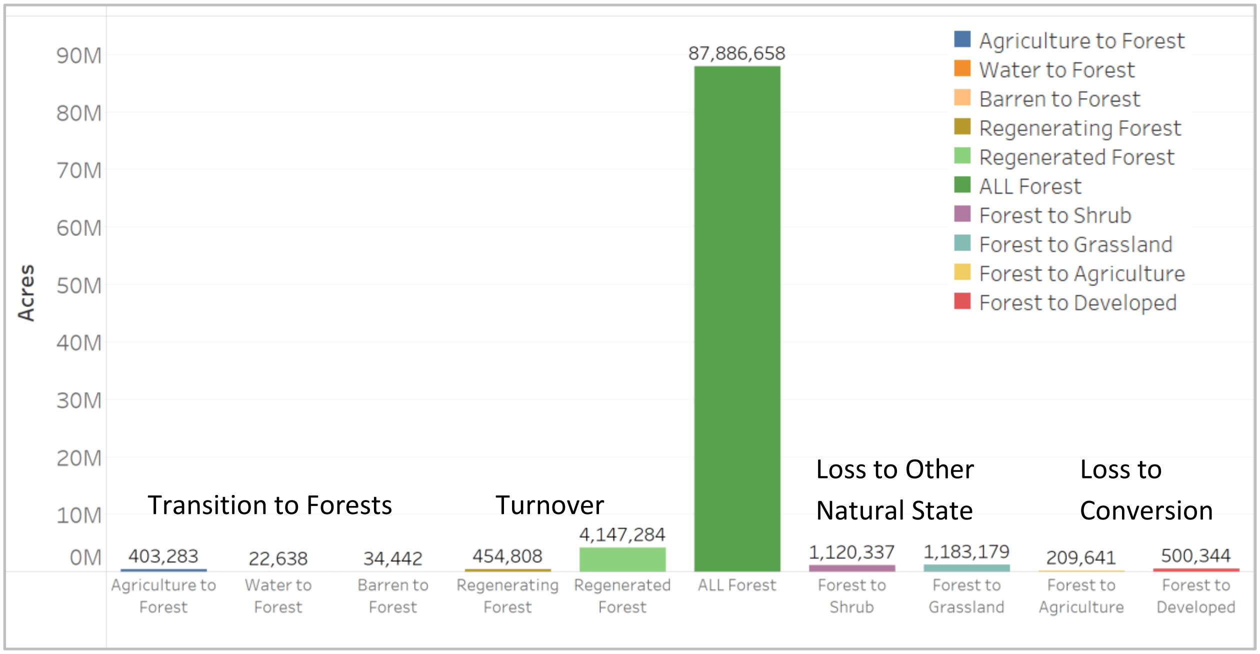


Figure 3.3: Forest in transition in the Northeast and Mid-Atlantic. 92% of forests were undisturbed across the last 20 years. Most forest change was due to turnover (5%) reflecting cutting and regrowth. Another 2% transitioned to another natural state (shrub or grassland) that may with succession eventually return to forests. Only 2.4% of forests were converted to development or agriculture.



Boreal forests had the largest percent forest change (15%), most of that due to turnover (10%) or change to other natural landcover (5%, Map 3.4, Figure 3.4). Presumably this reflects the many industrial forest operations in this part of the region. A small percentage (0.13%) of boreal forest was converted to development or agriculture. Change in northern hardwood forest was a more modest 8%, with 5% being turnover, 2% being change to other natural landcover and 1% loss to conversion (500 K acres). Central oak-pine forest had very similar transitions to northern hardwoods: 8% overall change, 4% being turnover, 3% being change to other natural landcover and 1% loss to conversion (Table 3.2).

Both historically and recently, losses to conversion in New England and New York were highest in oak-pine forest. This makes sense because this southern part of the region is where most of the new population growth and development is happening. A surprising pattern was that both historically and recently losses to conversion in the Mid-Atlantic were highest for northern hardwood forests, a forest type associated with higher elevations. This might be explained by the mapping of plantation forests which was concentrated on the coastal plain portion of the Mid-Atlantic, an area that historically would have been oak-pine forest (Map 3.4). As expected, plantation forests have the most forest change. 32% of plantation forests have changed state over the last 20 years, and most of that was either turnover or change to other natural land cover.

Map 3.4. Forest Change in the last 20 years by Forest Type.

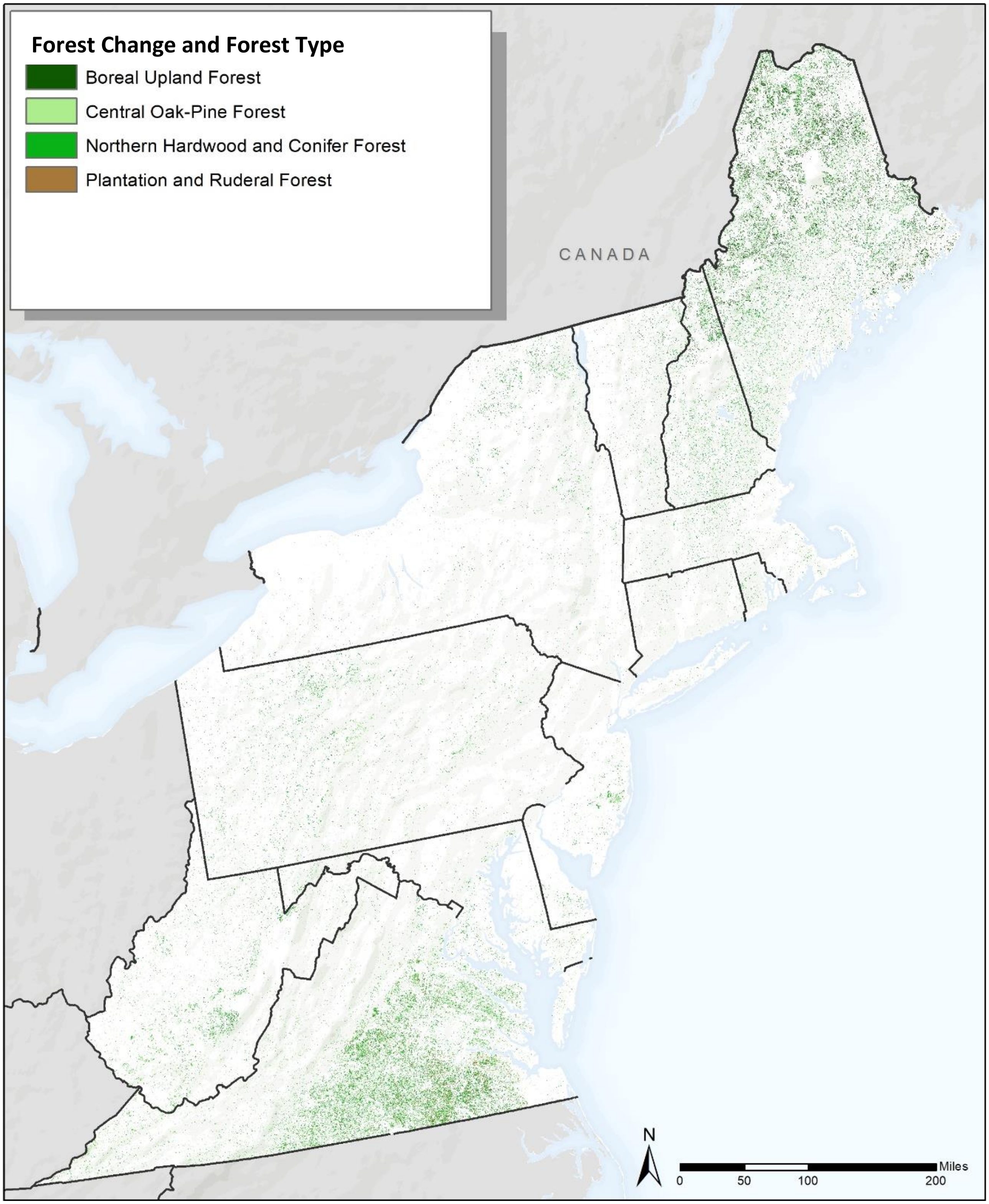


Figure 3.4: Forest Transition by Forest Type. By percentage, boreal forests had the largest amount of forest change. Across all types, forest turnover (light green) was the largest change that was observed.

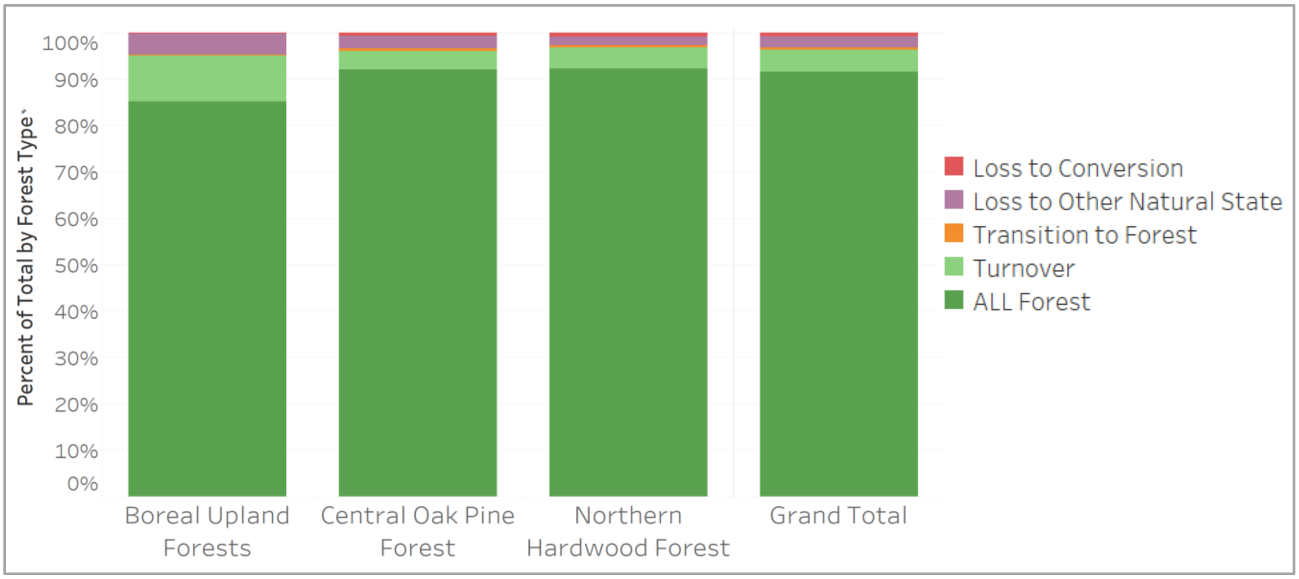


Table 3.2: Acres of Forest Turnover and Loss from 2001-2021 by Region and Subregion. Note - These totals will not match exactly with the current totals because some of the logged forest has regrown.

	Forest w No Change		Turnover		Transition to Forest		Loss to Conversion		Loss to Other Natural		TOTAL ACRES
	Acres	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	
Mid-Atlantic											
Boreal Upland Forests	63,393	79%	3,486	4%	39	0.0%	592	0.7%	13,096	16%	80,605
Central Oak Pine Forest	26,773,945	99%	1,189,536	4%	167,357	0.6%	123,369	0.4%	445,093	2%	28,699,300
Northern Hardwood Forest	18,543,200	88%	1,201,941	6%	123,165	0.6%	325,133	1.5%	861,718	4%	21,055,157
New England and New York											
Boreal Upland Forests	6,840,318	85%	802,020	10%	17,714	0.2%	9,702	0.1%	357,067	4%	8,026,821
Central Oak Pine Forest	4,865,287	86%	179,479	3%	27,570	0.5%	99,422	1.8%	505,997	9%	5,677,755
Northern Hardwood Forest	30,800,514	95%	1,225,630	4%	124,517	0.4%	151,769	0.5%	120,546	0.4%	32,422,975
Region Total											
Boreal Upland Forests	6,903,711	85%	805,506	10%	17,753	0.2%	10,294	0.1%	370,163	5%	8,107,426
Central Oak Pine Forest	31,639,232	92%	1,369,015	4%	194,927	0.6%	222,791	0.6%	951,090	3%	34,377,055
Northern Hardwood Forest	49,343,714	92%	2,427,571	5%	247,682	0.5%	476,902	0.9%	982,264	2%	53,478,132
TOTAL ACRES	87,886,658		4,602,092		460,362		709,985		2,303,516		95,962,613
Plantation Forests	1,005,113	62%	296400	18%	2,426	0.2%	4,852	0.4%	305,597	19%	1,615,355

Conservation and Forest Change

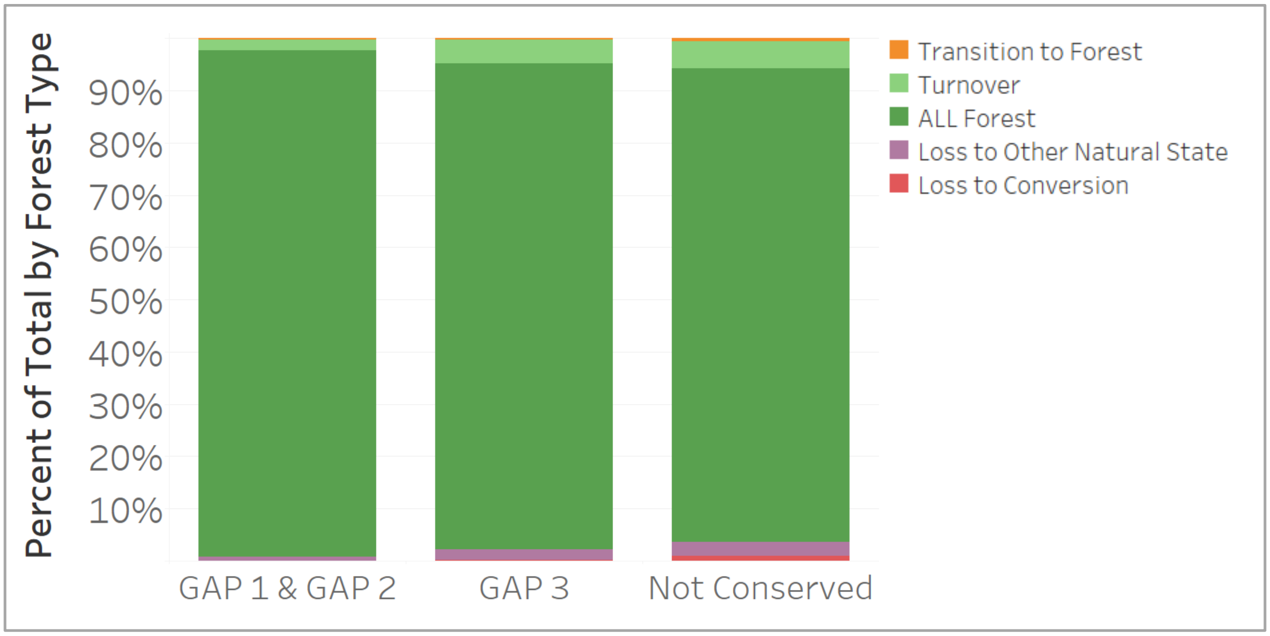
The 20-year period we analyzed for forest change was also very active for conservation with over five million acres of forest conservation land being acquired as fee or put under a conservation easement. Of the 2.1 M acres conserved over the last decade (2012-2022) about 75% was forested land. A conservation risk assessment (CRI = acres converted/acres conserved) across both decades indicates that **conservation greatly surpassed conversion for all forest types** (Table 3.3): Boreal Upland (CRI= 0.01), Northern Hardwood (CRI=0.14), Central Oak Pine (0.20). This equates to a CRI of 0.13 for the region or 7.6 acres conserved for every one acre converted.

Table 3.3. Conservation by Forest Type over the last Two Decades (2001-2022)

	2001-2011			2012-2022			2001-2022	2001-2022	CRI
Forest Type	GAP 1-2	GAP 3	Total	GAP 1-2	GAP 3	Total	Grand Total	Conversion	
Boreal Upland Forest	175,942	437,356	613,298	70,594	237,112	307,705	**921,004**	**10,294**	**0.01**
Northern Hardwood	788,812	1,698,249	2,487,061	195,559	619,051	814,610	**3,301,670**	**476,902**	**0.14**
Central Oak-Pine Forest	229,020	552,812	781,832	78,458	280,938	359,396	**1,141,228**	**222,791**	**0.20**
Ruderal Forest	4,819	15,581	20,399	4,211	25,113	29,323	**49,723**	**4,852**	**0.10**
Grand Total	**1,198,592**	**2,703,998**	**3,902,590**	**348,821**	**1,162,214**	**1,511,035**	**5,413,625**	**714,839**	**0.13**

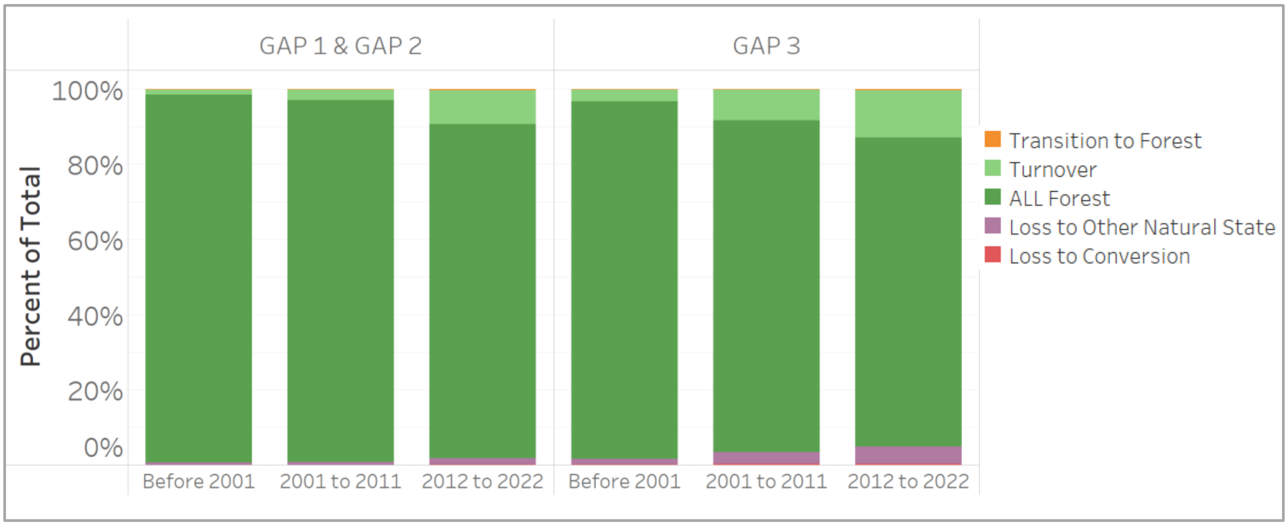
Does conserving forest have any effect on turnover and conversion rates? Do those effects differ between GAP Status? Overlaying the 2022 conservation lands on the forest change datasets allowed us to examine these questions and quantify the differences. We found that forest change differed markedly between unconserved forest (9%), forest conserved for multiple-uses (7%) and forests conserved for nature (3%). Unconserved forest had higher turnover rates, higher loss to conversion and higher change to other natural land covers (Figure 3.5). Forests conserved for nature (GAP 1-2) had no loss to conversion and much lower turnover rates, likely reflecting only natural disturbances. Surprisingly, GAP 3 multiple-use forests had turnover rates almost equivalent to unconserved forest although considerably less conversion to development or agriculture (Figure 3.5).

Figure 3.5: Forest Change by GAP Status.



The establishment date of the conservation lands explains some of the variation in turnover and conversion. Regardless of GAP status, the more recently the land was conserved the higher the turnover (Figure 3.6). Presumably this is because the turnover we are detecting over a 20-year period was largely happening before the land was conserved. For instance, land conserved in 2018, would have a change profile equal to 17 years unconserved and 4 years conserved relative to our time horizon. When time is factored out, GAP 3 land conserved for multiple uses has turnover rates intermediate between GAP 1-2 and unconserved (Figure 3.6, leftmost columns of each GAP class). Conversely, recently conserved GAP 1-2 land has a change profile that looks very similar to unconserved land, reflecting both the recent purchase time and the condition of the land when it was acquired.

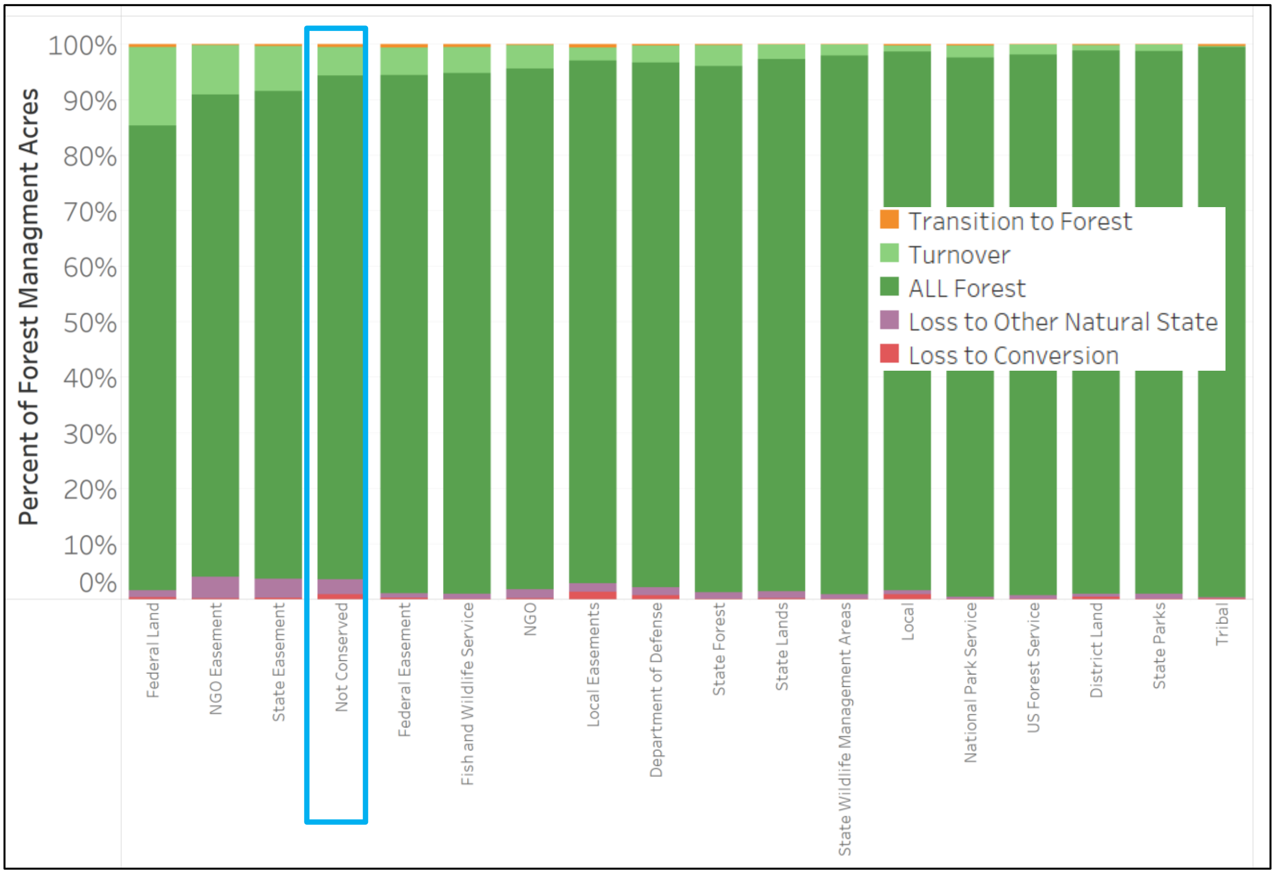
Figure 3.6: Forest Change by Protection Level and Date Conserved**.**



Trends in forest change also varies across ownership and management type. Surprisingly, we found that the percent of forest change was higher over the last two decades on NGO easements and State easements, than on unconserved land (Figure 3.7, left of the blue outline). This pattern may be explained by their recent increase in easement numbers and size. Over 25% have happened in the last 5 years and over 80% in the last 10 years. This is compounded by the fact that forest land is sometimes sold to conservation entities at a discount after it has been recently harvested. This would create the conditions where recent conservation easements show more internal change and turnover than unconserved forest.

Forest change was highest on miscellaneous federal lands not owned by the National Park Service, Fish and Wildlife Service or the Forest Service, all of which has lower amounts of change than unconserved lands (Figure 3.7). The latter two agencies showed less change than NGO lands perhaps reflecting longer ownerships. Notably, the least amount of forest change was seen on tribal land followed by State Parks.

Figure 3.7: Forest Change by Ownership Type. In this figure the dark green represents forest that remained forest over the last 20 years. The Orange represents is other land use classes that transitioned **to** forest. The lighter green is forest turnover (forest that was converted to non-forest but have either returned or are returning to forest). The purple is forest land that have converted to another natural land use class. The red is forest that has been converted to development of industrial agriculture.



Forest Condition: Block size and Connectedness

Forests in the Northeast have a long history of human use, from widespread local-scale burning by Native Americans, to extensive clearing for agriculture and pasture by settlers in the 1800s, to the current logging of hardwoods and conifers for materials. Moreover, as eastern forests recovered from turn-of-the-century clearing, other changes transformed the land. These include an increase of the human population from a few hundred thousand to 75 million, and the development of a road network that now includes over 732,000 miles of permanent roads (enough to circle the equator 29 times; Map 3.5). One effect of these changes has been dramatic shifts in the type and abundance of wildlife; most dramatically, a decrease in forest interior species, a spike in the abundance of open habitat species, and a recent increase in forest generalists and game species. While it is difficult to comprehend the scope of these changes, the aim of this section is to objectively assess the degree of forest fragmentation and its inverse “local connectedness” and determine the rate of change over the last decade.

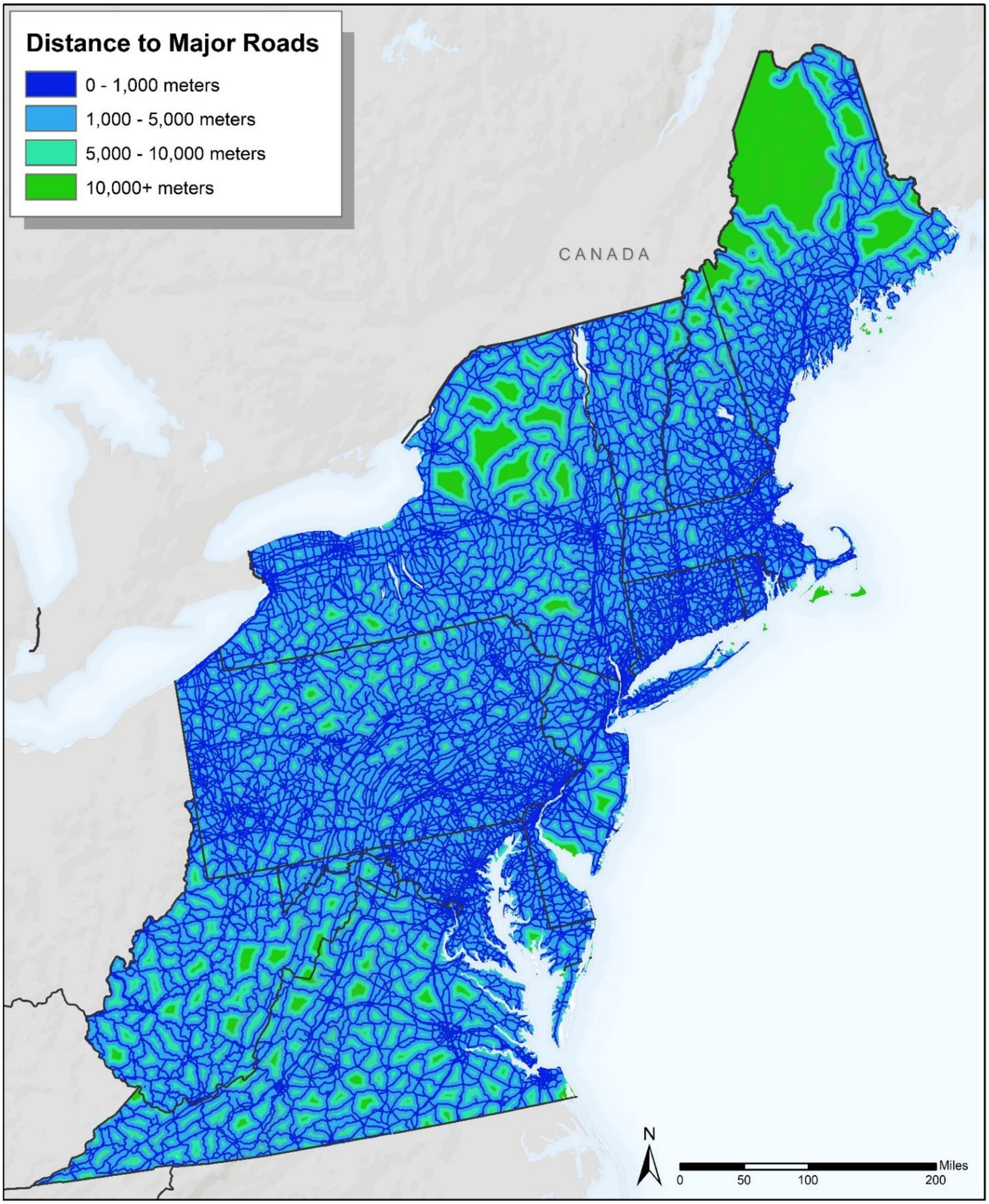
Fragmentation occurs when a contiguous area of forest is subdivided into smaller patches, resulting in each patch having more edge and less interior. Because edge habitat contrasts strongly with interior - drier and more exposed, higher predator densities, greater susceptibility to blowdowns - the surrounding edge habitat tends to isolate the interior region and contribute to its degradation. Thus, the divide-and-conquer effect of fragmentation can lead to an overall deterioration of forest quality and a shift in associated species from interior specialists to edge generalists.

A simple way to measure fragmentation is through the distribution of forest block sizes created by the road network. Roads affect forest systems primarily by providing access into forest interior regions, thus decreasing the amount of sheltered secluded habitat preferred by many species for breeding. Additionally, heavily used paved roads create noisy edge habitat that many species avoid, and the roads themselves may form movement barriers to small mammals, reptiles, and amphibians.

To evaluate the extent and potential impact of roads on Northeast forests, we examined the patterns created when major roads connect to encircle contiguous blocks of forest (Map 3.4). To this end, we defined a forest block as a distinct area of forest surrounded by major roads (Tiger roads 2022. Major Road classes MTFCC = S1100, S1200), and we mapped the major-road bounded blocks comprehensively across the region (Map 3.6). The area of each block was calculated, assigned to a block size class, and the amount of each forest type within each block was summarized to determine the size class distribution of different forest types (Figure 3.8). Our assumption was that the highest quality interior habitat would be found in the central core of each block, essentially the region greater than 100 meters from any major road, field or developed area, and that the effects of the fragmenting feature would decrease with the size of the blocks (Map 3.6).

Across the entire region, block size distribution patterns showed a relatively even distribution of forest block sizes (Figure 3.7 last column). Forest types differed markedly in their degree of fragmentation with boreal upland forest being the least fragmented forest type having 74 percent of its area in blocks over 250,000 acres. Central oak-pine forest, in contrast, had less than 1 percent of its distribution in blocks over 250,000 acres, and almost 19 percent of its distribution in blocks less than 5,000 acres (Figure 3.8).

Map 3.5: Northeast Road Network and Distance to Major Roads.



Map 3.6. Forest Block Size in Acres. Each area indicated a forested patch bounded on all sides by major roads.

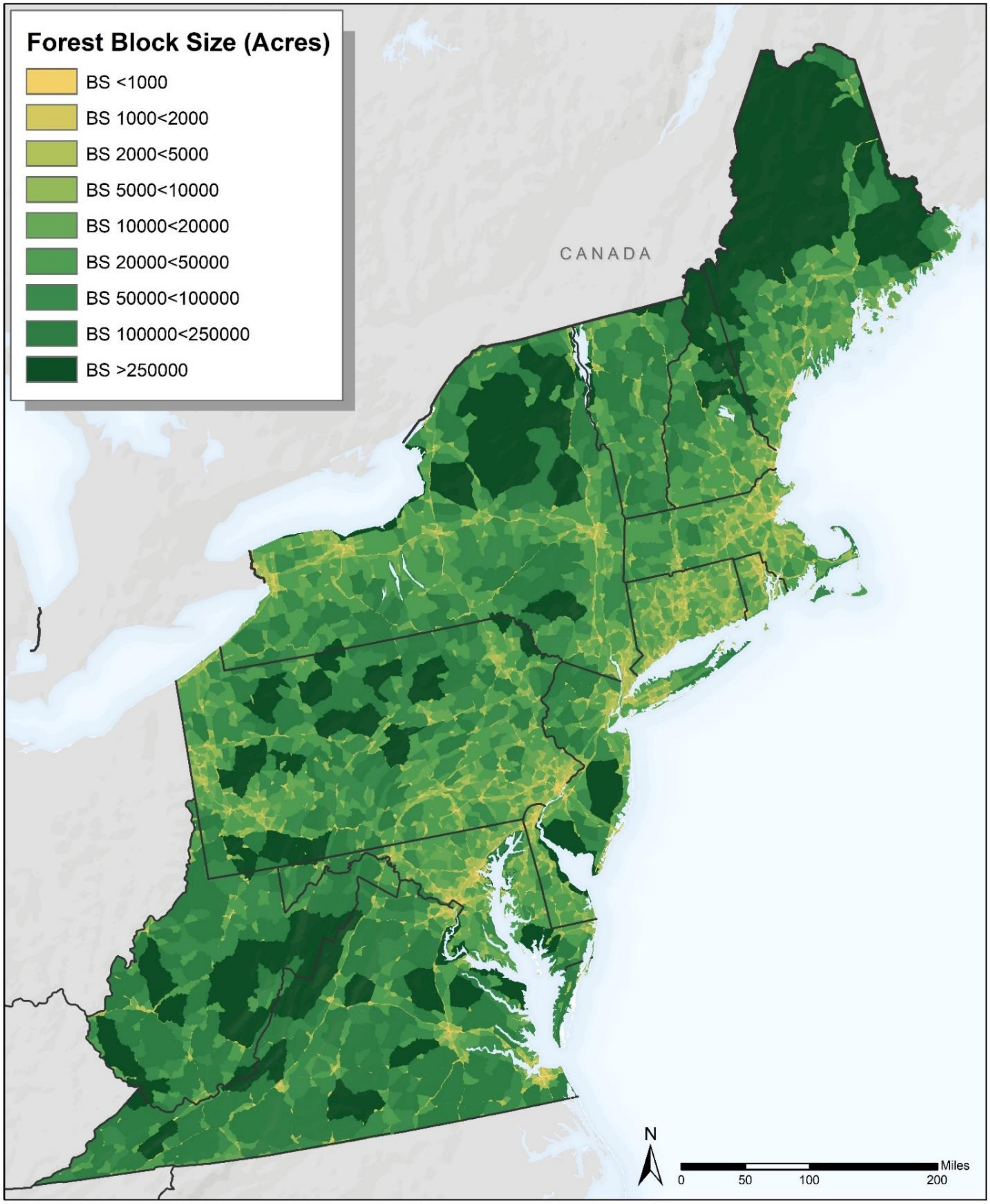
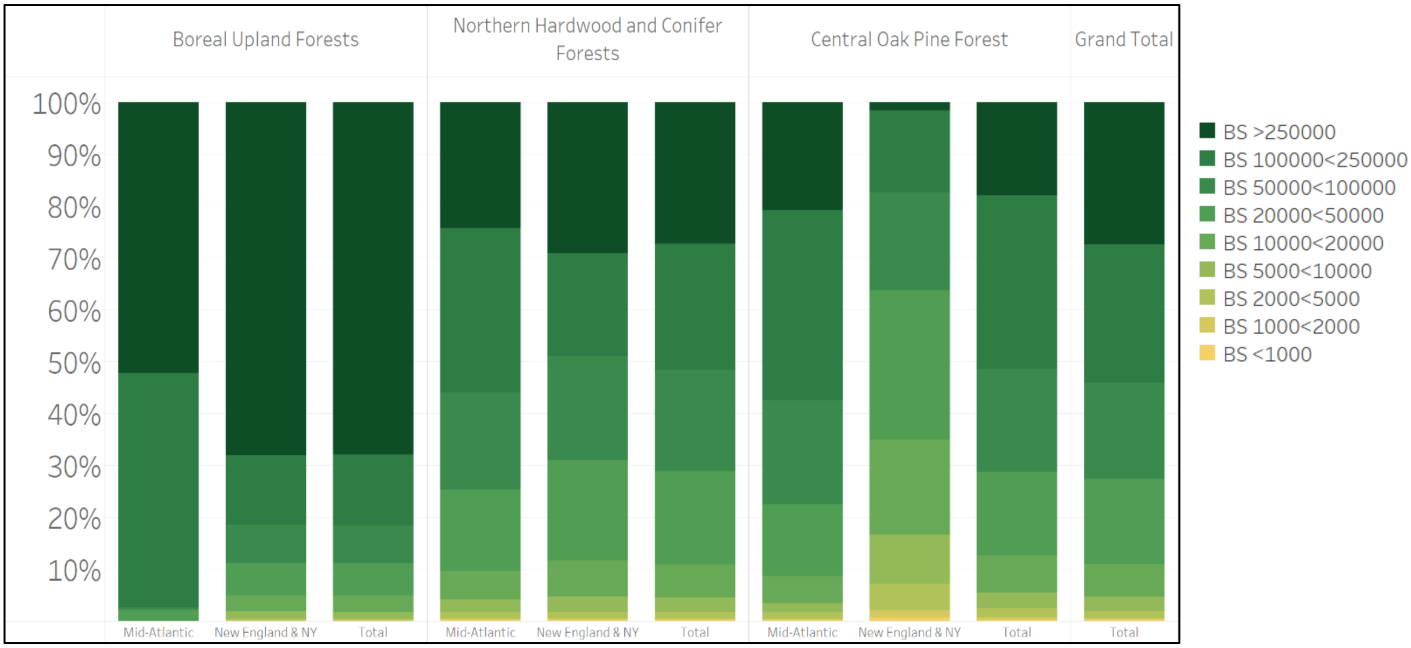


Figure 3.8. Percent of forest acres within major road bounded blocks. Size classes are in acres.



The two sub-regions differed in their degree of fragmentation. The New England and New York region had 20 percent more large blocks than the Mid-Atlantic, although both shared roughly the same amount of smaller blocks (Figure 3.8). Blocks of central oak-pine forest were larger in the Mid-Atlantic, where this forest type dominates, than in New England and New York, where it is restricted to low elevations and coastal areas which are highly developed (Figure 3.8).

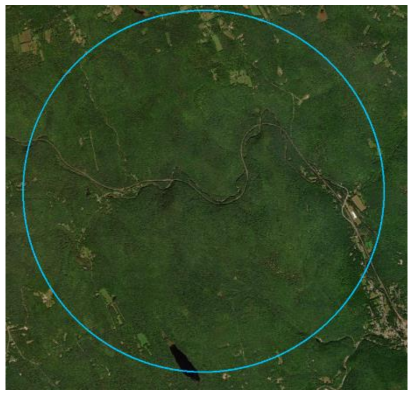
<u>Local Connectedness:</u>

One solution to the pervasive problem of fragmentation is to preserve connectivity, which helps maintain the quality of the whole ecosystem. The metric we used to measure connectivity - local connectedness - is related to, but more sensitive than, the forest block analysis in the previous section. We measured local connectedness metric using a resistant kernel algorithm to account for the impacts of major and minor roads, as well as the density of all nearby roads and the degree of nearby conversion. The method follows Compton et al. (2010) and treats the landscape as having a gradient of permeability where highly contrasting land cover types have reduced permeability between them, and highly similar ones have enhanced permeability. Every point on the landscape is scored based on how connected it is in all directions within its local 3-km neighborhood. In applying the metric, we differentiated between developed lands, agricultural lands, and natural cover, but all forms of natural land cover were combined into one class for the analysis. The assessment of local connectivity was developed by Brad Compton at the University of Massachusetts (detail in Compton 2010). Our application was run with the 30 m 2019 National Land Cover dataset (Homer et al. 2004) land cover map supplemented with major and minor road information (Tiger Roads 2022).

For every 30 m grid cell in the region, a circular area with a 3 km radius around the cell was evaluated and the amount of resistance /permeability was calculated to create a wall-to-wall grid with cell values ranging from 0 to 100; these scores were then put on a standard normal scale (z-score) and multiplied by 1000 to scale the results from -3500 (-3.5 SD below the mean) to 3500 (3.5 SD above the mean). In the results “-3500” indicates complete impermeability (e.g. developed), 0 = average local connectedness for the region, and “3500” indicates complete permeability (e.g. natural cover with no barriers, Figure 3.9).

Figure 3.9. Aerial photo image of areas with different local connectedness scores.

Local Connectedness = 3500
Completely natural, no roads, agriculture, or development



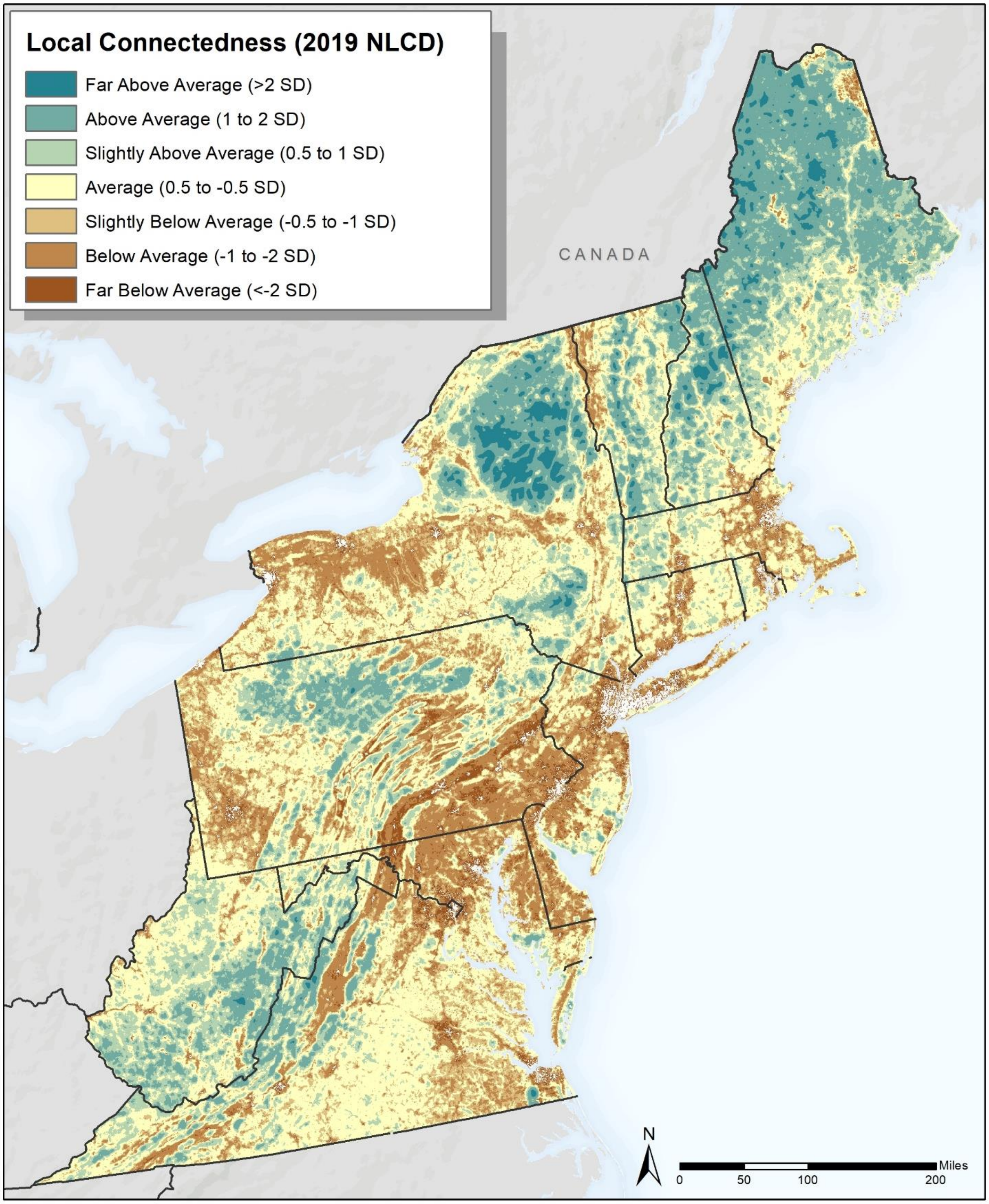
Local Connectedness = 1000
Mostly natural, some roads and minor development

Local Connectedness = 0
Mixed landscape, some natural, some agriculture/minor development/roads.

Local Connectedness = -1000
Mostly disturbed, roads, agriculture, and high density development.

Local Connectedness = -3500
High Density Development

Map 3.7. Local Connectedness Wall to Wall.

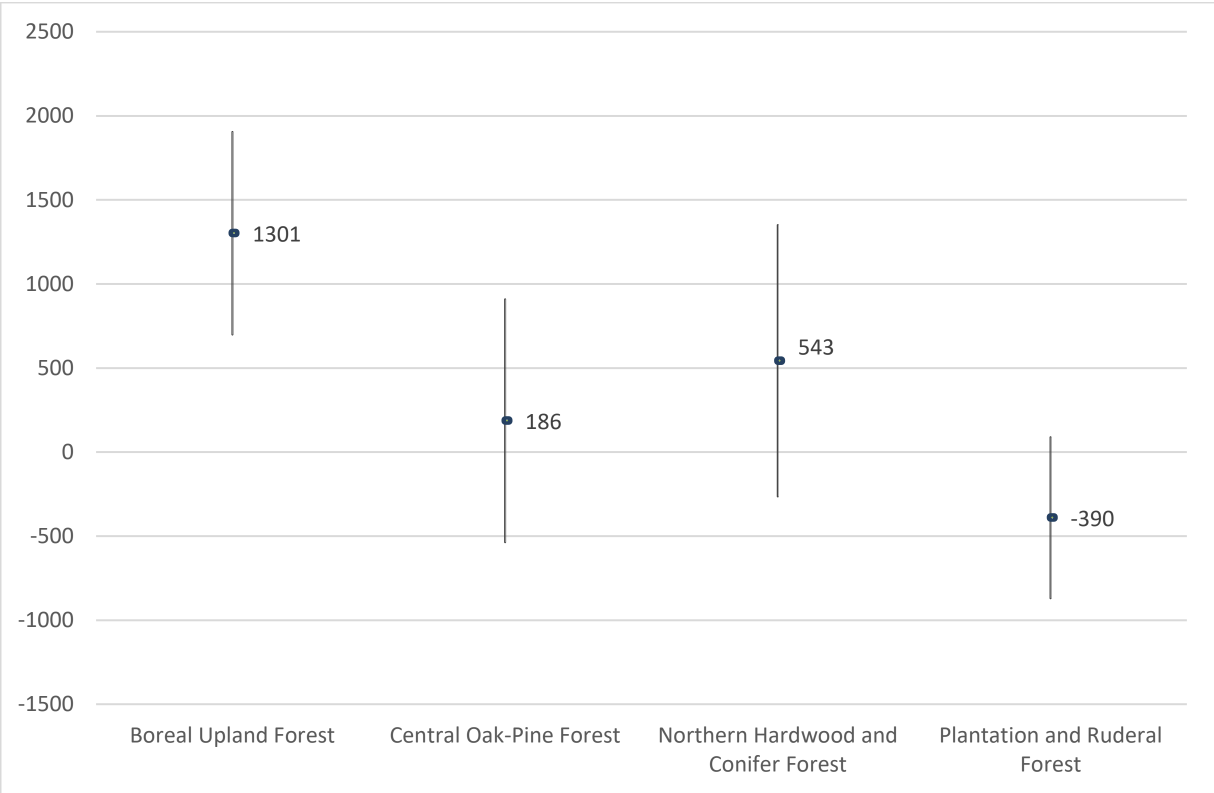


We measured the relative connectedness of all forest and the four forest types by overlaying the local connectedness grid on all cells of forest cover and tabulating the mean for all cells of each forest type.

The mean connectedness score for all forest (LC = 460, 0.46 SD) indicates that forests are more connected, on average, that the region in general (LC=0, Map 3.8). Visually, areas with this score appear to have fairly contiguous cover, broken by small patches of field, power-lines or minor roads (Figure 3.9).

The three natural forest types differed markedly in their connectedness scores. Boreal upland forest (LC = 1321, 1.3SD) scored the highest and was the only forest to score considerably above the region average mean. Plantation and ruderal forest (LC = -397, -0.4 SD) were the only forests to score below average with the lowest score of all of the forest types. Northern Hardwood and Conifer Forest (525, 0.53 SD) and Central Oak Pine (127, 0.13 SD) both scored close to average (Figure 3.7).

Figure 3.7. Average connectedness scores for the four forest types. The numbers are in Z-scores (standard deviations) multiplied by 1000. The average score for the region is 0 and Boreal Forest (for example) score 1.3 SD above the average.



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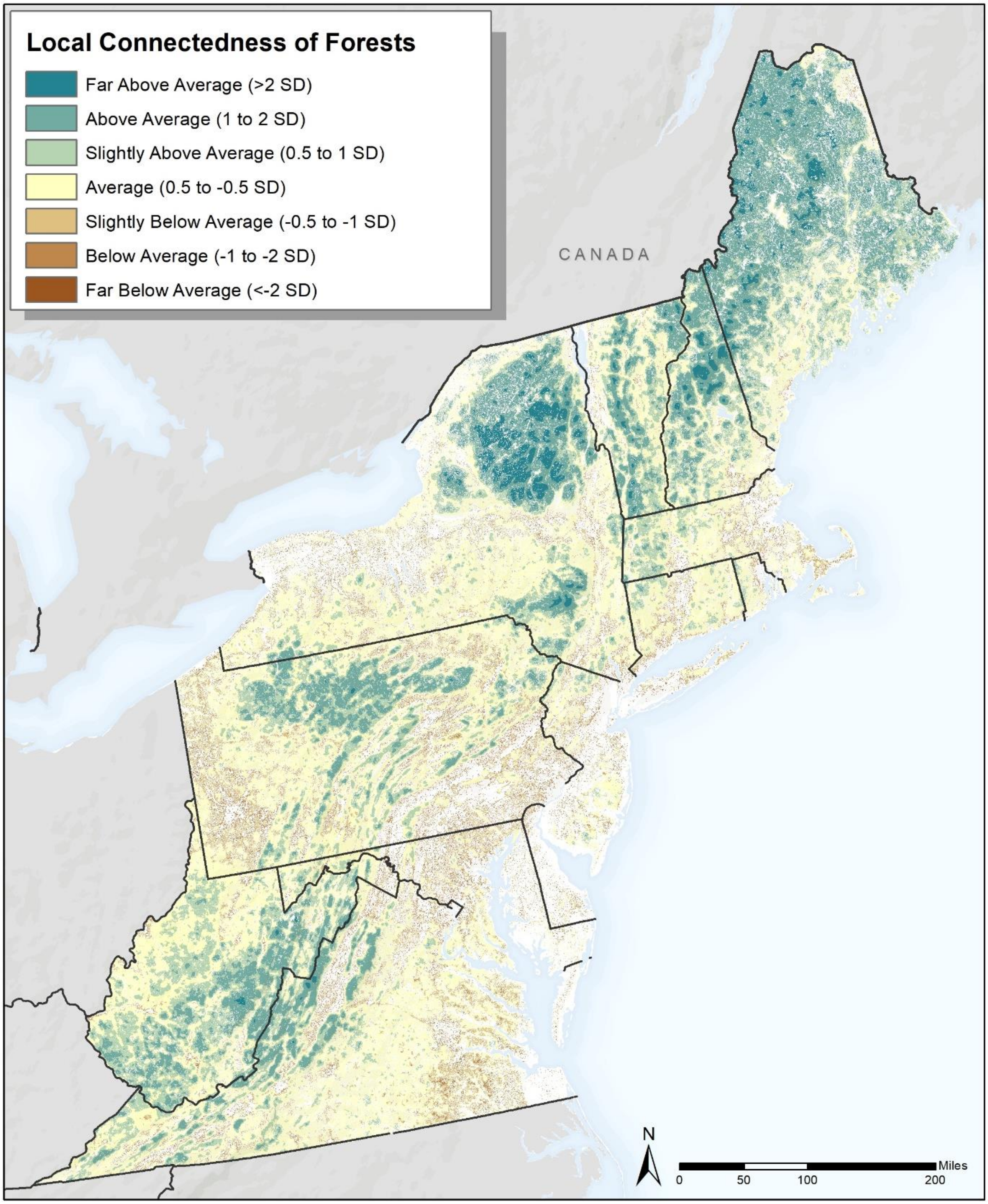
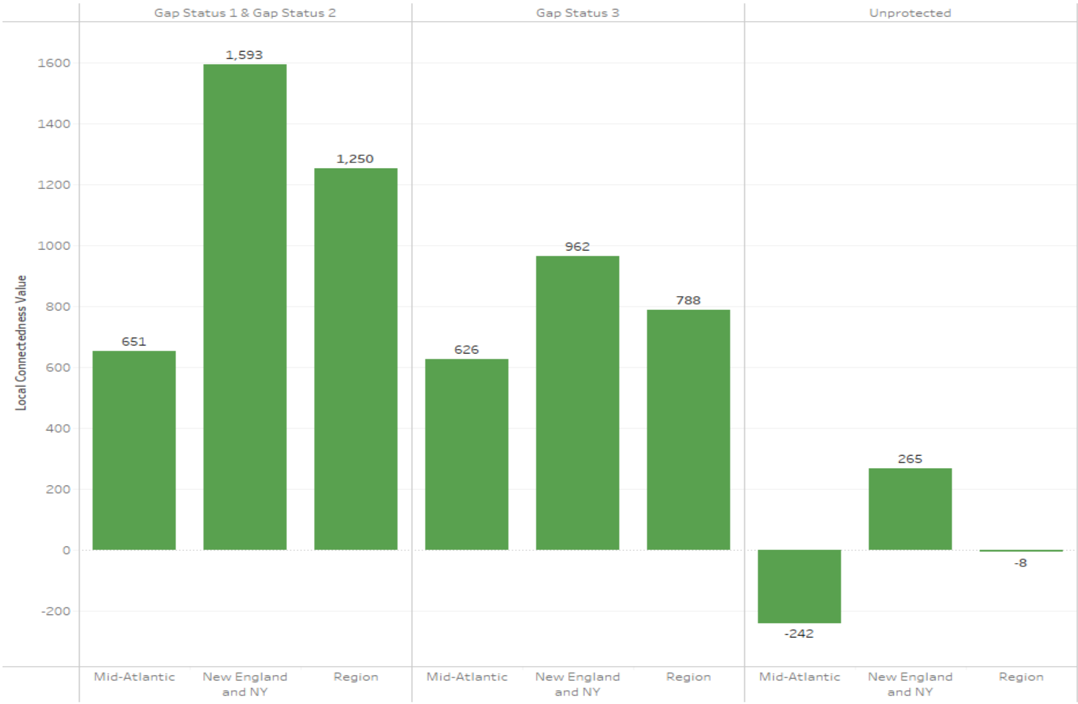
Map 3.8. Local Connectedness of Forests



By overlaying the 2022 conservation lands on the local connectedness grid we could examine whether conservation lands appeared to maintain local connectedness. Results of that overlay showed that forest on lands conserved for nature (GAP 1&2) had an average local connectedness score of 1250 (1.3 SD) while land conserved for multiple use lands (GAP 3) had an average of 788 (0.8 SD). Unsecured land (-8, -0.08 SD) had scores near the average. While this result was as expected, we could not say whether this pattern was due to conservation organizations selecting lands that had a high local connectedness for acquisition, or connectedness improving due to conservation. Likely it is a little of both.

Figure 3.8. Local Connectedness and Securement.

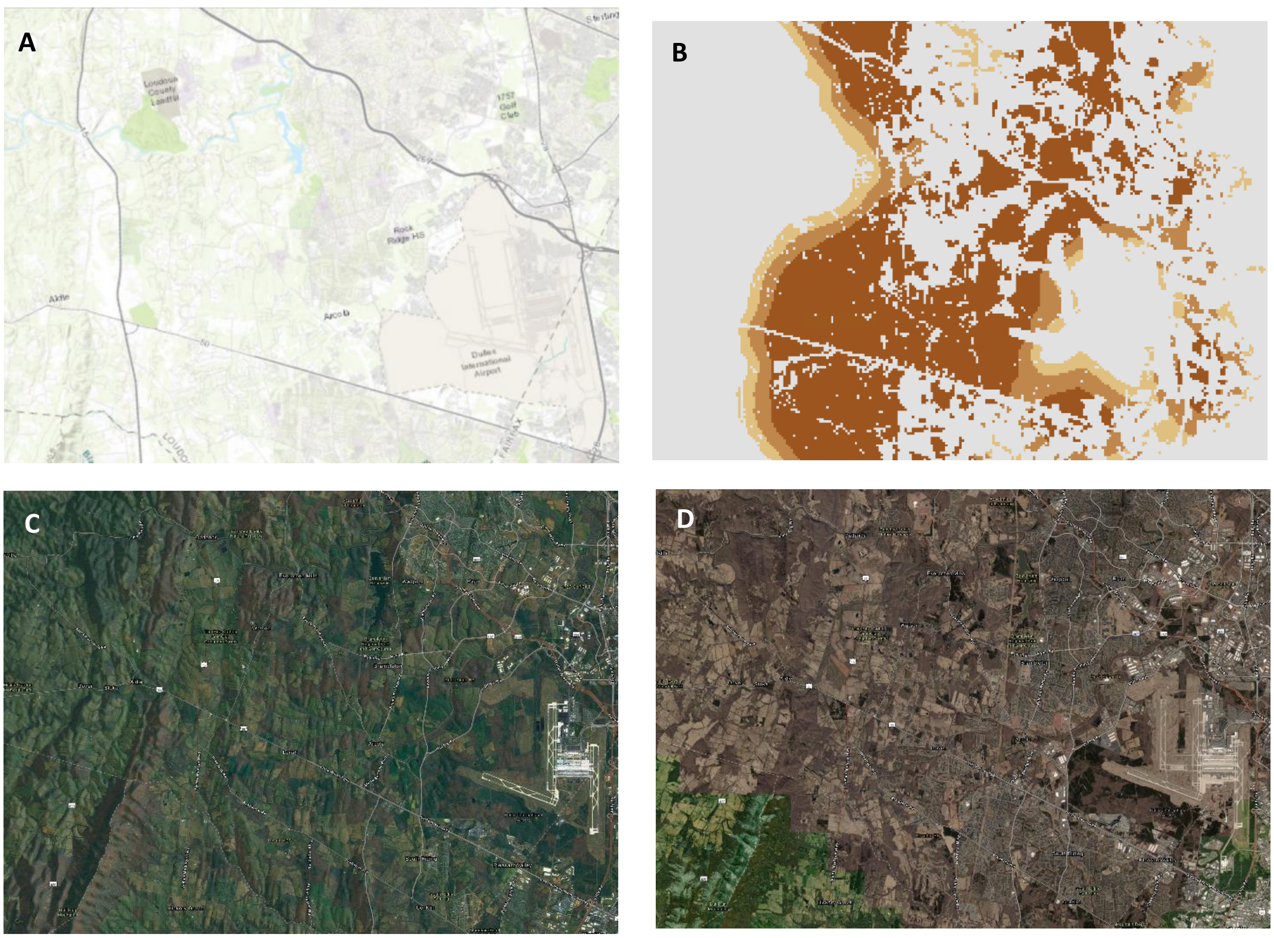


Local Connectedness also varied by state, region, and forest type. Boreal forests had high local connectedness in all states while plantation forests had low. Oak-pine forests varied from a very low in DC (LC= -1.8 SD) to relatively high in West Virginia (LC = 0.52 SD). Northern hardwood forests were generally above the mean in New England and below the mean in the Mid-Atlantic.

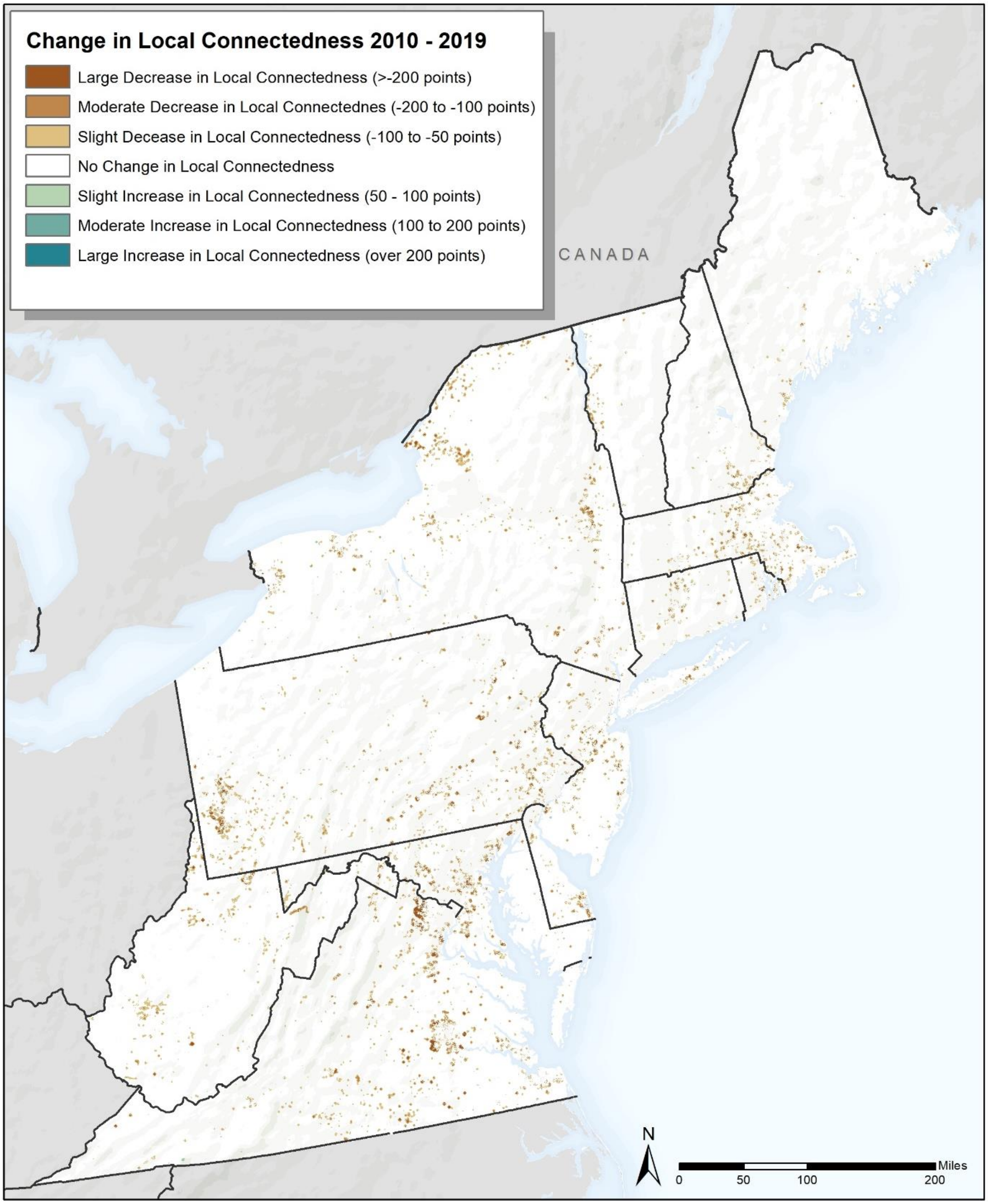
Trends in Local Connectedness (2010-2019)

We ran the local connectedness metric for two time periods: 2010 and 2019 and overlaid the data to detect any change in connectedness. The results were almost identical similar and suggest that changes in local connectedness are very localized. However, there were many places in the region where local connectedness has decreased, and decreases were much more common than increases. Many of the decreases were areas of suburban development (Figure 3.9, Map 3.9)

Figure 3.9: Local Connectedness Trends. Example area. In this area west of Dulles International Airport outside of Washington DC (A), local connectedness decreased between 2010 and 2019 (B). The darker brown areas in B indicate larger changes decreases in local connectedness. In aerial imagery from 2014 (C) the area was a mixture of agriculture, pasture, and forests. In 2020 (D), the area has been developed into medium density suburban development.



Map 3.9. Change in Local Connectedness (2010 to 2019).



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Appendix 3.1. Sections from the 2011 report that were not revised in 2022

After review of the data sources and discussion with our 2022 steering committee, it was agreed that we would not revise these three sections as the results were unlikely to have changed in ways detectable by our methods. We include them here for completeness sake.

Forest Disturbance:

Forest Disturbance: Eastern forests are subject to an array of natural disturbances and over time these structure the ecosystem. Disturbances have several benefits, as patches of tree damage free up resources such as light and water, and contribute nutrients and woody debris to the soil. Periodic insect outbreaks may be accompanied by irruptions of specialist bird species, and fires may stimulate the regenerations of particular species. This constant adjusting to the perpetual cycles of disturbances creates a shifting mosaic of ages and composition in an old forest.

To understand the extent of various forest disturbances we again used the FIA data, in which primary disturbances were noted by field crews when the data is collected. From this information it was possible to create a disturbance profile for each forest types (Figure 3.1A.1). Importantly, 96 % of the forest stands showed no effects from natural disturbance; the pie-charts and damage percentages shown in Figure 3.1A.1reflect only the 4 % of the samples that had evidence of disturbance. Harvesting is treated as a special case of disturbance by FIA and is tracked separately; we also examined it separately.

Natural Disturbance Types in FIA

Ice: snapping of branches or crown by ice load

Wind: blowdowns and breakage from downburst and hurricanes

Fire: mortality or scarring from crown and understory fires

Flood: mortality or stress from flooding

Drought: mortality due to insufficient water availability

Animal: damage by deer, porcupine, beaver

Insect: leaf and bark damage by insects

Vegetation: competition or suppression by vines etc.

Among all forests, ice was the predominant natural disturbance accounting for 24 % of all observed tree damage (Figure 3.1A.1). The next three most common disturbances were all biotic: animals, vegetation, and insects. Upland boreal forests had simpler disturbance regimes, ice and wind were the prevalent disturbances and five types accounted for all the observed damage. Northern hardwood forests had more complex disturbance profiles with evidence of nine disturbance types, and dominated by ice and animal damage. Oak-pine forests were similar to northern hardwoods but differed in having a larger component of fire and vegetation impacts, and less ice damage.

We examined forest harvesting patterns separately from disturbance using the treatment information recorded for each stand that indicated whether the stand was recently cut, or if it showed signs of harvest preparation. Over all forests types, 10 % showed some evidence of harvest (Figure 3.1A.2). More than twice as much harvesting was found in the upland boreal forest stands than in the oak pine forests, the former having evidence of cutting in 14 % of the stands, and the latter in 6 %.

Figure 3.1A.1. Disturbances and forest types: The relative amounts of disturbances affecting forest.

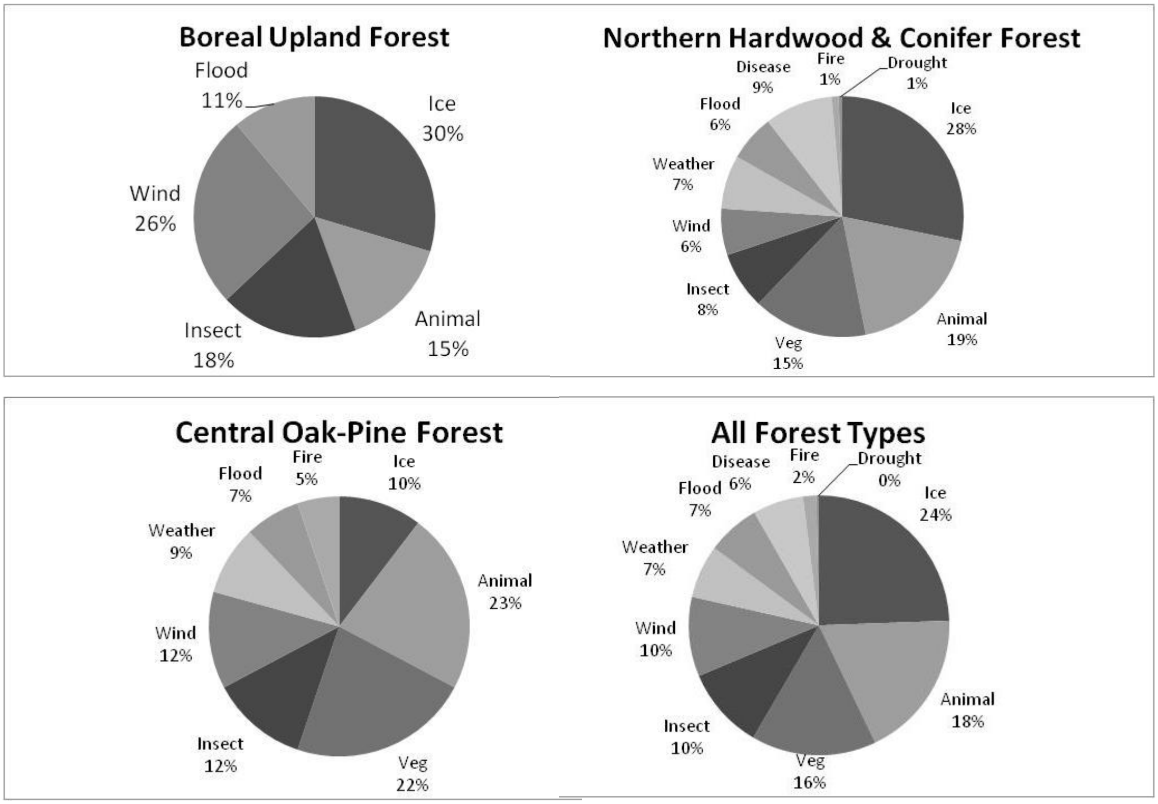
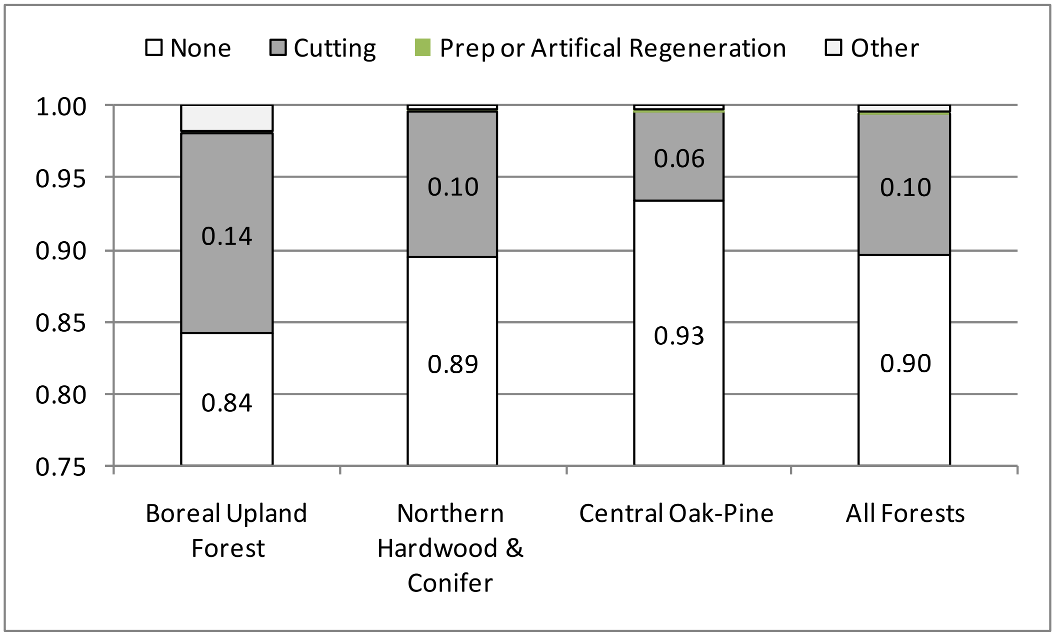


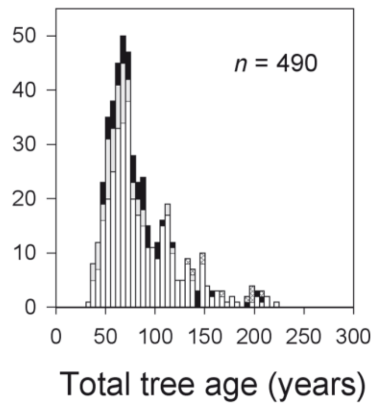
Figure 3.1A.2. Percent harvest by forest type.



Forest Stand Age, Size and Height.

Age and Size Structure: The age and size structure of a forest provides a picture of ecosystem development. Over centuries, an unmanaged forest will develop a complex structural heterogeneity characteristic of the classic self-regenerating uneven-aged old growth stand (Figure 3.1A.3). In contrast, a young or heavily managed forest is more likely to have an even age structure with most trees being close in age, and the spread of ages approximating a normal distribution with spikes of recruitment to the left of the mean.

Figure 3.1A.3. Characteristic old growth plots of a boreal forest stand. The chart shows the uneven age size classes as spikes in older age classes (adopted from McCarthy and Weetman 2006).



Note the low amount of regeneration and the high frequencies of trees over 100 years of age.

In 2011, we used USDA Forest Service's Forest Inventory and Analysis (FIA) data to assess the age and size structure of forests in the region and we did not redo this analysis in 2021 as we did not expect that it would detect changes. Instead, we analyzed and newly available dataset on forest height.

Here is a brief review of the 2011 methods and results. FIA is an annual and continuous forest census, designed to collect the information needed to evaluate whether current forest management practices are sustainable in the long run. The survey collects data on tree species composition, size, and health of trees; tree growth, mortality, and removals by harvest. More information on the program is available here: http://fia.fs.fed.us/

We obtained all 6,952 FIA samples points available for this region from USFS, with each point containing information on its tree composition, age, and size structure. To connect the FIA data with the maps of forest types, we overlaid the points on the forest type data layer and assigned each point to one of the four major forest types. Note that the FIA point locations we received were slightly generalized to protect the actual location of the plot, so there may be some error associated with these assignments; presumably the error was distributed evenly across the forest types so as not to skew the results.

We assessed forest age and size structure at two scales: across-stands and within stands. To examine the across-stand structure we tabulated the average stand age for each forest type using the FIA field "stand age," and examined the stand age distributions across all stands in the region using histograms to show the frequency of age classes (Figure 3.1A.4). Across all stands, we expected a wide range of stand ages indicating forests with different cutting histories and intensities, but the results showed that our forests are overwhelmingly similar in age with the average age being 60 years and most stands (68 %) averaging between 50 and 90 years old (Figure 3.1A.5). There was little difference in average stand age between forest types, although the upland boreal forest had a substantially larger component of young, 20-30 year old, stands, perhaps reflecting more active logging (Figure 3.1A.4 and 3.1A.5).

The size structure of forests is easier to measure in the field than the age structure, as the latter requires coring individual trees. Thus, the FIA data had more comprehensive information on size structure, and, because size is recorded along with each individual tree species, we could summarize the internal size structure for each sample. The results of summarizing the size structure across all plots indicated that the forest stands were almost entirely composed of small trees: 6" to 7" in diameter (Figure 3.1A.4). In the upland boreal forest the most frequent size class was even smaller, 3" in diameter, consistent with intensive logging. For the other two forest types, the most frequent size class was 6" to 7" in diameter, with the profiles of both types showing small spikes in the 2" to 3" diameter class. Although size is not necessarily related to age, the size structure patterns corresponded strongly with the patterns of age structure.

In addition to individual tree size measurements, FIA crews make their own plot-based field assessment of size class distributions using four simple categories, recorded in the data as the "field-stand size class code." We summarized this information by forest type and found that it strongly reinforced the patterns described above (Figure 3.1A.5). The upland boreal forest was composed of 30 % seedlings and saplings under 5" in diameter, while the northern hardwood and central oak-pine had had only 10 % of their trees this small size class; both of the latter types having the majority of their trees in size class 3 (9-20" in diameter). No significant component of any forest types was in the larger size classes 4 or 5, indicating that in none of the almost 7,000 samples was the plurality of the canopy cover made up of trees over 20" in diameter. The results suggest that the forests in this region are not simply growing back after 19th century clearing but are actively being maintained in a young state with small diameter trees.

Figure 3.1A.4. Stand level size structure of forests in the Northeast and Mid-Atlantic. The figures are based on all FIA samples that contained diameter at breast height (DBH) information for all trees. For each forest type, this amounts to the following: Upland Boreal (40,266 trees), Northern Hardwood and Conifer (145,832 trees), Central Oak-Pine (47,309 trees), Plantation and Ruderal (not shown 5664 trees).

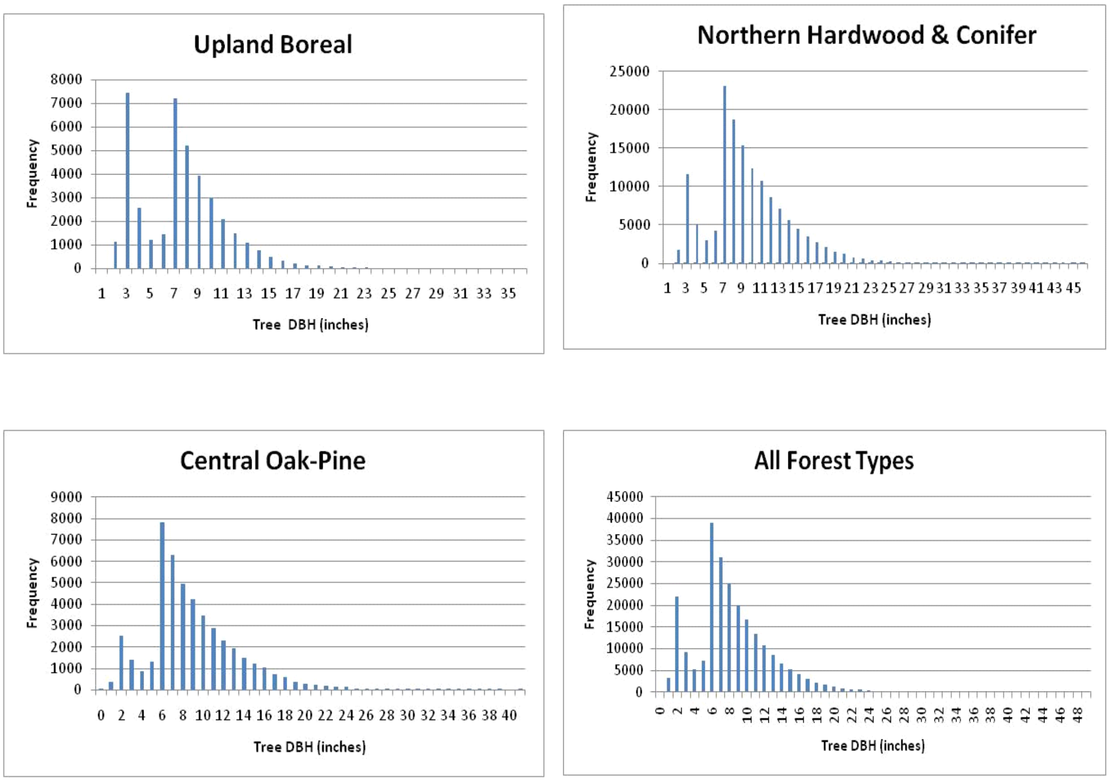
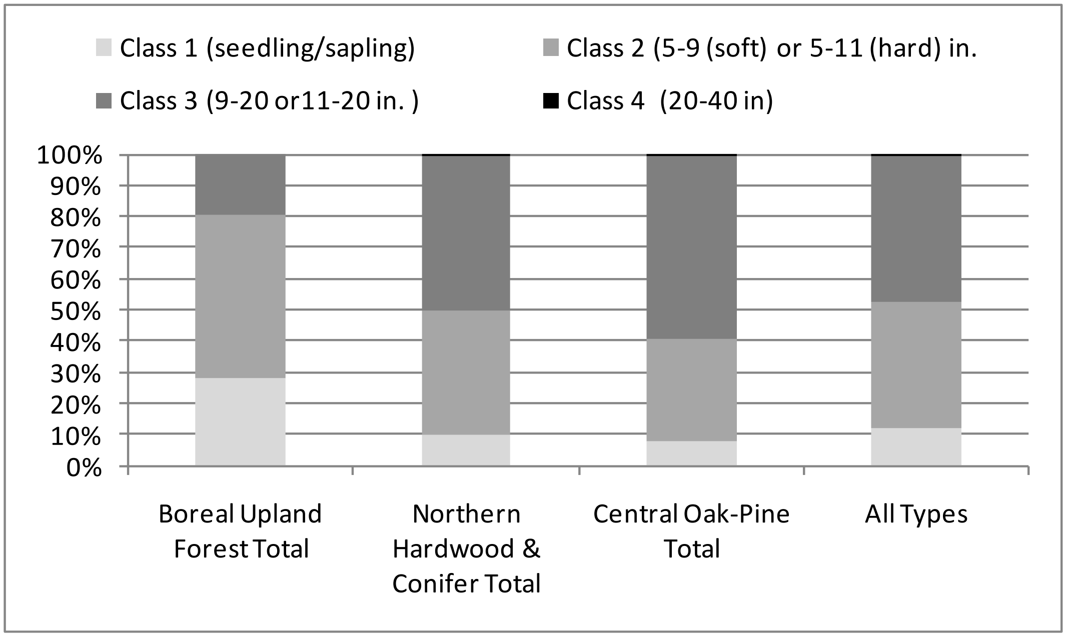


Figure 3.1A.5. Size structure classes for the forest types based on the field stand-size code. This is a field assigned classification where Class 1 = Seedlings, saplings, two-thirds of stand less than 5 inches, Class 2 = one-third of crown cover is in trees greater than 5 inches and the plurality of cover is softwoods 5-9 inches or softwoods 5-11 inches in diameter, Class 3 = plurality of cover is softwoods 9-20 inches or softwoods 11-20 inches in diameter, and Class 4 = plurality of crown cover is 20-40 inches in diameter.



Trends in Forest Bird Abundance

Changes in the abundance of forest breeding birds may give some indication of forest quality and condition. However, because abundance shifts in any individual species may be unrelated to local forest characteristics, bird data is most telling when they show consistent trends across many species and many states. We identified a set of breeding species associated with each of the four forest types based on a published list of preferred breeding habitat for northeast wildlife (DeGraaf and Yamasaki, 2001), and then used breeding bird survey data to examine their regional abundance patterns over the last four decades. The breeding bird survey (BBS) is a long-term, large-scale, avian monitoring program initiated in 1966 to track the status and trends of North American bird populations, and coordinated in the US by the USGS Patuxent Wildlife Research Center. More information on the program may be found here: http://www.pwrc.usgs.gov/bbs/.

The breeding bird survey annually collects bird population data along roadside routes allowing users to inspect trends occurring within states, regions, and continentally. We summarized statistically significant declines and increases for each species in each state, using only species for which there was adequate data (category blue or yellow). Next, we looked at the data across all states to examine how consistent the trend was across the region. In the tables below, for each species we show whether there was a consistent trend across states, whether it was an increase, decrease or mixed signal, how many states it was detected in, and whether the trend was apparent at both the 40 year time interval and a more recent 20 year time interval.

Upland Boreal Forest: DeGraaf and Yamasaki (2001) list 32 species as breeding in spruce or fir forests and the breeding bird survey had sufficient data on 19 of them to examine temporal trends. Results indicated more consistent increases than declines, with four species: **magnolia warbler, red-breasted nuthatch, northern parula,** and **yellow-rumped warbler**, increasing in three or four states over both (Table 3.1A.1). Mild declines were apparent in **purple finch** in four states. **Olive-sided flycatchers** have sharply declined in two states over forty years. In the last twenty years, **yellow warblers** have declined in five states and **Nashville warblers** in two, suggesting some concern about these species.

Table 3.1A.1. Forty year trends in the abundance of bird species associated with Boreal Upland Forests. DNS = Declining or not Significant, INS = Increasing or not significant, NS = Not significant. Data quality codes: B= blue adequate data, Y = yellow, usable but with significant gaps, R = red data not usable. The total possible states for this group was six.

BOREAL UPLAND FOREST	40 Year Trend (1966-2007)					20 Year Trend (1980-2007)				
SPECIES	Status	Declines (# of states)	Increases (# of states)	Data Quality	Regional Trend	Status	Declines (# of states)	Increases (# of states)	Data Quality	Regional Trend
Purple Finch	DNS	4	0	B	-0.6	DNS	2	0	B	0.5
Blackburnian Warbler	DNS	2	0	B	0.6	DI	1	1	B	1.1
Olive-sided Flycatcher	DNS	2	0	Y	-5.1	DNS	2	0	Y	-6.7
Bay-breasted Warbler	DNS	1	0	Y	-1	NS	0	0	Y	-1.3
Dark-eyed Junco	DNS	1	0	B	0	NS	0	0	B	0
Ruby-crowned Kinglet	DNS	1	0	B	-4.4	DNS	1	0	B	-2.7
Magnolia Warbler	INS	0	4	B	3.1	INS	0	3	B	2.1
Red-breasted Nuthatch	INS	0	4	B	1.6	INS	0	2	B	0.9
Northern Parula	INS	0	3	B	1.7	INS	0	3	B	1.8
Yellow-rumped Warbler	INS	0	3	Y	2.1	INS	0	2	Y	1.2
Swainson's Thrush	INS	0	1	B	0.5	INS	0	1	B	1
Yellow Warbler	DI	2	1	Y	-0.3	DNS	5	0	Y	-1.1
Hermit Thrush	DI	1	3	Y	2.5	INS	0	3	Y	2.8
Evening Grosbeak	DI	1	2	B	-8.1	DNS	1	0	B	-9.9
Nashville Warbler	DI	1	1	Y	-0.9	DNS	2	0	Y	-2.2
Boreal Chickadee	NS	0	0	Y	1.2	NS	0	0	Y	1.4
Cape May Warbler	NS	0	0	Y	-3.4	DNS	1	0	Y	-5
Golden-crowned Kinglet	NS	0	0	Y	1	DNS	1	0	Y	-0.3
Pine Siskin	NS	0	0	Y	-2.6	NS	0	0	Y	-2
Black-backed Woodpecker	NS	0	0	R	1.3	NS	0	0	R	-2.1
Sharp-shinned Hawk	INS	0	4	R	5.3	INS	0	2	R	3.2
Blackpoll Warbler	NS	0	0	R	-3.8	NS	0	0	R	-2.5
Gray Jay	NS	0	0	R	2.1	NS	0	0	R	-0.9
Merlin	NS	0	0	R	-5.2	NS	0	0	R	-5.6
Red Crossbill	NS	0	0	R	7.1	NS	0	0	R	-0.1
Rusty Blackbird	NS	0	0	R	10.6	NS	0	0	R	10.3
White-winged Crossbill	NS	0	0	R	0.5	NS	0	0	R	-1.2

Northern Hardwood and Conifer Forest: DeGraaf and Yamasaki (2001) list 37 species as breeding in Northern Hardwood forest; the breeding bird survey had adequate data on 27 of them (Table 3.1A.2). Of those 27, six species showed significant declines in four or more states and over multiple decades: **wood thrush, least flycatcher, common yellowthroat, black-and-white warbler, rose-breasted grosbeak**, and **scarlet tanager**. **Wood thrush** declines were the most widespread, occurring in ten states, and worsening in recent years. In contrast, five species showed increases across three or more states: **white-breasted nuthatch, ruby-throated hummingbird, black-capped chickadee, northern parula,** and **ovenbird**. Five of the six declining species are described in the literature (Poole and Gill, 1999-ongoing) as sensitive to forest fragmentation, as are ovenbirds which are increasing in three states. In contrast, the increasing chickadee, nuthatch and hummingbird are common feeder birds that appear to do well in fragmented systems. Among the mixed trend species, **pileated woodpeckers** are apparently rebounding from low population levels associated with forest clearing, but **veery** have declined in six states.

Table 3.1A.2. Forty year trends in the abundance of bird species associated with Northern Hardwood and Conifer Forest. DNS = Declining or not Significant, INS = Increasing or not significant, NS = Not significant. Data quality codes: B= blue adequate data, Y = yellow, usable but with significant gaps, R = red data not usable.

NORTHERN HARDWOOD & CONIFER	40 Year Trend (1966-2007)					20 Year Trend (1980-2007)				
SPECIES	Status	Declines (# of states)	Increases (# of states)	Data Quality	Regional Trend	Status	Declines (# of states)	Increases (# of states)	Data Quality	Regional Trend
Wood Thrush	DNS	10	0	Y	-2.2	DNS	11	0	Y	-2.3
Least Flycatcher	DNS	8	0	B	-2	DNS	8	0	B	-2.4
Common Yellowthroat	DNS	7	0	Y	-0.4	DNS	10	0	Y	-0.7
Black-and-white Warbler	DNS	6	0	B	-2.5	DNS	6	0	B	-3
Rose-breasted Grosbeak	DNS	4	0	Y	-0.8	DNS	6	0	Y	-2.2
Scarlet Tanager	DNS	4	0	Y	-0.4	DNS	4	0	Y	-0.6
Ruffed Grouse	DNS	2	0	Y	-3	DNS	1	0	Y	-7.4
Broad-winged Hawk	DNS	1	0	Y	1.2	DNS	1	0	Y	1.6
Tennessee Warbler	DNS	1	0	Y	-8.4	DNS	1	0	Y	-12.7
White-breasted Nuthatch	INS	0	5	Y	2.4	INS	0	6	Y	2.4
Ruby-thr. Hummingbird	INS	0	4	Y	2.5	DI	1	3	Y	1.5
Black-capped Chickadee	INS	0	3	B	1	DI	1	1	B	0.2
Ovenbird	INS	0	3	B	1.4	DI	2	3	B	1.1
Northern Parula	INS	0	3	B	1.7	INS	0	3	B	1.8
Philadelphia Vireo	INS	0	1	Y	12.6	INS	0	1	Y	11.1
Swainson's Thrush	INS	0	1	B	0.5	INS	0	1	B	1
Mourning Warbler	INS	0	1	Y	1	NS	0	0	Y	0.5
Prothonotary Warbler	INS	0	1	Y	1.5	NS	0	0	Y	1.6
Chestnut-sided Warbler	DI	5	1	B	-0.5	DI	4	2	B	-0.2
American Redstart	DI	4	1	B	-1.2	DI	4	2	B	-1.2
Veery	DI	4	1	Y	-1.3	DI	6	1	Y	-1.9
Red-eyed Vireo	DI	2	5	Y	1.3	DI	2	5	Y	1.2
Pileated Woodpecker	DI	1	10	B	3.1	DI	1	6	B	2.4
Hermit Thrush	DI	1	3	Y	2.5	INS	0	3	Y	2.8
Hairy Woodpecker	DI	1	2	Y	1.7	INS	0	2	Y	2.8
Downy Woodpecker	DI	1	1	Y	-0.4	DI	1	1	Y	-0.4
Nashville Warbler	DI	1	1	Y	-0.9	DNS	2	0	Y	-2.2

Central Oak-Pine Forest: DeGraaf and Yamasaki (2001) list 45 species as breeding in Oak-Pine forest; the breeding bird survey has adequate data on 40 of them (Table 3.1A.3). Of those 40, 11 showed significant declines in three or more states and over multiple decades: **eastern towhee, northern flicker, wood thrush, brown thrasher, least flycatcher, common yellowthroat, black-and-white warbler, rose-breasted grosbeak, scarlet tanager, blue-winged warbler**, and **prairie warbler** (six species overlap with northern hardwood forest). Declines of **eastern towhee** and **northern flicker** were the most widespread, occurring in 11 or more states, and continuing in recent years. In contrast, ten species showed increases in three or more states: **tufted titmouse, wild turkey, eastern bluebird, red-bellied woodpecker, pine warbler, red-tailed hawk, white-breasted nuthatch, red-breasted nuthatch, ruby-throated hummingbird**, and **ovenbird**. As for northern hardwood forests, the increasing birds are mostly common birds of rural landscapes, familiar with fragmentation, but other than ovenbird, the five declining species are known to be sensitive to forest fragmentation (Poole and Gill 1999-ongoing). Among the mixed trend species, **mourning dove** and **pileated woodpecker** are increasing in most states, while **blue jay s**howed decreases in six states.

Table 3.1A.3. Forty year trends in the abundance of bird species associated with Central Oak-Pine Forest. DNS = Declining or not Significant, INS = Increasing or not significant, NS = Not significant. Data quality codes: B= blue adequate data, Y = yellow, usable but with significant gaps, R = red data not usable.

CENTRAL OAK_PINE	40 Year Trend (1966-2007)					20 Year Trend (1980-2007)				
SPECIES	Status	Declines (# of states)	Increases (# of states)	Data Quality	Regional Trend	Status	Declines (# of states)	Increases (# of states)	Data Quality	Regional Trend
Eastern Towhee	DNS	12	0	Y	-2.6	DNS	7	0	Y	-0.7
Northern Flicker	DNS	11	0	Y	-2.9	DNS	8	0	Y	-1.1
Wood Thrush	DNS	10	0	Y	-2.2	DNS	11	0	Y	-2.3
Brown Thrasher	DNS	8	0	B	-2.4	DNS	3	0	B	-0.6
Least Flycatcher	DNS	8	0	B	-2	DNS	8	0	B	-2.4
Common Yellowthroat	DNS	7	0	Y	-0.4	DNS	10	0	Y	-0.7
Black-and-white Warbler	DNS	6	0	B	-2.5	DNS	6	0	B	-3
Rose-breasted Grosbeak	DNS	4	0	Y	-0.8	DNS	6	0	Y	-2.2
Scarlet Tanager	DNS	4	0	Y	-0.4	DNS	4	0	Y	-0.6
Blue-winged Warbler	DNS	3	0	Y	-1.2	DNS	3	0	Y	-2.9
Prairie Warbler	DNS	3	0	B	-2.1	DNS	4	0	B	-1.8
Blackburnian Warbler	DNS	2	0	B	0.6	DI	1	1	B	1.1
Canada Warbler	DNS	2	0	Y	-2.7	DNS	3	0	Y	-2.5
Whip-poor-will	DNS	2	0	Y	-2.9	DNS	2	0	Y	-3.8
Broad-winged Hawk	DNS	1	0	Y	1.2	DNS	1	0	Y	1.6
Yellow-throated Vireo	DNS	1	0	Y	0	DNS	2	0	Y	0
Tufted Titmouse	INS	0	9	Y	1.9	INS	0	8	Y	1.9
Wild Turkey	INS	0	8	Y	8.9	INS	0	7	Y	10.1
Eastern Bluebird	INS	0	7	Y	1.8	INS	0	6	Y	1.6
Red-bellied Woodpecker	INS	0	7	Y	2.4	INS	0	8	Y	3
Pine Warbler	INS	0	6	Y	1.7	INS	0	5	Y	0.3
Red-tailed Hawk	INS	0	6	Y	2.6	INS	0	1	Y	1.7
White-breasted Nuthatch	INS	0	5	Y	2.4	INS	0	6	Y	2.4
Red-breasted Nuthatch	INS	0	4	B	1.6	INS	0	2	B	0.9
Ruby-thr. Hummingbird	INS	0	4	Y	2.5	DI	1	3	Y	1.5
Ovenbird	INS	0	3	B	1.4	DI	2	3	B	1.1
Prothonotary Warbler	INS	0	1	Y	1.5	NS	0	0	Y	1.6
Worm-eating Warbler	INS	0	1	Y	-0.8	DI	1	1	Y	-1.2
Blue Jay	DI	6	2	B	-0.6	DI	6	1	B	-0.5
Gray Catbird	DI	4	2	Y	0.1	DI	3	2	Y	0.2
Black-billed Cuckoo	DI	4	1	Y	-2.6	DI	2	1	Y	-3.4
Chipping Sparrow	DI	3	4	Y	-0.8	DI	3	3	Y	-0.8
Yellow-billed Cuckoo	DI	3	1	Y	-0.6	DNS	3	0	Y	-1
Blue-gray Gnatcatcher	DI	2	1	B	-0.3	DNS	2	0	B	-0.7
Cerulean Warbler	DI	2	1	Y	-3.4	INS	0	1	Y	-1.7
Red-headed Woodpecker	DI	2	1	Y	-1.6	DNS	1	0	Y	1.8
Pileated Woodpecker	DI	1	10	B	3.1	DI	1	6	B	2.4
Mourning Dove	DI	1	8	Y	1.3	DI	2	7	Y	0.7
Hermit Thrush	DI	1	3	Y	2.5	INS	0	3	Y	2.8
Downy Woodpecker	DI	1	1	Y	-0.4	DI	1	1	Y	-0.4
Sharp-shinned Hawk	INS	0	4	R	5.3	INS	0	2	R	3.2
Barred Owl	INS	0	2	R	6	INS	0	2	R	6.3
Cooper's Hawk	INS	0	2	R	10	DI	1	3	R	7.2
Gray Jay	NS	0	0	R	2.1	NS	0	0	R	-0.9

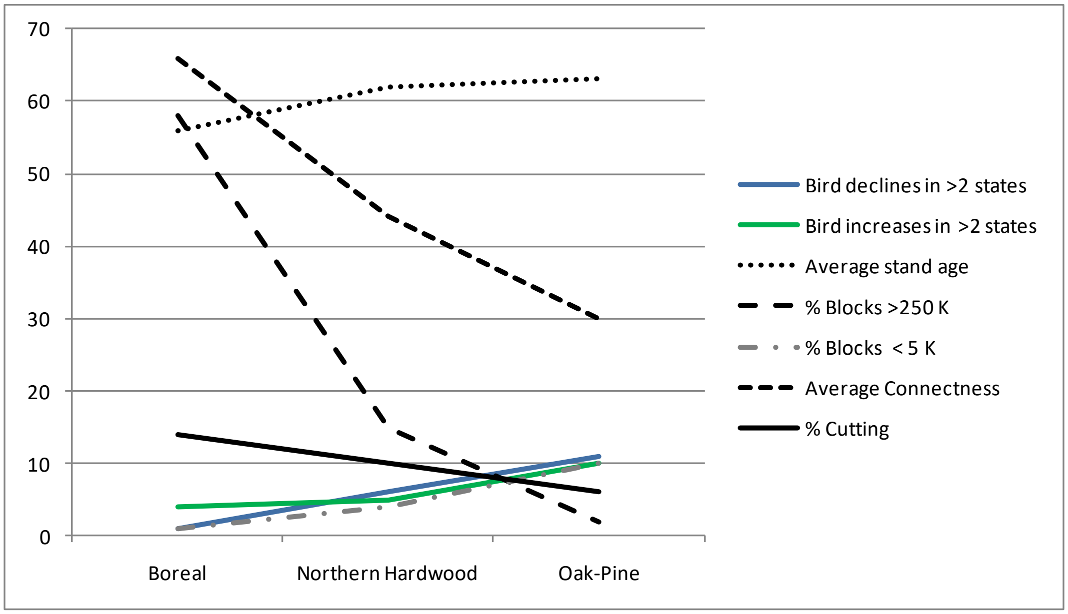
Synthesis of Species Data with Forest Condition

We tested whether significant trends in breeding birds – both increases and decreases – correlated in any way with the metrics of forest condition. To do this, we first tabulated the number of species in each forest type showing a significant trend in three or more states, and the proportion of all possible states that showed trends. Next, we tested whether these summary numbers correlated with the average connectedness, mean age, % cutting, and the % of the forest in very large or very small blocks. The results suggest that breeding bird changes were most extensive in the oak-pine forest, and changes across the three forest types correlated with increasing forest fragmentation (Figure 3.1A.6). Degree of harvest was less correlated with changes in bird abundances suggesting that logging has had a less dramatic effect of bird populations than fragmentation. This question, however, needs further research as we did not correct for the different amounts of usable data in the forest types or the degree of overlap between types.

Table 3.1A.4. Summaries of bird declines and increases. This chart shows stand age, forest fragmentation and local connectedness, by forest types. All of these averages are strongly correlated with forest type but the correlations are highest between the number of declines and the average connectedness and between the total changes in bird composition (summary of declines and increases) and the number of block less than 5,000 acres.

	Species Change in >= 3 States			Species Change in >= 30 % of All Possible States			Average stand age	% Blocks >250 K	% Blocks < 5 K	Average Connectness
Forest Types	Declines	Increases	Total Change	Declines	Increases	Total Change				
Boreal Upland	1	4	5	3	4	7	56	58	1	66
Northern Hardwood	6	5	11	6	5	11	62	15	4	44
Oak-Pine	11	10	21	9	9	18	63	2	10	30

Figure 3.1A.6. Relationships between bird declines and increases, forest fragmentation, connectivity, mean age, and degree of cutting.



Species names

American basswood (Tilia americana)
American beech (Fagus grandifolia)
American ginseng (Panax quinquefolius)
American mountain-ash (Sorbus americana)
balsam fir (Abies balsamea)
bear oak (Quercus. ilicifolia)
birch (Betula spp.)
black bugbane (Actaea racemosa)
black bugbane (Cimicifuga racemosa)
black cherry (Prunus serotina)
black oak (Quercus velutina)
Black spruce (Picea mariana)
black walnut (Juglans nigra)
blue cohosh (Caulophyllum thalictroides)
Catawba rosebay (Rhododendron catawbiense)
chalk maple (Acer leucoderme)
chestnut oak (Quercus prinus)
Clayton's sweetroot (Osmorhiza claytonia)
cucumber-tree (Magnolia acuminata)
eastern red-cedar (Juniperus virginiana)
eastern white pine (Pinus strobes)
heartleaf (Hexastylis spp.)
highland doghobble (Leucothoe fontanesiana)
jack in the pulpit (Arisaema triphyllum)
jack pine (Pinus banksiana)
mockernut hickory (Carya alba)
mountain magnolia (Magnolia fraseri)
mountain silverbell (Halesia tetraptera)
mountain woodfern (Dryopteris campyloptera)
mountain woodsorrel (Oxalis montana)
northern maidenhair (Adiantum pedatum)\
northern mountain-ash (Sorbus decora)
northern red oak (Quercus rubra)
paper birch (Betula papyrifera)
pitch pine (Pinus rigida)
red hickory (Carya ovalis)
red maple (Acer rubrum)
red pine (Pinus resinosa)
red spruce (Picea rubens)
running strawberry bush (Euonymus obovatus)
scarlet oak (Quercus coccinea)
shagbark hickory (Carya ovata)
smooth Solomon's seal (Polygonatum biflorum)
sourwood (Oxydendrum arboreum)
southern sugar maple (Acer barbatum)
Spruce (Picea spp.)
stickywilly (Galium aparine)
strawberry bush (Euonymus americana)
sugar maple (Acer saccharum)
sweet birch (Betula lenta)
Table Mountain pine (P. pungens)
tuliptree (Liriodendron tulipifera)
umbrella-tree (Magnolia tripetala)
Virginia pine (Pinus virginiana)
white ash (Fraxinus Americana)
white oak (Quercus alba)
white trillium (Trillium grandiflorum)
wild hydrangea (Hydrangea arborescens)
yellow birch (Betula alleghaniensis)
yellow buckeye (Aesculus flava)

CHAPTER

Wetlands 4

Condition and Conservation Status Feb 2023

M. Clark, M.G. Anderson, & A. Olivero Sheldon

From marshes, to swamps, to bogs, to fens, to floodplains, wetlands are among the most productive and diverse ecosystems on earth, and a truly distinctive feature of the eastern landscape. In this region, there are over 11.6 million acres of wetlands, representing 8 %of the land area. In this chapter, we examine their loss and degradation, as well as their conservation, and consider the implications of these factors to wildlife.

Distribution, Loss, and Protection: An estimated 21 million acres of the region was once covered by swamps, peatlands, floodplains, and marshes supporting 1,500 obligate or facultative plants and at least 475 rare species. Today, 27% of that historic wetland area has been permanently converted to development (13%) or industrial agriculture (13%). At the same time wetland appreciation and conservation had grown and 20% of the remaining wetland are now conserved primarily for nature (8%) or for multiple uses (12%), a ratio of 1.3 acres of habitat lost for every one acre conserved.

Recent Conservation Trends 2001-2012. In the last two decades, conservation of wetlands has increased, and regulations have been enacted to prevent wetland conversion. As a result, wetland conservation surpassed habitat conversion and loss almost 250 to 1, reversing the historic trend. This pattern held across all wetland types. Emergent marshes lost 21,000 acres to development but conserved 602,000. Alluvial floodplain and riparian wetlands lost 5000 acres but conserved 2.1 million acres. Wetland extent have been remarkably stable through this time with 99% unchanged.

Local Connectedness: Wetlands are not as intact and connected as they used to be. Our previous study found that 66% all the region's wetlands were close to paved roads and had development or agriculture directly in their buffer zones. Our reassessment with a more comprehensive analysis found that regardless of wetland type, all had measures of connectedness and fragmentation equal to the average of the region. This equates to a mixed landscape, with some natural elements, some agriculture, some minor development, and roads. Conserved wetlands had a very different connectedness profile with wetlands conserved for nature having a score far above the average (1.8 SD), and wetlands conserved on multiple use land also being above average (0.5 SD).

Wetland Types and their Fauna

Wetland are vegetated habitats dominated by rooted plants that thrive in saturated soils. The Northeast Terrestrial Habitat Map (NETHM, Ferree and Anderson 2013) recognizes 35 wetland types covering 11 million acres. They range in size from tiny limestone fens that form where alkaline water is discharged on a hillslope to extensive blanket bogs and peatlands that cover thousands of acres. Depending on their hydrology, wetlands maybe dominated by trees (swamps and forested peatlands), shrubs (bogs and shrub swamps) or emergent herbaceous vegetation (marshes, wet meadows, fens), and this difference in structure greatly influences their composition and wildlife communities. Wetlands, however, are extremely dynamic ecosystems that constantly change. During wet years, emergent marshes may expand in size while during dry years they contract as trees and shrubs reclaim ground.

For this report we group wetlands into three basic types based on their hydrology (Table 4.1, Map 4.1) and we crosswalk our names to the NE Lexicon Project:

- Basin Wetland: swamps, marshes and peatland that form in depressions where surface water collects (*Lexicon = non-tidal wetland*):
- Alluvial Wetland: forests and marshes that form in areas subject to regular flooding by stream overflow and ground water discharge (*Lexicon = land-water interface)*
- Tidal Wetland: Marshes and forests that form in places of regular tidal inundation (*Lexicon = tidal wetlands and flats)*

Basin Wetland (*Lexicon: Non-Tidal Wetland*): Basin wetlands form the vast majority (72%) of wetlands in the Northeast including the familiar bogs, swamps, marshes, peatlands, shrub swamps, wet meadow, and fens - virtually any wetland not associated with a flowing river or tidal flooding. They are commonly subdivided into two structurally distinct types based on the dominance of woody or herbaceous vegetation:

Woody Wetlands: Wetlands dominated by trees and shrubs that tolerate occasional inundation or semipermanent saturation. They often surround and intermix with permanently saturated marshes. It is no surprise that in our predominantly forested region, woody wetlands dominate, making up **67% of wetlands** by total area. Throughout the region woody wetlands support birds like barred owl, alder flycatcher, Wilson's snipe, northern harrier, northern waterthrush, swamp sparrow, willow flycatcher, yellow-bellied flycatcher blue-headed vireo, great-crested flycatcher, green heron, green-winged teal, veery, and wood duck. Black bear, northern flying squirrel, snowshoe hare, northern leopard frog, and spotted turtle may be abundant

Emergent Herbaceous Wetlands: Wetlands dominated by herbaceous perennials like cattail, bullrush, tussock sedge, and rush. Tolerating permanently saturated, wetter soils than the woody wetlands, they are found throughout the region in depressions where water and organic matter accumulates. These wetlands comprise **5% of the total wetlands** by area and collectively cover over half a million acres. They sustain an abundant and diverse invertebrate fauna and support an array of wildlife including least bittern, Virginia rail, sedge wren, king rail, marsh wren, yellow rail, red-winged blackbird, great blue heron, least bittern, marsh wren, pied-billed grebe, sora, swamp sparrow, muskrat, racoon, bog lemming, water shrew, lesser siren, and boreal chorus frog, To map basin wetlands. we used the latest 2019 National Land Cover Dataset (Dewitz, J., and U.S. Geological Survey, 2021) to identify the extent of current wetlands. These were separated into tidal and non-tidal wetlands based on distance to coast, landscape setting, and overlay analysis (see below). The non-tidal wetlands were further separated into land-water interface (Alluvial systems) based on position in a river floodplain (See below). The remaining wetlands were considered Basin Wetlands. Basin wetlands were classified into their two physiognomies using the NLCD dataset: woody wetlands (woody vegetation) or emergent herbaceous wetlands (emergent herbaceous).

Alluvial Wetlands (*Lexicon: Land-Water Interface*): Alluvial wetland exist in the land water interface associated with the riparian and floodplain region around flowing streams and rivers. The wetlands tolerate periodic inundation and during floods provide critical nursery, breeding and feeding areas for fish and a wide variety of wildlife. Alluvial wetlands are common throughout the region, composing **19% of total wetlands** by area. Floodplain associated species include bald eagle, cerulean warbler, red-shouldered hawk, veery, warbling vireo, wood duck, kingfisher, yellow warbler, big brown bat, eastern pipistrelle, little brown myotis, northern long-eared bat, long-tailed weasel, mink, river otter, moose, and northern short-tailed shrew.

To map alluvial wetlands, we used current wetlands from the 2019 NLCD overlaid with the 100-year floodplain area (Bates et al, 2021, First Street Foundation, 2020) or wetlands that were identified as floodplain in the NETHM (Ferree and Anderson, 2013) including: Laurentian-Acadian Large River Floodplain, North-Central Appalachian Large River Floodplain, North-Central Interior Large River Floodplain, North-Central Interior Large River Floodplain.

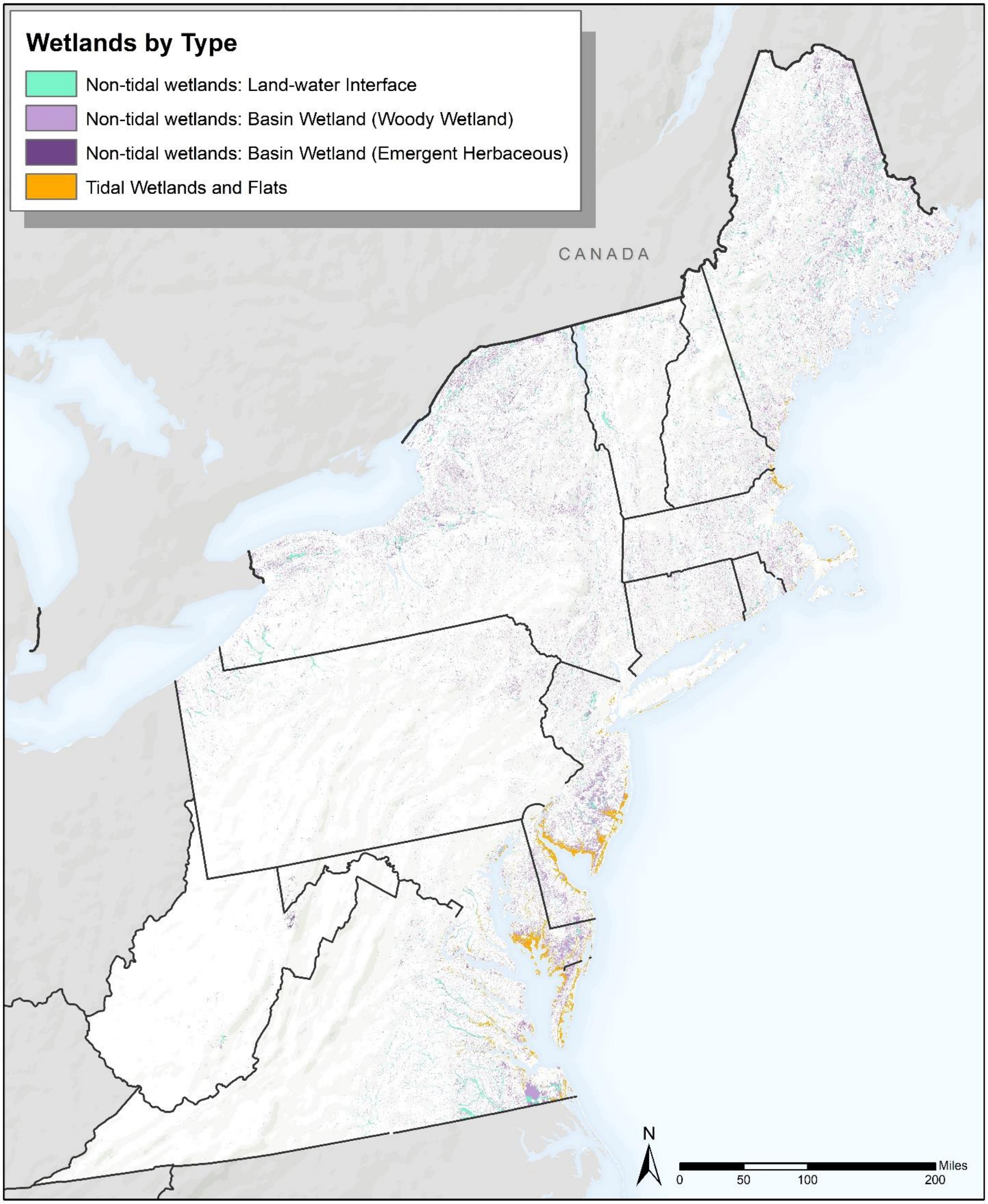
Tidal Wetlands (*Lexicon = Tidal Wetlands and Flats*): Tidal wetlands form in the intertidal region inundated regularly by salt water and occasionally exposed to freshwater. Only a few plant species, such as cordgrass, saltgrass, and glasswort (all of them herbaceous perennials), can tolerate such conditions and these species dominate these unique wetlands. Tidal wetlands provide habitat for a remarkable set of specially adapted species and are important feeding areas for many birds. When inundated they become nursery areas for several marine species. Fringing the coast from Virginia to Maine, tidal wetlands and flats account for **9% of the region's total wetlands.** In the Mid-Atlantic coastal states, they account for between a fifth to a third of total wetlands by area. Species associated with tidal wetlands include saltmarsh sparrow, American oystercatcher, arctic tern, black skimmer, black-crowned night-heron, clapper rail, common tern, Forster's tern, glossy ibis, great egret, gull-billed tern, little blue heron, osprey, royal tern, willet, yellow-crowned night-heron, and North American least shrew

To map tidal wetlands, areas identified as wetlands in the NLCD 2019 were classified as tidal if they occurred as part of a tidal Complexes in TNC resilient coastal sites study (Anderson and Barnett 2017) or were mapped as tidal habitats in the NETHM. The tidal habitats in the NETHM included: Coastal Plain Tidal Swamp, Tidal Salt Marsh, Estuarine Marsh, Atlantic Coastal Plain Embayed Region Tidal Freshwater/Brackish Marsh.

Table 4.1: Distribution of Wetland Types

Sub Region	State	Emergent Basin Wetland (Non-tidal Wetland)	Woody Basin Wetland (Non-tidal Wetland)	Alluvial Wetland (Land-water Interface)	Tidal Wetlands & Flats	Total Acres
Mid-Atlantic	VA	42,794	796,599	365,665	266,104	1,471,163
	NJ	20,269	662,386	118,810	249,603	1,051,069
	MD	20,758	500,753	69,571	281,479	872,562
	PA	49,564	333,218	157,739	1,732	542,252
	DE	5,826	199,528	16,765	87,731	309,850
	WV	16,342	17,179	13,965	0	47,486
	DC	7	115	265	99	487
	Mid-Atlantic Total	**155,561**	**2,509,779**	**742,780**	**886,748**	**4,294,868**
New England & New York	ME	179,153	2,006,989	583,907	33,229	2,803,277
	NY	168,224	1,982,525	553,257	39,251	2,743,257
	MA	32,600	474,365	93,224	58,818	659,007
	NH	26,058	303,978	86,862	6,904	423,802
	VT	27,155	208,150	88,102		323,407
	CT	10,278	229,363	39,538	14,836	294,016
	RI	3,009	68,406	11,707	6,437	89,559
	New England & New York Total	**446,477**	**5,273,777**	**1,456,597**	**159,475**	**7,336,326**
Total Acres		**602,038**	**7,783,556**	**2,199,376**	**1,046,223**	**11,631,194**

Map 4.1. Distribution of Wetlands by Type.



Distribution, Loss, and Protection Status

Wetland Conversion and Loss:

Wetlands comprise only 7 %of the total land area in this region, but this small percentage of land supports a large piece of the total biodiversity of the region, including over 1,500 plants considered obligate or facultative wetland species (Reed and Porter 1988), and at least 475 rare species (see chapter on open habitats). The immense value of wetlands was unrecognized for most of the last two centuries during which time they were systematically drained to create land suitable for agriculture and development.

How many wetlands were lost to conversion? Using historical literature, Dahl (1990) estimated that across all 14 states, about 7.2 million acres were lost between 1780 and 1980. Here we revised these estimates using spatially-specific flow accumulation models combined with topographic position to identify areas where wetlands naturally occur. Our model encompassed all the known wetlands mapped by NLCD 2019, but also identified wet basins where wetlands would be expected to occur but that are now filled with development or agriculture. Assuming all potentially suitable wetland habitat now occupied by development or agriculture can be considered converted wetlands, the analysis suggests 6.9 million acres have been converted: 28% of all historic wetland area. Our estimate was slightly smaller than Dahl's but agrees in terms of pattern and magnitude of loss.

Using a spatial model allowed us to quantify all the transitions apparent in the data. We found that just over 13% of the potential historic wetlands were converted to agriculture and just over 13% were converted to development (Table 4.2, Figure 4.1). An additional 24% appear to have transitioned to forest, shrubland, or grasslands, although much of this area could result from misclassification in the 2019 NLCD. Basin wetland had the largest proportion converted (29%), followed by alluvial wetland (20%), and tidal wetland (14%) (Table 4.2, Figure 4.1b).

Transitions to upland habitats suggesting drier conditions, mostly affected basin wetland (18%) and alluvial wetland (18%) and most of that transitioned to forest. Less than 3% of tidal wetlands transitioned to forest which makes sense as these are tidally inundated. However, 8% of tidal wetlands transitioned to grassland and shrubland which could indicate drier conditions, but more likely indicates classification error as the distinction between emergent marsh or grassland can be hard to detect using remote information. We had the most confidence in the conversion to development or industrial agriculture as these state changes can be detected with remote sensing and spot checking the data confirmed them to be real in all the places we examined. This chapter does not address loss of tidal wetlands to open ocean or mudflats, but tidal wetlands are currently being lost to sea level rise.

Wetland Conservation:

Conservation of wetlands effectively began in the 1970's when their value was widely recognized, and federal and state laws were enacted to curb their loss (Mitsch and Gosselink 1986). Conservationists also increased their efforts to conserve, protect and restore existing wetlands. To quantify the amount of wetland area currently conserved, we overlaid the TNC 2022 conservation lands dataset on the wetland extent and tabulated the degree of securement these habitats have from conversion or degradation.

Table 4.2. Amounts of conversion, transition, and conservation securement in historic wetland area. The units are in acres, organized by wetland type. CRI = area converted/area conserved (GAP1-3). NRI = area converted/ area conserved for nature (GAP 1-2).

Historic Wetland Type	Current Landuse	Wetland not conserved	Wetland GAP 3	Wetland GAP 1-2	Total Current Wetlands	Transition to Forests	Transition to Shrubland/ Grassland	Agriculture	Development	Total Historic Wetlands	Total Converted to Developed Classes	Total Conserved	CRI	NRI
Basin Wetland	Acres	5,463,609	2,035,190	1,091,883	8,590,680	2,993,052	434,956	2,497,268	2,498,978	17,014,934	4,996,245	3,127,072	1.60	4.58
		32%	12%	6%		18%	3%	15%	15%		29%	18%		
(Emergent Herbaceous)	Acres	402,850	172,311	81,375	656,536	0	197,545	1,013,867	864,672	2,732,620	1,878,538	253,686	7.40	23.09
		15%	6%	3%		0%	7%	37%	32%		69%	9%		
(Woody)	Acres	5,060,759	1,862,878	1,010,508	7,934,144	2,993,052	237,411	1,483,401	1,634,306	14,282,314	3,117,707	2,873,386	1.09	3.09
	%	35%	13%	7%		21%	2%	10%	11%		22%	20%		
Tidal Wetland	Acres	446,163	213,455	312,888	972,505	18,850	96,935	42,946	99,119	1,230,356	142,065	526,344	0.27	0.45
	%	36%	17%	25%		2%	8%	3%	8%		12%	43%		
Alluvial Wetland	Acres	1,351,694	455,898	260,185	2,067,777	458,676	69,459	332,031	242,182	3,170,125	574,212	716,083	0.80	2.21
	%	43%	14%	8%		14%	2%	10%	8%		18%	23%		
All Wetlands	Acres	7,261,465	2,704,543	1,664,956	11,630,963	3,470,578	601,350	2,872,244	2,840,279	21,415,415	5,712,523	4,369,498	1.31	3.43
	%	34%	13%	8%		16%	3%	13%	13%		27%	20%		

Figure 4.1. Distribution of Historic Wetland Acres by Current Land Use and Conservation Status.

These figures display the historic wetland area by land use and conservation status

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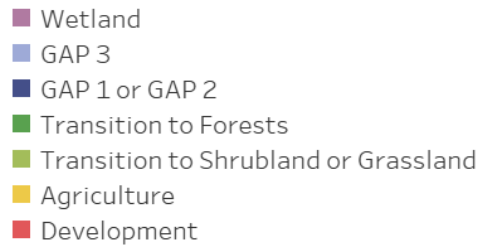
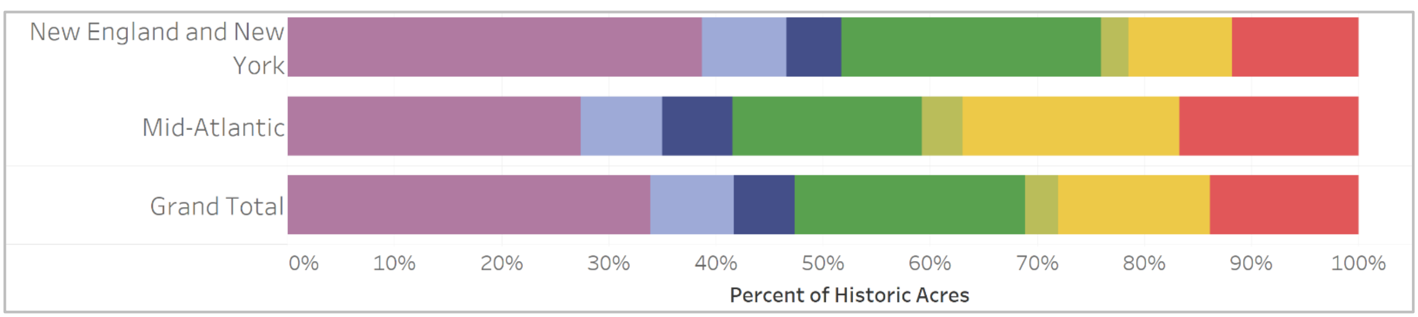


A. Distribution by Subregion and Region



B. Distribution by Wetland Type

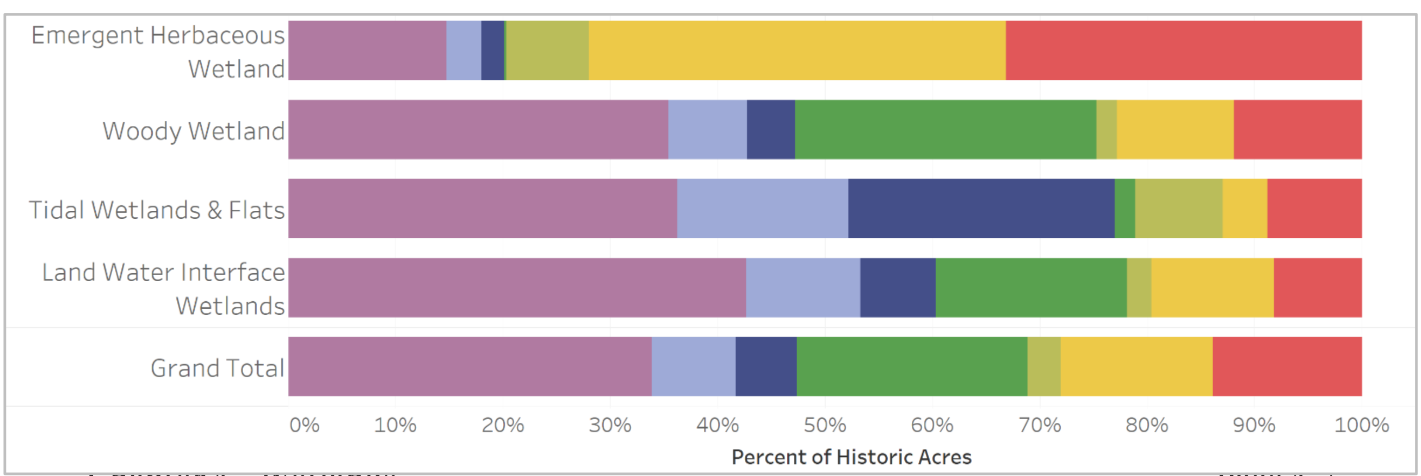
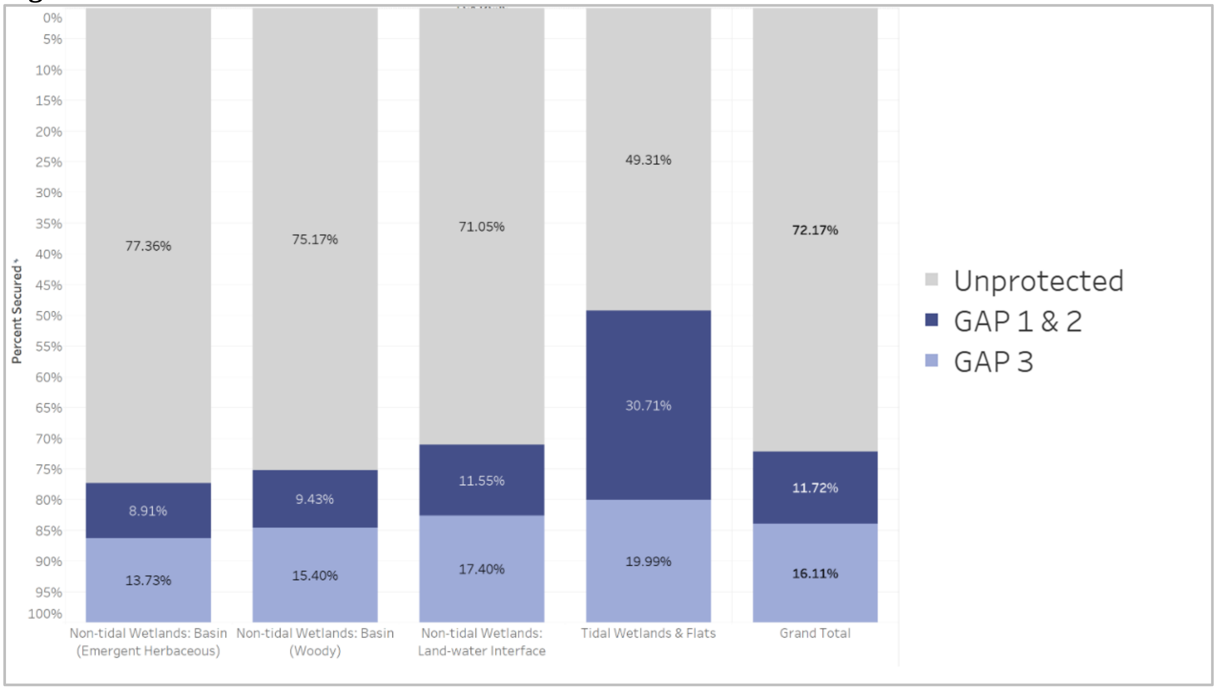


Figure 4.2: Conservation of Current Wetland Extent.



The results of the overlay indicate that 28% of current wetlands now fall on land that is either permanently conserved for nature (GAP 1-2: 12%) or conserved for multiple uses (GAP 3: 16%), leaving 72% is on unsecured land (Figure 4.2). Tidal wetland have the highest level of securement (51%), followed by alluvial wetland (29%), woody basin wetland (25%) and emergent basin wetlands (13%).

We calculated a Conservation Risk Index (CRI, Hoekstra et al. 2005) to compare the amount of wetland converted to development or agriculture to the amount of conserved wetland in both the historic and recent footprint. This can help determine whether conservation is outpacing or losing to the conversion of wetlands. CRI is calculated as:

CRI = acres of wetland converted to development or agriculture / acres permanently conserved (GAP1-3)

The calculation yields a ratio that when less than one indicates more conservation than habitat loss and when greater than one indicates more conversion than conservation. A similar ratio, the Nature Risk Index (NRI), compares the amount of loss only to land conserved explicitly for nature (GAP 1-2) excluding the GAP 3 lands which are for multiple use.

The results of applying the CRI to the *historic* wetland footprint suggests that conversion of wetland has surpassed conservation 2 to 1. That is, 2.1 acres of wetland habitat has been converted to development or agriculture for every one acre that has been conserved (Figure 4.1, Table 4.2). The Mid-Atlantic states has lost 37% of its historic wetland footprint and shows a higher ratio of loss to conservation (CRI=2.6) than New England and New York which have lost 22% of their historic wetland footprint and have a lower ratio of conversion to conservation (CRI=1.6).

All wetland types except basin wetlands had CRI ratios less than one indicating more conservation than loss in their historic footprint (Table 4.2). Basin wetlands had the highest risk (CRI = 1.6) having lost

29% of their historic footprint but conserved 18% equivalent to 4.9 million acres lost and 3.1 million acres conserved. Conservation of basin wetland largely occurs on GAP 3 multiple-use land and the NRI (4.58) is relatively high: 5 acres converted for every one acre conserved explicitly for nature.

Alluvial wetlands had a CRI of 0.8 indicating less conversion (18%) than conservation (23%) of these critical riparian and floodplain zones. That they flood regularly may be part of the reason for their low ratio but as they store water during extreme precipitation and runoff events it is beneficial for people as well as wildlife to have ample amounts under conservation. Again the NRI is greater than one (3.46) suggesting the conservation is mostly multiple use land.

Tidal wetlands had a very low CRI of 0.3 as only 12% have been converted to development or agriculture and 43% are conserved. This makes sense given these areas are likely some of the wettest and hardest to develop given coastal inundation and frequent flooding from river systems is incompatible with most development and many types of agriculture. Not only are these wetlands extremely productive and full of distinct biodiversity but they also buffer the coastline from extreme storms. The question now under sea level rise is whether we have conserved the migration space needed to help them migrate and reform in response to the changing tidal patterns.

Recent Trends in Wetland Loss and Conservation (2001-2022):

In addition to analyzing historic patterns of wetland loss, we also examined trends in wetland turnover loss and conservation over the last 20 and 10 years. To explore this, we overlayed the 2001, 2011 and 2019 National Land Cover dataset (NLCD 2019, Dewitz and U.S. Geological Survey 2021) on the wetland dataset. The NLCD products have been corrected for evolving mapping methods and allow direct comparisons between time periods. We did the same with the 2022 TNC conservation lands selecting only conservation that occurred in one of three time sets pre-2001, 2002-2011, and 2012-2022.

Results show that less than 1% (45,000 acres) of wetland was converted to development or agriculture over the last 20 years (Table 4.3). Most of this was emergent basin wetland (21,000 acres, 3% of extent) followed by woody basin wetlands (16,000 acres, 0.2% of extent). Transition to forest or other natural cover converting to wetland were all very small (<1%). In all, wetlands have remained surprisingly stable in extent over the last two decades, with 99.7% staying the same (Table 4.3, Figure 4.3).

The stability of wetlands is especially striking compared to forests that in response to logging and disturbance have almost 8% turnover as forest change to open shrubland and then regrow as forest. However the rate of permanent conversion to development or agriculture is on par, with both wetlands (0.4%) and forest (0.8%) both having less than one percent (Table 4.4).

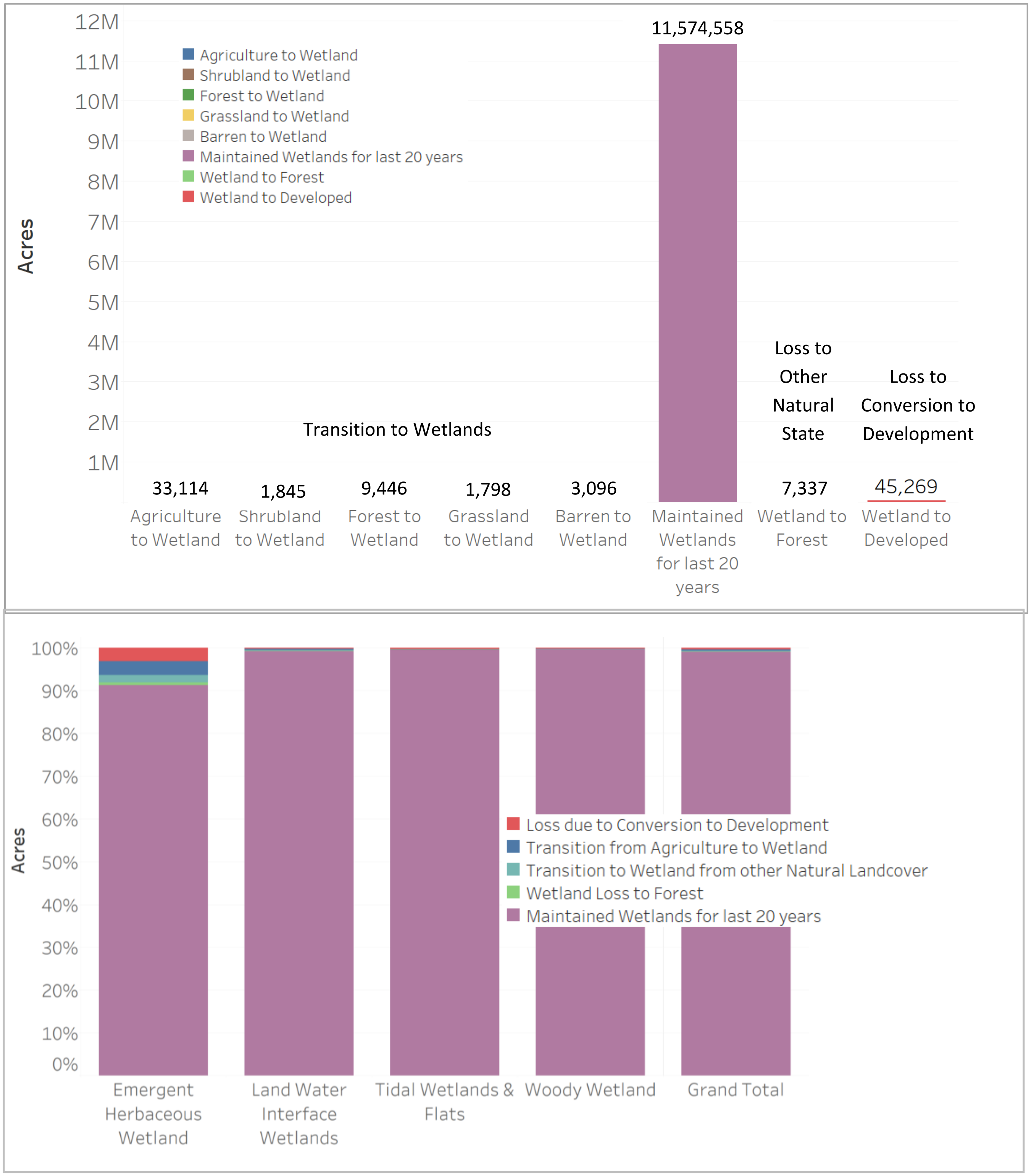
Table 4.3: Acres of Wetland Turnover and Loss from 2001-2021 by Wetland Type.

	Maintained Wetland for last 20 Years		Transition from Agriculture to wetlands		Transition to Wetland from other Natural Cover		Wetland Loss to Forest		Wetland Loss to Conversion to Development	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Emergent Basin Wetlands	571,665	96.75%	17,711	3.00%	1,480	0.25%	3,531	0.60%	20,787	3.52%
Alluvial Wetlands	2,187,917	99.62%	7,881	0.36%	481	0.02%	1,267	0.06%	4,826	0.22%
Tidal Wetlands & Flats	1,045,012	99.90%	96	0.01%	929	0.09%	54	0.01%	3,716	0.36%
Woody Basin Wetlands	7,769,965	99.90%	7,426	0.10%	207	0.00%	2,485	0.03%	15,942	0.20%
Grand Total	**11,574,558**	**99.69%**	**33,114**	**0.29%**	**3,096**	**0.03%**	**7,337**	**0.06%**	**45,270**	**0.39%**

Table 4.4. Conversion of Natural Land Use (2001-2021). This table provides conversion of natural land uses to and from agriculture and development in the last 20 years by total acres in the region. The large fluctuations in the grasslands and shrublands are likely classification error.

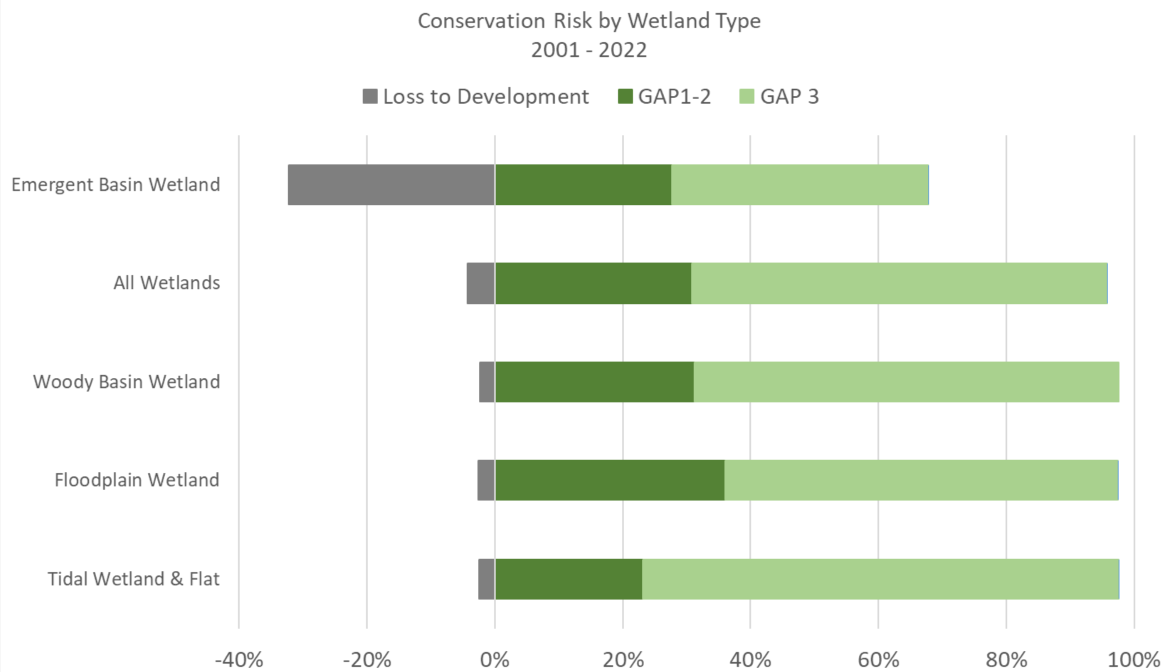
	Conversion from Agriculture or Developed back to Natural		Maintained Natural State in last 20 years	Conversion from Natural to Agriculture or Developed	
	Acres	Percent	Acres	Acres	Percent
Wetlands	33,163	0.29%	11,643,300	-45,269	-0.39%
Forests	403,283	0.44%	92,033,942	-709,985	-0.77%
Grasslands and Shrublands	54,864	1.31%	4,198,954	- 53,431	-1.27%
Total Natural	**491,310**	**0.46%**	**107,876,196**	**-808,685**	**-0.75%**

Figure 4.3: Wetlands in transition in the Northeast and Mid-Atlantic. 99% of wetlands were unchanged in extent across the last 20 years. Most change was due to loss from conversion to development (0.4%).



The Conservation Risk Index (CRI, Figure 4.4) for the last two decades shows that conservation has surpassed conversion almost 250 to 1. This reflects the large decline in wetland conversion due to regulatory action combined with over a million acres of wetland on new conservation land (Figure 4.4). The CRI is less than one for all wetland types, and the Nature Risk Index, which looks explicitly at land conserved for nature is less than one for all types except emergent basin marsh (NRI=1.16) which indicates 1.2 acres converted for every on conserved for nature.

Figure 4.4. Conservation Risk Index by Wetland Type (2001-2012).



	Tidal Wetland & Flat	Floodplain Wetland	Woody Basin Wetland	All Wetlands	Emergent Basin Wetland
Loss to Development	-3716	-4826	-15942	-45271	-20787
GAP1-2	34,302	68,449	208,470	329,087	17,865
GAP 3	109,871	116,612	442,143	694,412	25,787
CRI	0.00	0.00	0.00	0.00	0.03
NRI	0.11	0.07	0.08	0.14	1.16

Recent Wetland Conservation (2012-2022)

To quantify the amount of wetland area conserved in the last decade, we overlaid the TNC 2022 conservation lands dataset on the wetland extent and restricted the data only to conservation since 2012 using the "date conserved" field.

Results show that over the last decade 231,654 acres of wetlands were conserved through land acquisition and easement including 80,000 acres (35%) conserved explicitly for nature (GAP1-2) and 152,000 acres (65%) for multiple use (GAP 3, Table 4.5). Conservation was spread across all wetland types with 64% for woody basin wetland, 23% for floodplain wetland, 8% for tidal wetland and 4% for emergent basing wetland. State Wildlife Management Areas added the most wetland to the conservation network followed by NGO and State easements (Table 4.6).

Table 4.5. Conservation of Current Wetland Extent. This table provides the total acres and percent of the current wetland extent in GAP 1-2 and GAP 3 conservation land. It also summarizes the acres and percent of all conservation gained in the last decade.

							Conservation Gains 2012-2022		
Wetland Type		**GAP 1 & 2**	**GAP 3**	**Total GAP 1-3**	**Unprotected**	**Total**	**New GAP 1 & 2**	**New GAP 3**	**New GAP 1-3**
Non-tidal Wetlands: Basin (Emergent Herbaceous)	Percent	8.91%	13.73%	22.64%	77.36%	100.00%	0.51%	1.18%	1.68%
	Acres	53,619	82,681	136,300	465,718	602,017	3,057	7,083	10,140
Non-tidal Wetlands: Basin (Woody)	Percent	9.43%	15.40%	24.83%	75.17%	100.00%	0.61%	1.30%	1.92%
	Acres	734,191	1,198,818	1,933,009	5,850,533	7,783,542	47,845	101,413	149,258
Non-tidal Wetlands: Land-water Interface	Percent	11.55%	17.40%	28.95%	71.05%	100.00%	0.95%	1.49%	2.44%
	Acres	254,134	382,605	636,739	1,562,637	2,199,376	20,826	32,789	53,615
Tidal Wetlands & Flats	Percent	30.71%	19.98%	50.69%	49.31%	100.00%	0.79%	0.99%	1.78%
	Acres	321,217	209,020	530,237	515,790	1,046,028	8,280	10,362	18,642
Total of All Wetlands	Percent	11.72%	16.10%	27.82%	72.18%	100.00%	0.69%	1.30%	1.99%
	Acres	1,363,161	1,873,125	3,236,286	8,394,677	11,630,963	80,008	151,646	231,654

Table 4.6. Top Ten Entities for Recent Wetland Conservation

Protection Holder	Emergent Basin Wetland	Woody Basin Wetland	Floodplain Wetland	Tidal Wetlands	Total Acres
State Wildlife Management Area	34,922	570,493	180,201	135,449	921,065
NGO Easement	23,700	285,041	79,476	18,809	407,025
State Easement	13,078	220,554	56,084	39,097	328,813
Fish and Wildlife Service	11,678	117,506	59,161	100,555	288,899
NGO Fee	10,764	148,454	50,319	51,375	260,913
Local Fee	7,854	148,734	51,030	23,798	231,416
State Forest	4,098	106,518	21,501	71,467	203,584
State Land	7,307	101,220	42,469	29,847	180,842
State Park	6,466	68,643	21,982	16,804	113,894
Dept. of Defense	3,238	34,648	25,621	14,195	77,703

Wetland Condition

Local Connectedness:

One solution to the pervasive problem of fragmentation is to preserve connectivity, which helps maintain the quality of the whole ecosystem. The metric we used to measure connectivity - local connectedness - uses a resistant kernel algorithm to account for the impacts of major and minor roads, as well as the density of all nearby roads and the degree of nearby conversion. The method follows Compton et al. (2010) and treats the landscape as having a gradient of permeability where highly contrasting land cover types have reduced permeability between them, and highly similar ones have enhanced permeability. Every point on the landscape is scored based on how connected it is in all directions within its local 3-km neighborhood. In applying the metric, we differentiated between developed lands, agricultural lands, and natural cover, but all forms of natural land cover were combined into one class for the analysis. The assessment of local connectivity was developed by Brad Compton at the University of Massachusetts (detail in Compton 2007). Our application was run with the 30 m 2019 National Land Cover dataset (Dewitz, J., and U.S. Geological Survey 2021) supplemented with major and minor road information (Tiger Roads 2022).

For every 30 m grid cell in the region, a circular area with a 3 km radius around the cell was evaluated and the amount of resistance /permeability was calculated to create a wall-to-wall grid with cell values ranging from 0 to 100; these scores were then put on a standard normal scale (z-score) and multiplied by 1000 to scale the results from -3500 (-3.5 SD below the mean) to 3500 (3.5 SD above the mean). In the results "-3500" indicates complete impermeability (e.g. developed), 0 = average local connectedness for the region, and "3500" indicates complete permeability (e.g. natural cover with no barriers, Figure 4.6).

The results create a wall-to-wall map of connectedness that is both spatially comprehensive and sensitive to local scale fragmentation (Map 4.2). The approach can detect difference in local patterns from completely natural, to a few minor roads and houses, to a mixed landscape with some agriculture to fully developed (Figure 4.5) conveying a lot of information about the context of the site and intactness of its local neighborhood.

We measured the relative connectedness of all wetlands and wetland types by overlaying the local connectedness grid on all cells of wetland cover and tabulating the mean for all cells of each forest type. Additionally, we overlaid the 2022 TNC conservation lands on the wetland data to detect difference in local connectedness associated with their GAP status.

Map 4.2. Local Connectedness Wall to Wall.

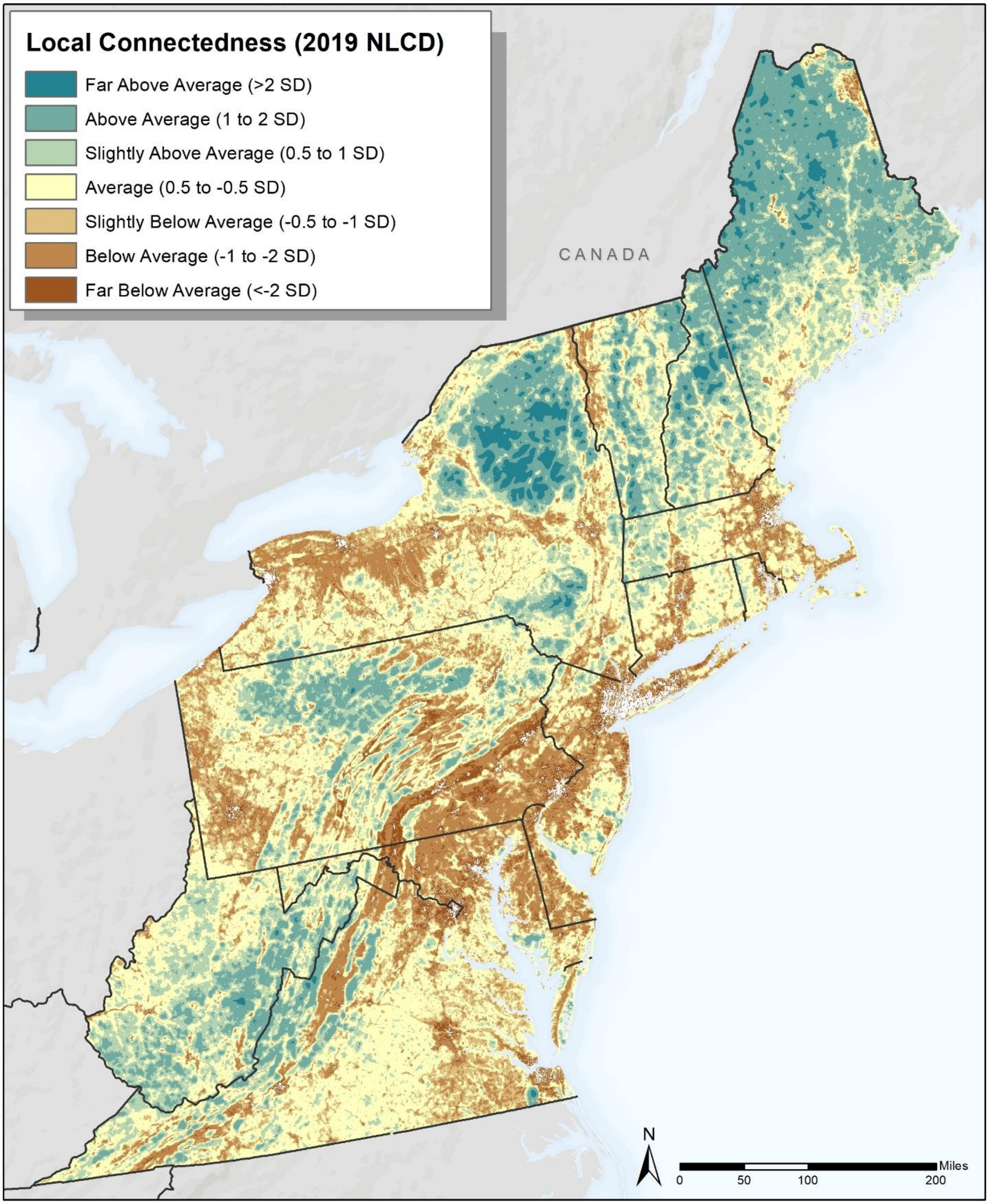
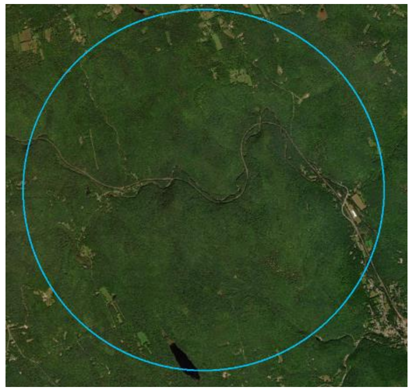


Figure 4.5. Aerial photo image of areas with different local connectedness scores.

Local Connectedness = 3500
Completely natural, no roads, agriculture, or development



Local Connectedness = 1000
Mostly natural, some roads and minor development

Local Connectedness = 0
Mixed landscape, some natural, some agriculture/minor development/roads.

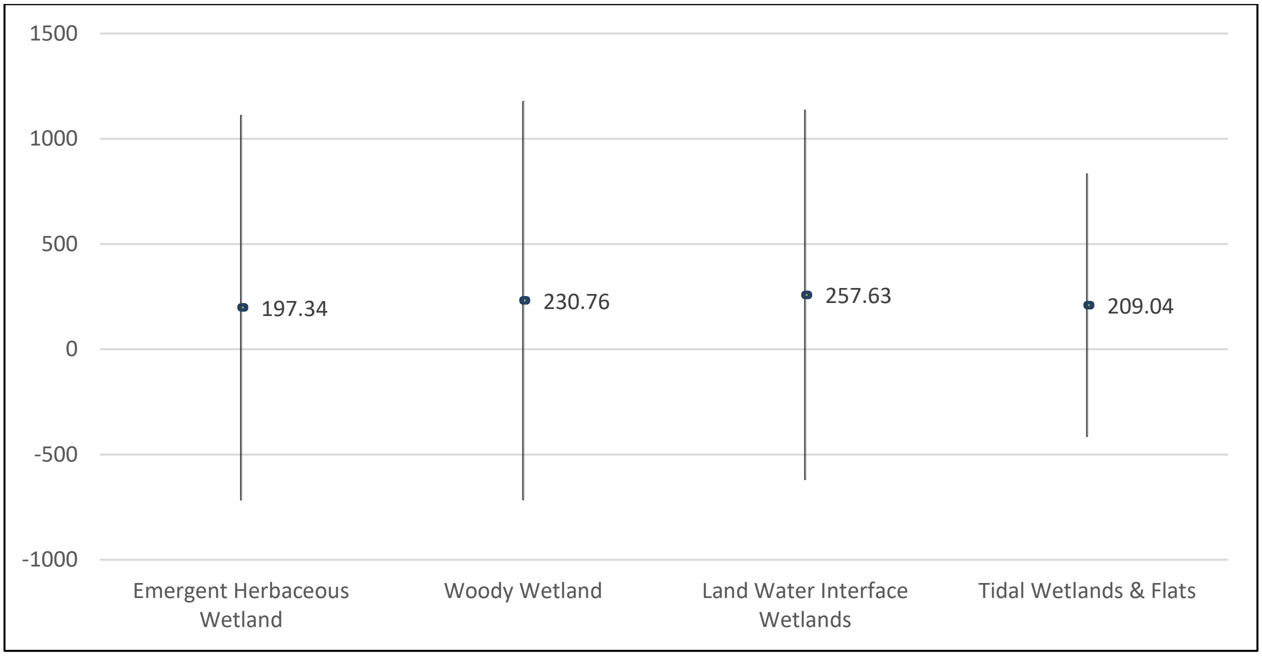
Local Connectedness = -1000
Mostly disturbed, roads, agriculture, and high density development.

Local Connectedness = -3500
High Density Development

Results show the mean connectedness score for wetlands to be slightly above the regional mean (LC = 232, 0.23 SD) indicating that wetlands have about the same or slightly better connectedness than the region in general (Figure 4.6). Visually, areas with a score of 0 (the mean) appear to have mixed landscape, with some natural and some agriculture or minor development and roads (Figure 4.5).

The three wetland types did not differ markedly in their connectedness scores (Figure 4.7). Floodplain wetlands (Land-Water interface) had the most connectedness (LC = 258) followed by woody basin wetland (LC=231), tidal wetland (209, and emergent basin wetland (LC=197). All of these are well within the range of the mean considered as +/- a half standard deviation.

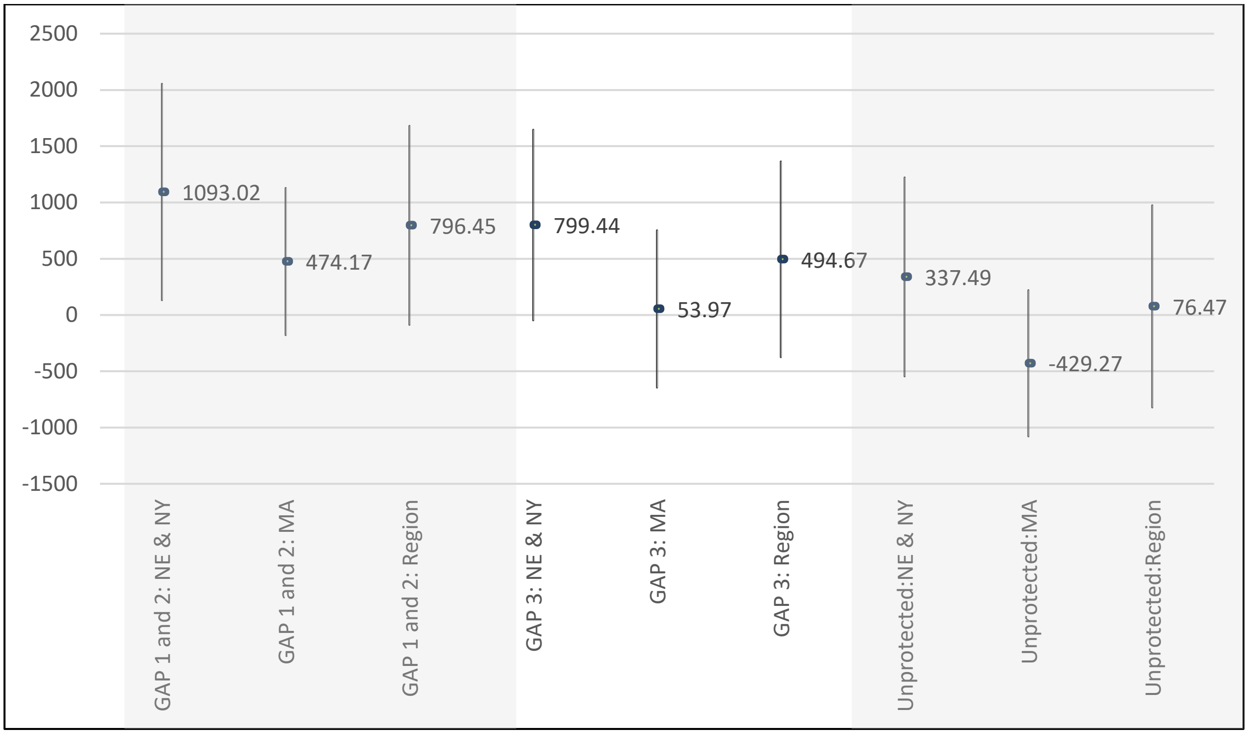
Figure 4.6. Average connectedness scores for the four wetland types. The numbers are in Z-scores (standard deviations) multiplied by 1000. The average score for the region is 0 and all wetland types are well within the range of average (+/- 500) with the highest being the interface floodplains (0.26 SD).



Conserved wetlands score distinctly better for local connectedness than unconserved wetlands, suggesting that conservation land may help maintain wetland connectivity (Figure 4.7). Wetlands on land conserved primarily for nature (LC=795) scored above the average for the region and above one standard deviation (LC = 1093 = 1.1 SD) for New England and New York. They scored well in the Mid Atlantic (LC = 474) although a little lower. Multiple use land was not quite as connected, scoring (LC = 495) for the region, (LC=799) for New England and New York, and (LC = 54) for the Mid Atlantic.

Without the conservation lands the region still scored about average but the two subregions differed as New England and New York scored a little above the mean (LC = 337) and the Mid Atlantic scored below the mean (LC = -429).

Figure 4.7. Average connectedness scores for the four wetland types. The numbers are in Z-scores (standard deviations) multiplied by 1000. The average score for the region is 0. The GAP 1 conserved for nature lands score distinctly higher for local connectedness than the multi-use conservation lands, but both type scored above the unconserved wetlands.



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Appendix 4.1 (these sections are from the 2011 report)

With approval of the project steering committee, we chose to focus our 2022 analysis on the highest priority metrics, those we expected to see more change in, and/or that were not covered in other recent reports (e.g. birds). These metrics are from the previous 2011 Conservation Status of Fish, Wildlife and Natural Habitats in the Northeast Landscape report (Anderson and Olivero-Sheldon 2011). They may be of interest to some readers looking for additional information on wetlands..

Impacts in the Buffer Zone:
The area immediately surrounding a wetland, its buffer zone, has a strong influence on the quality and diversity of the wetland. To assess the condition of this area, we defined a 100 m zone around each individual wetland greater than 2 acres in size and calculated the amount of development, agriculture, and natural vegetation within it. We summarized this information in an index of disturbance, by calculating a weighted sum of the anthropogenic features present and weighting the effect of development more than agriculture. Scores ranged from 100 for a wetland with its buffer zone totally developed, to 0 where the buffer was completely within natural cover types:

> *Disturbance Score = 1.0 times the %high intensity development + 0.75 times the %low intensity development, + 0.50 time the %agriculture*

To interpret the index, we developed categories of impact based on the correlation of the impact scores to observed measurements of shoreline human disturbance for sites sampled by the National Lake Assessment (EPA National Lake Assessment 2009, R^2 squared = 0.56, $p < 0.0001$). We matched the three disturbance categories used in the lake assessment by calculating the mean impact score for the set of known sites in each disturbance category, using the point halfway (log scale) between the means as the cutoffs:

- Low disturbance 0 < 3.7
- Moderate disturbance >= 3.7 < 15.0
- Severe disturbance >=15.0

Across all wetlands, the results indicated a nearly equal distribution of total acres in each of the three impact categories (Map 4.1.1, Table 4.1.1, Figure 4.1.1). By type, tidal wetlands were the most disturbed, with only 15 %of them in the undisturbed class. Basin wetlands were the least disturbed with 43 %undisturbed, and alluvial wetlands were intermediate with 31 %undisturbed. The %of wetlands in the undisturbed class in New England and New York (43 percent) was over twice that of the Mid-Atlantic (18 percent) although this largely reflected the basin wetlands. Alluvial and tidal wetlands were relatively less impacted in the Mid-Atlantic (Table 4.1.1).

Map 4.1.1. Wetland occurences by impact classes.

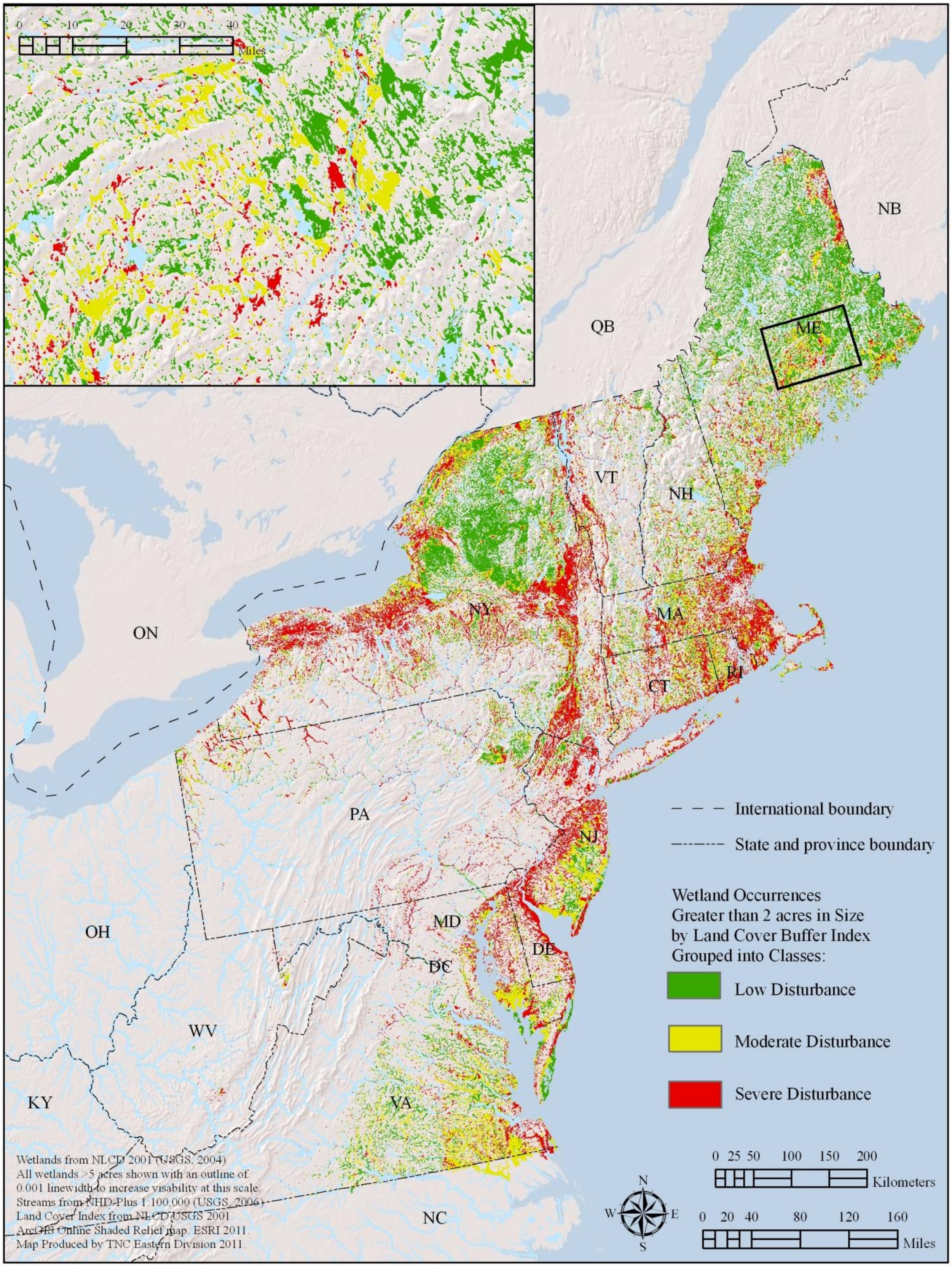
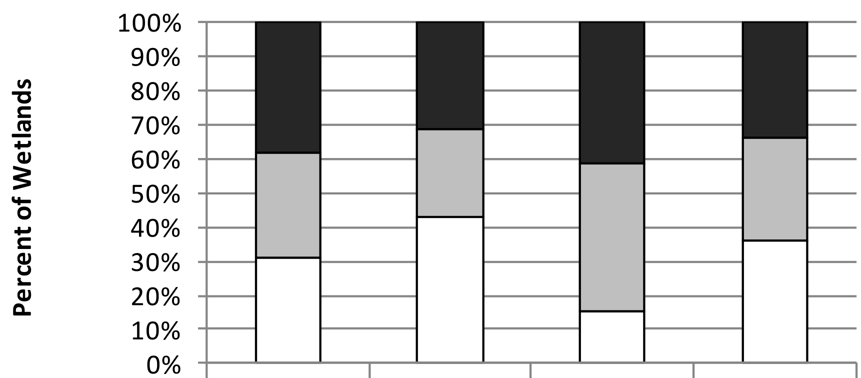


Table 4.1.1. %of wetland acreage in each impact class across wetland types and subregions.

Region	Type	Low disturbance	Moderate disturbance	Severe Disturbance
Mid-Atlantic	Alluvial	15%	55%	30%
	Basin	26%	37%	37%
	Tidal	14%	49%	37%
Mid-Atlantic Total		18%	46%	36%
New England & New York	Alluvial	37%	23%	40%
	Basin	47%	24%	29%
	Tidal	18%	24%	58%
New England & New York Total		43%	24%	33%
Region	Alluvial	31%	31%	38%
	Basin	43%	26%	31%
	Tidal	15%	44%	41%
Region Total	All Wetlands	36%	30%	34%

Figure 4.1.1. Disturbance in the 100 m buffer zone. This chart shows the percentage of 435,000 individual wetlands in each disturbance class. Only wetlands >2 acres were included.



	Alluvial	Basin	Tidal	All Wetlands
Severe disturbance	38%	31%	41%	34%
Moderate disturbance	31%	26%	44%	30%
Low disturbance	31%	43%	15%	36%

Road Density: The species richness of birds, amphibians, reptiles, and plants within an individual wetland is negatively correlated with the density of paved roads surrounding a wetland (Forman 2003), with the sensitive impact distances varying from 500 m to 2,000 m depending on the taxa (Findlay and Houlahan, 1997). To measure this, we created a road density data layer for the whole region by calculating the density of roads (meters/hectare) within a 1,000 meter radius of each 30 m pixel of land ar in the region.

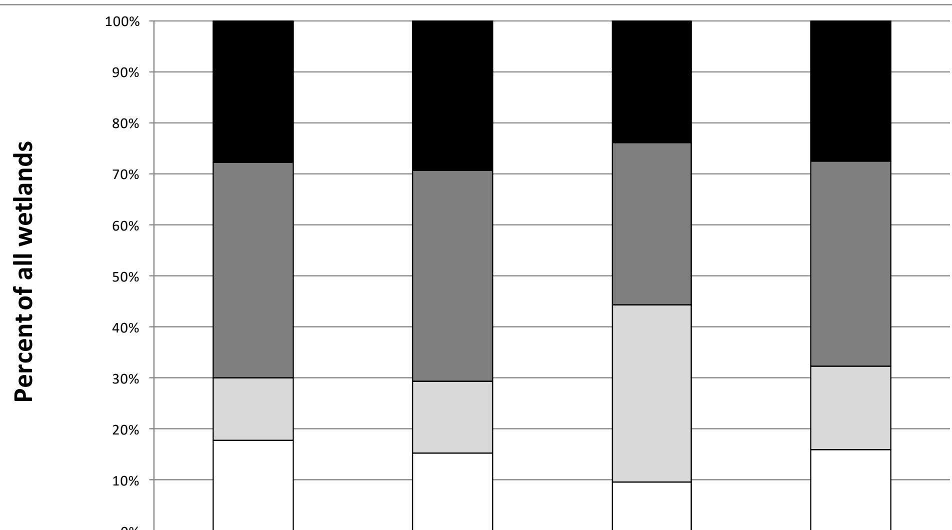
Subsequently, we calculated the mean road density value for each wetland by taking the average of all pixels within each occurrence. This method takes into account roads in the buffer zone as well as the total size of the wetland, so that large wetlands show fewer impacts from roads.

We created a road impact index for each wetland occurrence based on Findlay and Houlahan (1997) who found that plant species richness decreased 13 %with every 2 m/ha of paved roads within a buffer zone, and showed similar patterns for other taxa. The road dataset we used consisted primarily of paved roads including major highway, local thoroughfares, neighborhood connectors, and rural roads, but we do not know the number of unpaved road in the dataset (Tele Atlas North America, Inc 2009). Four-wheel drive roads and other trails were not included due to inconsistencies in their mapping across the region in the source dataset. Our index, based on roads in the 1,000 m buffer, was as follows:

- No impact: 0- 2 m/ha roads of roads (estimated 80-100% of natural species richness)
- Moderate impact: 2 to 6 m/ha of roads (estimated 50-80% of natural species richness)
- Impacted: 6 to 18 m/ha of roads (estimated 25-50 of natural species richness)
- Severe impact: >18 m/ha of roads (estimated >25% of natural species richness)

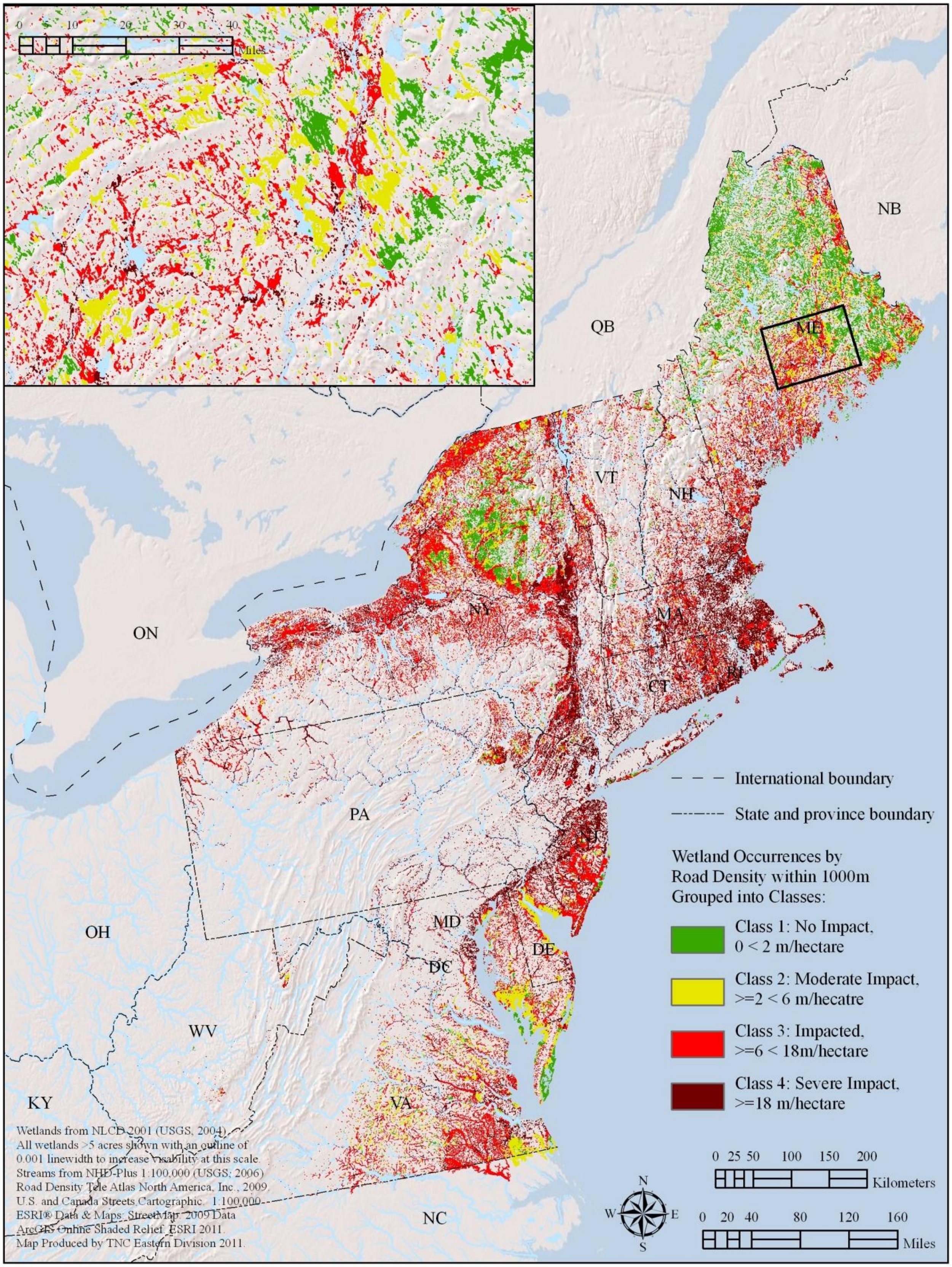
The results of applying the index to all wetlands indicated that only 16 %of all wetlands in this region were free of road impacts. Sixty-seven %were in the impacted to severe impact categories, suggesting that most wetlands in the region do not support a full complement of native species. The alluvial and basin wetlands had the largest proportion of impacted wetlands, perhaps because they were smaller than tidal wetlands (Figure 4.1.2, Map 4.1.2).

Figure 4.1.2. Acres of wetlands in each road impact category across wetland types. This metric was calculated for a 1,000 m buffer zone around each individual wetland.



	Basin	Alluvial	Tidal	All Wetlands
Class 4: Severe Impact (>=18 m/hectare)	28%	29%	24%	27%
Class 3: Impacted (>=6 < 18m/hectare)	42%	41%	32%	40%
Class 2: Moderate Impact (>=2 < 6 m/hecatre)	12%	14%	35%	16%
Class 1: No Impact (0 < 2 m/hectare)	18%	15%	10%	16%

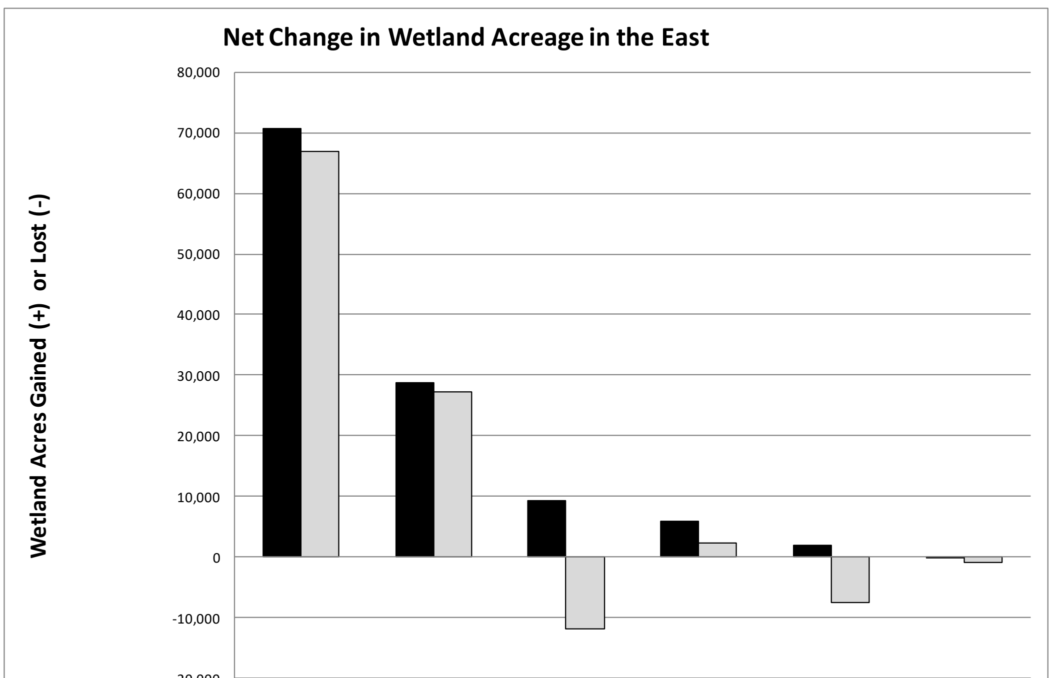
Map 4.1.2. Wetland occurrences by road impact category.



Lastly, to identify the wetlands in the best condition with respect to both roads and land use, we combined the buffer impact index and the road density index and selected those wetlands that were above the average value for both attributes. This highlighted wetlands in northern Maine, the Adirondacks, southern New Jersey, the Chesapeake Bay region, and the Virginia coast.

Changes in Wetland Acreage over Time: Over the last two decades, the region has seen both losses and gains in wetland acreage. The National Land Cover Database (NLCD) 1992–2001 Land Cover Change Retrofit Product (Fry et al. 2009) was developed to provide a more accurate and useful land cover change dataset. At a resolution of 30 meters, this dataset contains unchanged pixels that have been cross-walked to a modified Anderson Level I class code along with changed pixels labeled with a "from-to" class code. Judging from this dataset, wetlands appear to have increased by roughly 100,000 acres since 1992 (Figure 7). Close examination of the data revealed that, 91 %of this change was explained by small increases in the size of thousands of existing forested wetlands. Because 63 %of the gained acres were located within the 1 pixel edge of existing wetlands, this trend might reflect mapping error between the between the 1992 and 2001 satellite-derived maps in the exact boundaries of each wetland. However, when the acres of wetland gained beyond those in the 1 pixel edge zone were examined independently, the data still suggested a net gain of wetlands in the region of about 9,000 acres. The largest and most consistent transitions to wetlands appear to be from forests, agriculture, and open water (Figure 4.1.3), but the data on transitions were occasionally contradictory.

Figure 4.1.3. Estimated net change in wetland acreage from 1992 to 2001. The chart compares changes within and without of the 1 pixel margin. Data from The National Land Cover Database (NLCD) 1992–2001 Land Cover Change Retrofit Product (Fry et al. 2009)



	Forest	Agric.	Water	Urban	Grassland	Barren
■ Net change outside of margin	70,672	28,698	9,242	5,968	2,039	-62
□ Net change within margin	66,812	27,239	-11,732	2,396	-7,463	-816

CHAPTER

Unique Habitats

5

Condition and Conservation Status

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The rich biodiversity of the Northeast and Mid-Atlantic is associated with unique habitats that reflect the complex geologic history and varied landscape of the region. It is one of the few regions where one can find coastal beaches, alpine summits, limestone valleys, and silty floodplains all in relative proximity.

Geophysical Settings and Rare Species: Eleven distinct geophysical settings collectively sustain the 17,556 plants, vertebrates and macro invertebrates that inhabit the Northeast. Each setting supports a set of preferential species that are concentrated within it, although not necessarily restricted to it. Six geologic, topographic, or elevational settings had much higher densities of rare species than would be expected based on their abundance. These were coarse-grained sand, calcareous bedrock, ultramafic serpentine, cliffs and steep slopes, high elevation and the coastal zone.

Conservation and Habitat Loss: On average, for every one acre of habitat conserved, 1.8 acres of habitat has been lost through conversion to development or agriculture. The exceptions are high elevations and granitic bedrock regions where conservation exceeds habitat loss. At low elevations, habitat loss exceeds conservation 3:1, and 13:1 if you exclude multiple use land. Areas underlain by calcareous limestone, shale, coarse sand, and fine silt are at risk due to their high ratio of conversion to conservation ranging from 3:1 to 36:1.

Recent Conservation Trends: Over the last decade conservation has surpassed habitat conversion across every geologic type, elevation zone and slope class. Regions underlain by acidic shale had the highest level of conversion reflecting the rise of shale gas fracking, but although 50,000 acres were lost to conversion, 122,000 acres were put under conservation. Most of the conservation land on shale and calcareous limestone areas were multiple-use, and both these settings still lack many lands where the primary purpose is nature conservation

Fragmentation and Connectivity: Fragmentation and loss of connectivity is pervasive at lower elevation across all geology classes. The highest fragmentation and lowest connectivity were in calcareous bedrock, coarse and fine sediment settings, and elevations under 800 feet. Over the last decade connectivity decreased across every geophysical setting the largest decreases in land underlain by acid shale (2%), calcareous limestone (1%) or elevations below 800 feet (1%),

Non-Forested Upland Habitats. Patches of non-forested habitats on summits, cliffs, barrens, outcrops, dunes and grasslands are hotspots of diversity. High elevation alpine habitats are almost fully conserved as are many cliff and outcrop habitats, but low elevation limestone glades and ephemeral grasslands need more conservation focus.

This chapter first assesses the geophysical settings that underlie our forests, wetlands, and unique natural habitats. Second, we look specifically at the unique non-forested and non-wetland habitats that support much of the region's rare plants and animals. In both sections we examine the distribution, condition, securement, and trends in recent conversion.

Geophysical Settings and Natural Habitats

This section is organized by geologic, elevational, and landform settings that have distinct ecological and biological expressions. Total species diversity in the Northeast is highly correlated with the variety of geophysical settings (Anderson and Ferree 2010). Here we evaluate the condition and conservation status of the natural land in respect to the geological classes, elevation zones and landforms that support distinctive biological diversity. The geophysical settings include:

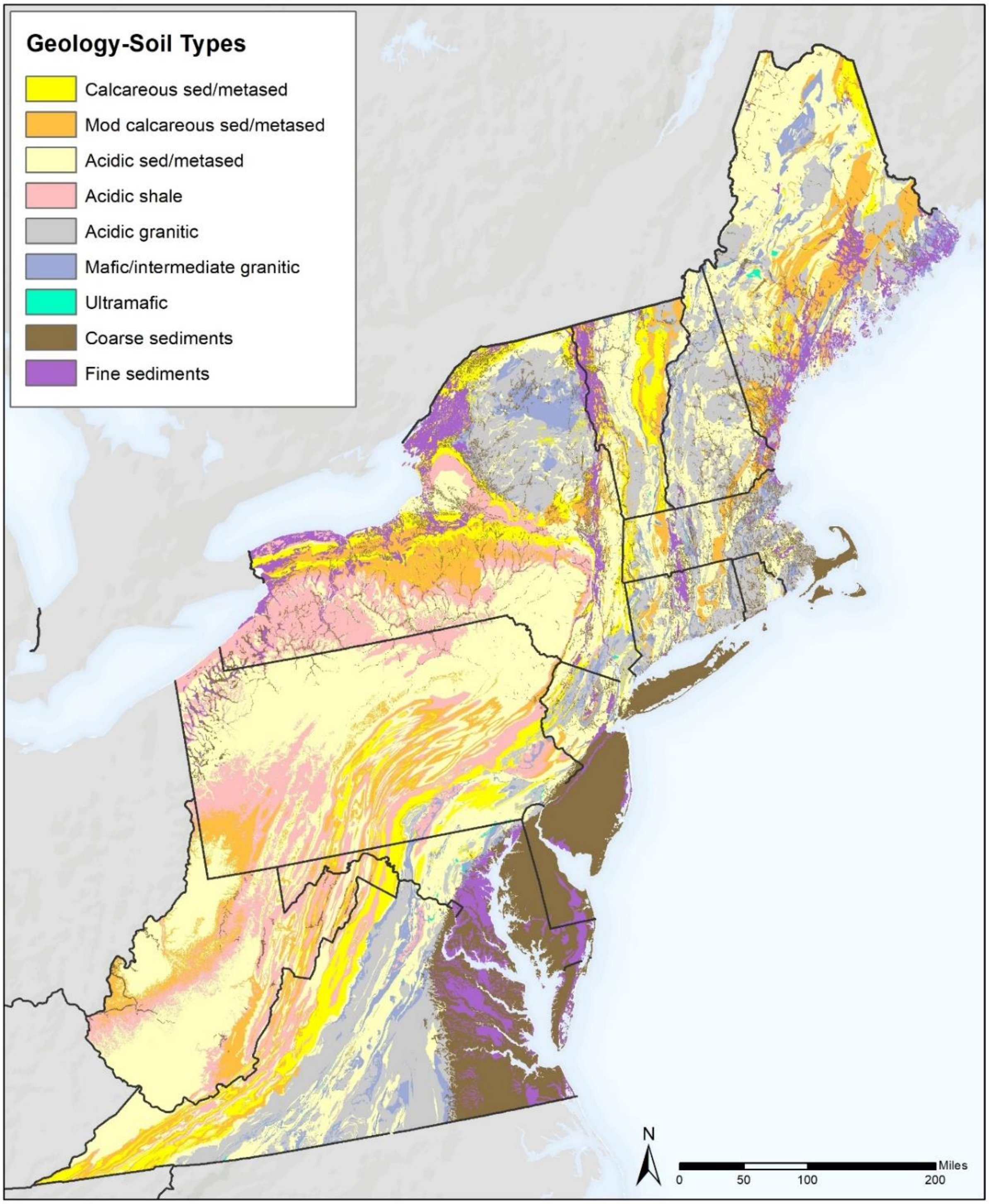
- Limestone valleys, wetlands and barrens (Calcareous settings)
- Soft sedimentary valleys and hills (Moderately calcareous settings)
- Acidic sedimentary pavements and ridges (Acidic sedimentary settings)
- Shale barrens and slopes (Shale settings)
- Granitic mountains and wetlands (Granite and Mafic settings)
- Serpentine outcrops (Ultramafic settings)
- Coarse sand barrens and dunes (Coarse-grained sediment settings)
- Silt floodplains and clayplain forests (Fine-grained sediment settings)
- Alpine meadows and krumholz (High elevation settings)
- Coastal dunes and marshes (Coastal settings)
- Steep cliff communities (Cliff landforms)

Characterization of the Geophysical Settings and Habitats

We created a spatially comprehensive regional database of bedrock geology classes at a resolution of 30 m by obtaining digital bedrock and surficial geology data layers from each of the 14 states (Figure 5.1) and compiling the individual state geological maps into a single integrated digital layer at the scale of 1:125,000. We grouped the 400+ bedrock types into nine lithogeochemical classes based on genesis, chemistry, weathering properties, and the textures of soils derived from the classes following Anderson and Ferree (2010) and relying heavily on the description and the US Geological Survey (USGS) crosswalk of state geologic maps to a national taxonomy (http://mrdata.usgs.gov/geology/state/). Our classification was irrespective of geologic age or degree of metamorphism. We used surficial data derived from the bedrock geology maps and grouped the sediments into two size classes: course sediment and fine sediment. In a few unmapped surficial areas we supplemented the data with SSURGO soils map units to fill in holes (Soil Survey Staff, 2014). Elevation zones were mapped from a DEM using zone boundaries from Anderson and Ferree (2010).

To characterize the biodiversity associated with each geophysical setting, we used information from a previously published overlay (Anderson and Weaver 2015) consisting of compiled information on the point location of natural communities and rare species tracked by the 14 State Natural Heritage programs intersected with information on the geology, elevation and landform maps that characterized each point. Keep in mind that while the relationships between species, communities and geophysical settings have likely remained the same, the numeric information on rare species counts are only an approximation of the true values because our data sources are a few years old and varied in effort, focus, and completeness.

Map 5.1. Geology of the Northeast. This map was assembled from state-based sources crosswalked into seven bedrock and two surficial classes particularly relevant to species and habitats.



We quantified the relationships between rare species and geophysical settings by defining a "**preferential species**" as one that occurred more often than expected on a particular setting (landform, elevation zone or geology class) than on any other setting. We defined this mathematically as a species-setting relationship with an Importance Value greater than one (IV >1) where:

*Importance Value (IV) = %AE * Number of Observations)*

Percent above expected (%AE) was defined as the percent of samples occurring on a given setting minus the percent of samples expected to occur on the setting from random chance (*%Observed - % Expected)*. The number of observations was the number of element occurrences of that species in the entire region. Using this method we calculated a %AE and IV for every species-setting relationship (Table 5.1 provides a worked example for Timber Rattlesnake).

Table 5.1. Example illustrating calculation of the %AE and IV for Timber Rattlesnake (*Crotalus horridus*). Based on the element overlay on the landform map, there were seven topographic settings where dens occurred (or were in error). Of those 29% occurred on steep slopes. As steep slopes are relatively rare (1% expected) they had the highest percent above expected (%AE = 0.28). The %AE for all other topographic settings were negative except for warm sideslopes (0.08) and summits (0.01). We had 738 independent observations, so our importance value was much greater than 1 (IV=206) and our confidence in the results is high. Timber rattlesnake was identified as a preferential to steep slopes.

Timber Rattlesnake (Crotalus horridus) Observations = 738							
	Steep Slopes	Sideslope	Cove	Summit	Dry flat	Wet flat	Water
Expected %	0.01	0.36	0.14	0.16	0.18	0.08	0.06
Observed %	0.29	0.44	0.07	0.17	0.02	0.01	0
O-E	0.28	0.08	-0.07	0.01	-0.16	-0.07	-0.06
MAX %AE	0.28 = Steep Slopes						
N =737	IV = 206						

Although the region's dominant species occur across many geophysical settings, we found that each setting supported a distinct set of preferential species. These were non-overlapping within a class but a species could be preferential to several classes. For example, Cow Knob Salamander was preferential to slope crests and sideslopes on sedimentary rock at high elevation which describes the upper reaches of the Central Appalachian Mountains where it occurs. This approach and species relationship tables were developed in Anderson and Weaver (2015).

The numbered of preferential species differed strikingly across geology classes. Coarse sand (295) and calcareous bedrock (255) had the most. Although they both supported all taxonomic groups, coarse sand was particularly high for plants, birds, and reptiles, while calcareous was high for invertebrates, fish, and mussels perhaps reflecting the importance of limestone in creating alkaline waters. Ultramafic, a very rare setting consisting mostly of serpentine bedrock, had the highest density of species supporting 11 preferential plants and 7 preferential invertebrates even though there is less than 500,000 acres of serpentine in the region.

Table 5.2 Count and Density of Preferential Species by Geophysical Setting. The table shows the number of G1-G4 species preferential to each geophysical setting measured by an Importance Value greater than one (IV > 1). Density is the count of species divided by the area of the setting in the Northeast.

Geology Class	Amphibians	Reptiles	Birds	Mammals	Fish	Mussels	Invertebrates	Plants	Total	Density / 100 K Ac.
Coarse Sand	4	5	14	4	6	4	84	174	295	2.29
Calcareous	1	2	5	3	16	25	109	94	255	1.81
Acidic Sedimentary	5	2	1	5	10	10	40	86	159	0.20
Mod. Calcareous	1	3	3	2	16	23	34	53	135	0.82
Granitic	5	1	4	1	6	4	42	49	112	0.37
Mafic		2	1		2	4	9	39	57	0.54
Acidic Shale					3	4	10	21	38	0.29
Ultramafic							7	11	18	3.68
FineSediment			1	1			1	7	10	0.10
Grand Total	**16**	**15**	**29**	**16**	**59**	**74**	**336**	**534**	**1079**	**Ave =1.12**

Below we briefly characterize each geophysical setting and give examples of the preferential species. The section is arranged in order of the total preferential species

Sand and other Coarse-grained Surficial Sediments (295 preferential species)

Deep, coarse, sandy soils characteristic of outwash plains, coastal shorelines, and large riverbeds. Deep sand accounts for nine percent of the landscape and underlie some of our most iconic natural communities like coastal beaches and dunes, sandplain grasslands, and pitch pine barrens. The setting occurs in highly fragmented human-dominated landscapes, where it is difficult to maintain natural fire regimes or allow for natural shore migration. Many well-known species are associated with these environments and rarities are abundant including several federally listed species (Table 5.3. Appendix 1). Species that thrive in sand often have adaptations for burial, salt spray, or fire.

Table 5.3 Examples of typical communities and species. Longer list in appendix 5.2

Sand and Coarse Sediment		
Communities	**Rare Species**	
Example	**Taxa Group**	**Example**
Coastal Oak-Hickory Forest	Amphibians	Pine Barrens Tree Frog
Pitch Pine-Scrub Oak Barrens	Birds	Piping Plover
Coastal Plain White Cedar Swamp	Mammals	Maritime Shrew
Beach and Dune communities	Reptiles	Loggerhead
Sandplain and Maritime grassland	Insects	NE beach tiger beetle
Coastal Pitch Pine barren	Mollusks	New England Siltsnail
Sea level Fen	Ferns	Northern Appressed Clubmoss
Maritime interdunal swale	Plants	Pine Barren Gentian

Calcareous Bedrock (255)

Limestone, dolomite, and marble are sedimentary rocks composed of calcite derived from the remains of marine organisms and deposited in a shallow water environment. Calcareous settings make up six percent of the region and degrade to slightly alkaline soils (pH 6-8) that support a host of plants and animals sensitive to low pH. Soluble in slightly acidic water, calcareous settings are riddled with caves, springs and alkaline fens, the latter supporting botanical jewels like pumpkin sedge (*Carex aurea*) or Kalm's lobelia (*Lobelia kalmii*). Soils derived from limestone are productive for agriculture, although in bedrock form it is relatively infertile. Calcareous barrens, glades, and alvars, dominated by trees like chinquapin oak and red cedar, are low in biomass but rich species diversity (Table 5.4).

Table 5.4 Examples of typical communities and species. Longer list in appendix 5.2

Calcareous Bedrock		
Communities	**Rare Species**	
Example	**Taxa Group**	**Example**
Cave	Fish	Popeye Shiner
Calcareous fen & seep	Mammal	Indiana Bat
Dry Calcareous Forest	Reptile	Bog Turtle
Calcareous cliff and summit	Arthropod	Greenbrier Valley Cave Millipede
Calcareous glade and prairie	Insect	Northern Metalmark
Alvar grassland	Mollusk	Spiny Riversnail
	Vascular Plant	Ram's Head Lady's Slipper
	Fern	Hart's-tongue Fern

Acidic Sedimentary Bedrock (159):

This is a catch-all group of similar granular rock formed by consolidation and compaction of weathered mineral grains and rock fragments. The group includes sandstone, mudstone, siltstone, conglomerate, breccia, and greywacke, and their metamorphic equivalents, from slate to granofels. Most are relatively erodible, but some, like quartzite, are highly resistant and underlie ridges and slopes. This widespread class makes up a full 40 percent of the region (Map 5.1) and supports most of the common communities. Although this setting has its unique habitats and plenty of rarities (Table 5.5), because it is so widespread its density of rare species is relatively low (0.20 species per 100,000 acres).

Table 5.5 Examples of typical communities and species. Longer list in appendix 5.2.

Acidic Sedimentary Bedrock		
Communities	**Rare Species**	
Examples	**Taxa Group**	**Example**
Most Northeast forest and wetland habitats	Amphibian	Cheat Mountain Salamander
Unique communities include:	Fish	Northern Redbelly Dace
Sandstone Pavement Barrens	Mammal	Allegheny Woodrat
Acidic cliff and talus	Reptile	Timber Rattlesnake
Riverwash Bedrock Prairie	Insect	Bog Copper
Acidic Cove Forest	Mussel	Longsolid
	Vascular Plant	Alpine Milkvetch
	Lichen	Appalachian Trail Lichen
	Fern	Mountain Spleenwort

<u>Moderately Calcareous Bedrock (135):</u>
Moderately calcareous bedrocks are substrates composed of sand or silt particles cemented by a calcareous matrix and having a neutral pH, for example, calcareous shales or sandstones. These settings share many of the attributes of calcareous limestone settings but are less extreme and more widespread, covering 11 percent of the region (Map 5.1). Caves, rich woods, underground streams and alkaline waters are all typical, but not the hard calcareous glades and pavements formed by limestone or dolomite. Rare species, especially plants, arthropods and mollusks are common (Table 5.2) and common trees, such as black locust, hackberry, redbud, and American elm are abundant in these settings (Table 5.6).

Table 5.6 Examples of typical communities and species. Longer list in appendix 5.2

Moderately Calcareous Bedrock		
Communities	**Rare Species**	
Examples	**Taxa Group**	**Example**
Yellow oak - redbud woodland	Amphibians	Hellbender
Significant karst area	Fish	Ohio Lamprey
Underground pond and stream	Mammals	Northern Myotis
Appalachian Terrestrial Riparian Cave	Reptiles	Blanding's Turtle
Freshwater Mussel Concentration Area	Arthropod	Cave Cobweb Spider
	Insects	Karner Blue
	Mollusks	Tennessee Clubshell
	Plants	Orono Sedge
	Ferns & Bryophytes	Blunt-lobed Grape Fern

Granitic Bedrock (112):

Granitic bedrocks include all forms of igneous or metamorphic rocks with interlocking grains dominated by siliceous minerals: granite, granodiorite, rhyolite, felsite, pegmatite, granitic gneiss, and others. Similar rock with a high proportion of iron and magnesium (mafic) minerals are described under mafic or ultra mafic rock. Granites weather to acid, nutrient poor, shallow soils and are not particularly rich in rare species, but because they are very resistant to weathering and underlay many of the region's mountain ranges and rocky coasts they support some of our most distinct species and habitats (Table 5.7). Poor soil and spectacular rugged scenery make granite settings a favorite for hiking and conservation.

Table. 5.7 Examples of typical communities and species. Longer list in appendix 5.2

Acidic Granitic		
Communities	**Rare Species**	
Examples	Taxa Group	Example
Granitic flatrock	Amphibians	Peaks of Otter Salamander
Jack or Red Pine woodland	Fish	Kanawha Minnow
Montane acidic cliff and summit	Mammals	Eastern Red Bat
Boreal Talus Woodland	Reptiles	Northern Red-bellied Cooter
Boreal heath barrens	Mollusk	Eastern Pearlshell
Low-elevation Bald	Insects	Ringed Bog Hunter
Lowland spruce flat	Vascular Plants	Northeastern Bladderwort
Red oak woodland	Bryophytes & Lichens	Narrowleaf Peatmoss
Alpine heath & tundra	Ferns	Acadian Quillwork

Mafic or Intermediate Bedrock (57):

Mafic bedrocks include forms of volcanic, plutonic or metamorphic rocks with a high proportion of dark colored minerals high in magnesium and iron (the term comes from contracting "magnesium and ferric"), often the result of rapid cooling, such as in the extrusive basalts. Rock types include: anorthosite, gabbro, diabase, basalt, diorite, andesite, and others, as well as their metamorphic equivalents: greenstone, and amphibolites. Mafic rocks weather to a richer soil that granites, but like granites they are resistant to weathering and underlay many of the region's ridges, mountains, and rocky coasts. Derived soils may be of neutral pH, hence the name "basic" in some natural community names, and they may share species with moderately calcareous soils (Table 5.8). In the extreme, mafic substrates may share flora with the ultramafic serpentines. Mafic soils only account for 5 percent of the region but underlay large sections of the Adirondack Mountains (Map 5.1).

Table 5.8. Typical communities and species of Mafic bedrock. Longer list in appendix 5.2

Mafic or Intermediate Granitic		
Communities	**Rare Species**	
Examples	Taxa Group	Example
Alpine Krummholz & Meadow	Reptiles	Five-lined Skink
Circumneutral Rocky Summit/Rock Outcrop	Mollusk	Intricate Fairy Shrimp
Mountain fir forest	Insects	Spine-crowned Clubtail
Basic Oak - Hickory Forest	Vascular Plants	Longleaf Bluet
Mountain / Piedmont Basic Woodland	Ferns	Ledge Spikemoss
High-elevation Outcrop Barren		
Low-elevation Basic Outcrop Barren		

<u>Acidic Shale Bedrock (38):</u>
Shale is a mud-based fine-grained fissile sedimentary rock that characteristically flakes into thin layers along bedding planes, creating unstable hill slopes. Shale underlies many common forest habitats, amounting to 11 percent of the region (Map 5.1). Although less permeable than sandstone, its ability to store natural gas has made shale the focus of the recent boom in hydrologic fracturing (fracking). Ecologically shale is best known for creating the unique shale barrens and cliff communities found in the Appalachians. Plant rarities, such as shale barren rockcress and shale barren evening primrose, are adapted to hot dry slopes and continually creeping bedrock. Although a few fish, reptiles and small mammals are found almost exclusively in shale settings it is not clear whether this is a coincidence or if there an ecological reason for their distribution patterns (Table 5.9). Shales held together by a calcareous matrix are not placed here but in the moderately calcareous class.

Table 5.9 Typical communities and species of shale bedrock. Longer list in appendix 5.2

Acidic Shale		
Communities	**Rare Species**	
Examples	Taxa Group	Example
Appalachian Shale Barren	Amphibians	Northern Cricket Frog
Shale Cliff And Talus Community	Fish	Roughhead shiner
Red-cedar - hardwood rich shale woodland	Arthropod	Northern Clearwater Crayfish
	Insects	Olympia Marble
	Mollusks	James Spinymussel
	Plants	Shale barren Pussytoes
	Ferns	Appalachian Woodsia

Ultramafic Bedrock (18):

Ultramafic bedrocks include igneous and meta-igneous rocks that are very high in magnesium and iron, and very low in silica and potassium: serpentine, soapstone, pyroxenite, dunite, peridotite, talc schist. These substrates weather to soils that are rich in magnesium, but poor in calcium, and they may have elevated levels of chromium or nickel. These extreme soils are toxic to many plants and a unique flora of tolerant species has evolved. Serpentine barrens tend to be open woodlands with stunted trees and a herb flora rich with endemics. Ultramafic settings cover less than 1 percent of the region (Map 5.1) and have the highest density of rare species of any geology (3.7 per 100,000 acres).

Table 5.10. Typical Communities and Species of Ultramafic Bedrock. Longer list in appendix 5.2

Ultramafic		
Communities	**Rare Species**	
Examples	Taxa Group	Example
Serpentine Barren	Insect	Falcate Orangetip
Serpentine Outcrop	Plant	Serpentine aster
Mafic Fen	Fern	Green Mountain maidenhair-fern

Fine-grained Mud and Silt Deep Surficial Sediment (10):

This is a deep sediment setting formed of fine-grained mud and silt. It can be found in clay-plains formed in old lake beds, silt floodplains created by river deposits, and organic mud underlying the tidal marshes. This environment favors species that tolerate poorly drained soils, and most of the characteristic communities are marshes, floodplains or swamps. Forests that form on river floodplains or on ancient clay-plains often have a diversity of trees species uncommon in the surrounding landscape. This setting covers 6 percent of the region and supports a few rare species (Table 5.11).

Table 5.11. Typical Communities and Species of Fine Silt and Clay. Longer list in Appendix 5.2.

Fine Silt and Clay		
Communities	**Rare Species**	
Examples	Taxa Group	Example
Deep Bulrush Marsh	Amphibians	Lesser Siren
Freshwater Tidal Swamp & Marsh	Fish	Slenderhead Darter
Lakeside Floodplain Forest	Reptiles	Canebrake Rattlesnake
Major-river Floodplain Forest	Insects	Two-striped Forceptail
Pond Pine Woodland / Pocosin	Mollusks	Pink Papershell
Valley Clayplain Forest	Plants	Elongated Lobelia

Elevation and Landform-based Communities

Elevation strongly influences species diversity patterns especially at the extremes. Nowhere is this more apparent than in the mountainous high elevation settings where wind, ice, and snow create alpine-like conditions. Supporting 103 preferential species high elevation and alpine environments have the highest density of rare species in the region (Table 5.12). At the other extreme, regular tidal movement at sea level creates its own distinct environment favoring species adapted to some level of salt spray or complete inundation. The thin coastal zone that flanks the region supports 177 preferential rare species as well as many common species like saltmarsh cordgrass (Spartina alterniflorus) that are adapted to this zone.

Table 5.12. The Number and Type of Preferential Species by elevation zone.

Elevation Zone	Amphibians	Reptiles	Birds	Mammals	Fish	Mussel	Invertebrate	Plant	Total	Density / 100 K ac.
Coastal 0-20	1	6	14	6	8	3	35	104	177	1.60
Very Low 20-800'	2	4	4	2	12	14	102	162	302	0.28
Low 800-1700'	1	4	4	3	28	40	71	105	256	0.49
Mid 1700-2500'	3		1	4	12	14	75	44	153	1.04
High 2500-3600'	3		1	2		4	27	35	72	2.01
Very High 3600'+	5		1				6	19	31	6.64
Grand Total	**15**	**14**	**25**	**17**	**60**	**75**	**316**	**469**	**991**	**Avg. = 2.01**

Altitudes above 3600 ft. cover less than one percent of the region, but these areas support a distinctive flora and fauna that share elements with alpine regions around the world. Habitats tracked by the heritage network include alpine meadows, bogs, tundra, snowbanks, and krummholz communities formed by stunted and wind-twisted trees. In the north, spruce and fir are characteristic of these habitats, but in the Central Appalachians gnarled red oaks are one of the dominant trees. Many rare species are associated with high elevation communities, the majority of them being plants or invertebrates (Table 5.13).

Table 5.13. Typical Communities and Species of Alpine and High Elevations. Longer list in Appendix 5.2.

Alpine and High Elevation		
Communities	**Rare Species**	
Examples	**Taxa Group**	**Example**
Alpine Krummholz/Mt fir forest	Amphibians	Cheat Mountain Salamander
Alpine tundra, wind-swept ridge	Bird	Bicknell's Thrush
Alpine bog, meadow, sliding fen	Mammals	Rock Shrew
Central Appalachian soft sedge fen	Insects	Mitchell's Saytr
High elevation red oak forest	Plants	Alpine Azalea
High-elevation boulderfield woodland	Ferns	Appalachian Firmoss
High-elevation Cove Forest		

The coastal zone between sea level and 20’ is one of the most distinctive and productive zones in the Northeast supporting tidal marshes. Mud flats, beaches, sand dunes, and a thin strip of distinctive maritime forest. This is a very dynamic portion of the region and sea level rise is already changing the profile of the zone. We report on the zone here as if it where static but see the climate resilience chapter for a discussion of sea level rise and marsh migration.

Table 5.14. Typical Communities and Species of the Coastal Zone. Longer list in Appendix 5.2.

Coastal Zone		
Communities	**Rare Species**	
Examples	Taxa Group	Example
Atlantic Coastal Plain Beach and Dune	Bird	Roseate Tern
Great Lakes Dune and Swale	Bird	Salt Marsh Sparrow
North Atlantic Coastal Plain Heathland and Grassland	Fish	Atlantic sturgeon
Tidal Salt Marsh	Reptiles	Loggerhead
Coastal Plain Tidal Swamp	Mollusk	Tidewater mucket
Estuarine Marsh	Insects	Rare skipper
Tidal Salt Flat	Vascular Plants	Seabeach knotweed
Coastal Plain Maritime Forest	Vascular Plants	Estuary Beggarticks
	Ferns	Curly Grass Fern

Topographic settings influence the distribution of species because local relief controls the distribution of solar radiation and moisture. The relationship between most landforms and species is less direct than for geology or extreme elevations as most species occur across several related landform types but still show a preference for a particular topographic position (Figure 5.2).

Two topographic settings that do determine species composition are wetlands and cliffs, as they create unique conditions that demand specific adaptations. Wetlands are by far the most widespread and species rich of the landform habitats covering 14% of the region and supporting over 1000 preferential species. They are discussed in their own chapter. Cliffs and steep slopes (3 percent of the region) offer a challenging setting for many species. Species partial to cliffs range from tenacious wiry herbs to falcons and ravens that use their isolated ledges for nesting (Table 5.15). Note: this dataset maps large cliffs and does not accurately reflect all small cliffs and outcrop in the region; for example, only 35 percent of peregrine falcon nests show up on the mapped cliffs, although almost all of the nests are on cliffs.

Figure 5.2. Preferences of Two Plant Species for Landform Types. The “0” line indicates no preference, positive numbers equal more than expected and negative equal less. Occurrences of Smooth cliff fern (*Woodsia glabella*) were preferential to cliffs (%AE =30) but are also found on warm south-facing steep slopes (24), slope crests (14) and coves (5). They are negative to all other topographic settings. Sandplain Gerardia (*Agalinis acuta*) was preferential to flats especially hilltop flats (21), dry flats (12) and moist flat (17) but were neutral to wet flats and negative to gentle slopes and sideslopes.

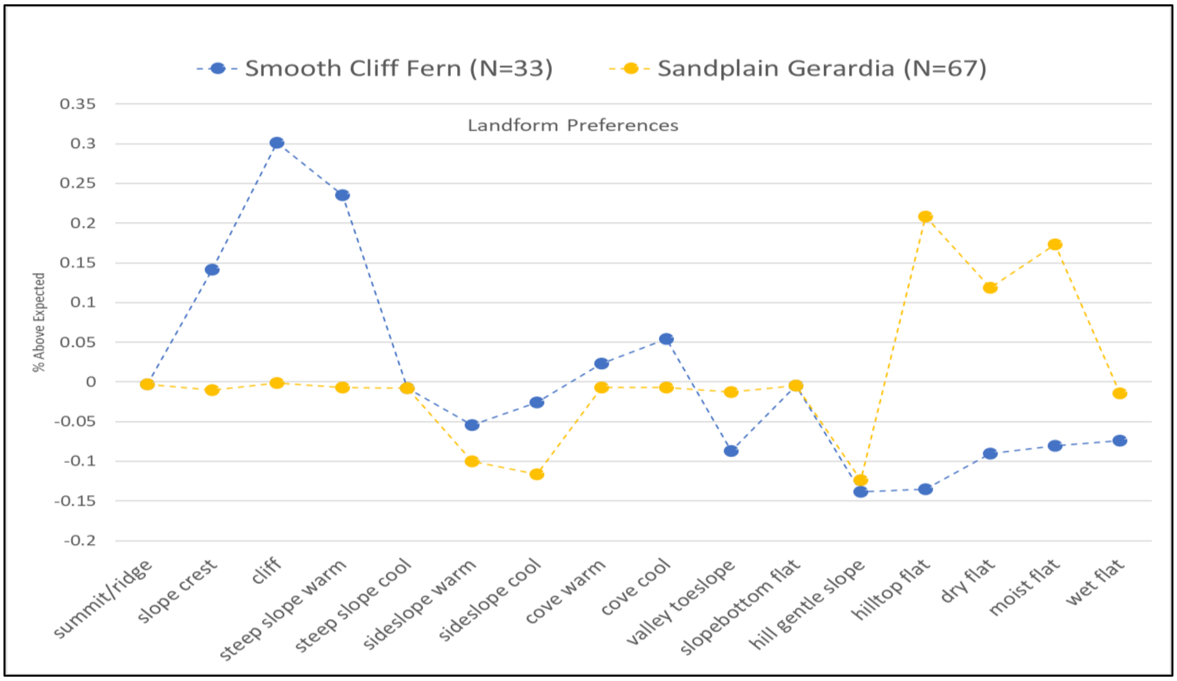


Table 5.15. Typical Communities and Species of Cliffs and Steep Slopes. Longer list in Appendix 5.2.

Cliff and Steep Slope		
Communities	**Rare Species**	
Examples	Taxa Group	Example
Acidic Cliff	Amphibians	Shenandoah Salamander
Acidic Talus Slope Woodland	Birds	Golden Eagle
Boreal Talus Woodland	Mammals	Rock Vole
Calcareous Cliff Community	Reptiles	Timper Rattlesnake
Sandstone cliff	Vascular Plants	Purple Clematis
High-elevation Boulderfield Forest / Woodland	Fern	Fragrant Cliff Fern
Northern White-Cedar Slope Forest		
Shale Cliff And Talus Community		

Distribution, Loss, and Protection by Geophysical Setting

To understand the relative level of habitat conversion in relation to land conservation within each geophysical setting, we overlaid the conservation lands data (The Nature Conservancy. 2022) and the NLCD landcover data (Dewitz and U.S. Geological Survey, 2021) on the geophysical maps and tabulated the amount of each by geology class, elevation zone, and landform. Below we summarize the results for each geophysical settings and compare the rate of conversion and conservation in the last 10 years to the average rate overall.

In this section we use the terminology presented in the conservation lands chapter:

Conserved = GAP 1-3. Land secured against conversion regardless of primary purpose
Conserved for Nature = GAP 1-2. The primary purpose is nature conservation
Conserved for Multiple Uses = GAP 3. The primary purpose is multiple use: recreation, harvest

Conservation Risk Index (CRI) = (Percent Converted)/ (Percent GAP 1,2&3)
Nature Risk Index (NRI) = (Percent Converted)/(Percent GAP 1&2)

Results of this analysis show that on average land conservation has not caught up with habitat conversion. For every one acre of habitat conserved, 1.8 acres of habitat has been converted, and for every acre conserved for nature, 4.4 acres have been converted to development or agriculture (Table 5.16).

Conservation and conversion, however, were distributed unevenly across the region's geophysical settings (Table 5.16 Figures 5.3-5.5). Granitic and mafic settings with their resistant bedrock and thin shallow-to-bedrock soils, show the reverse of the regional pattern with two acres conserved for every one converted. At the other extreme, calcareous settings show 8 acres converted for every 1 acre conserved, and 32 acres converted for every 1 acre conserved for nature (CRI 7.9, NRI 31.6). The high value of these productive soils makes calcareous settings the most converted (51%) and the least conserved (6%) of all settings. Acidic shale had the second highest risk with 4 acres lost to conversion for every 1 acre conserved, and 29 acres converted for every 1 acre conserved for nature. Coarse-grained sands were the second most converted (43%) but had higher levels of conservation (11%) equivalent to 4 acres converted for every 1 acre conserved. In all, six settings had conservation risk indices greater than 1 (range 1.4-7.9) indicating higher amounts of conversion than securement for all settings except granitic, mafic and acidic sedimentary (Table 5.16). All settings had nature risk indices greater than one (range 1.1-31.7) suggesting that we have not conserved enough quality habitat explicitly for breeding and population growth of wildlife and plants relative to the amount we have converted for our own needs and uses (Table 5.16).

Similar trends were apparent by elevation zone, with the three highest elevation zones (all over 1700') showing more habitat conserved than lost to conversion (Table 5.16, Figure 5.4). At very high elevations over 3600' conversion is virtually absent (1%) and almost 71% percent of the area is conserved, most of that for nature (NRI = 0.03). Alpine is, of course, a tiny proportion of the landscape. The zones where most of the population live (20-800') are the most converted (36%) and the least conserved (11%) with 3.3 acres converted for every 1 acre conserved. The coastal zone is also highly converted (34%) but has significantly more conservation (27%, CRI = 1.3)) reflecting a network of coastal protection like Cape May and Parker River National Wildlife Refuges and Cape Cod National Seashore. Unfortunately beaches and tidal marshes are now threatened by sea level rise (see the climate resilience chapter).

Table 5.16. The percent of habitat conversion compared to percent of land conservation. The ratios of conversion to conservation are given in various combinations where CRI is the ratio of conversion to conservation for nature or multiple uses (GAP 1-3) and NRI is the ratio of conversion to conservation explicitly for nature (GAP 1-2).

	Conversion versus Conservation: All Years (acres)									
	Habitat Loss to Conversion			Conservation			Unconserved		Risk Index	
Geology	Developed	Agriculture	%	GAP 1 & 2	GAP 3	%	Natural	%	CRI	NRI
Calcareous	3,535,018	1,549,565	51%	160,592	481,791	6%	4,332,952	43%	7.92	31.66
Acidic shale	4,230,657	1,924,656	33%	339,095	1,627,046	11%	10,263,284	56%	3.13	18.15
Fine sediments	1,858,596	1,423,144	37%	451,635	692,629	13%	4,511,784	50%	2.87	7.27
Coarse sediments	3,270,208	3,916,984	41%	1,032,333	1,728,864	16%	7,460,113	43%	2.60	6.96
Moderately Calcareous	*2,935,861*	*1,549,220*	*29%*	*349,564*	*1,564,137*	*12%*	*9,240,396*	59%	*2.34*	*12.83*
All Geology Classes	*23,301,667*	*17,766,124*	*26%*	*9,277,844*	*20,298,339*	*19%*	*84,646,567*	*55%*	*1.39*	*4.43*
Ultramafic	11,998	18,697	26%	9,175	13,056	19%	64,759	55%	1.38	3.35
Acidic sedimentary	5,301,104	4,734,588	18%	2,705,976	9,729,563	22%	33,457,820	60%	0.81	3.71
Mafic/Intermediate	530,101	775,206	18%	1,031,367	1,105,953	30%	3,763,586	52%	0.61	1.27
Acidic granitic	1,628,124	1,874,063	16%	3,198,108	3,355,302	30%	11,551,873	53%	0.53	1.10
	Habitat Loss to Conversion			Conservation			Unconserved		Risk Index	
Elevation	Developed	Agriculture	%	GAP 1 & 2	GAP 3	%	Natural	%	CRI	NRI
20-800'	11,980,216	11,628,008	36%	1,813,358	5,340,487	11%	33,933,019	52%	3.30	13.02
All Elevation Zones	*23,301,667*	*17,766,124*	*26%*	*9,277,844*	*20,298,339*	*19%*	*84,646,567*	*55%*	*1.39*	*4.43*
< 20'	523,508	978,526	34%	592,829	591,669	27%	1,760,945	40%	1.27	2.53
800-1700'	8,235,736	4,119,059	22%	2,461,045	7,639,036	18%	34,347,629	60%	1.22	5.02
1700-2500'	2,094,932	859,179	13%	2,789,245	5,200,967	36%	11,449,063	51%	0.37	1.06
2500-3600'	464,408	175,835	10%	1,349,304	1,296,728	42%	2,955,985	47%	0.24	0.47
> 3600'	2,867	5,517	1%	272,064	229,451	71%	199,926	28%	0.02	0.03
	Habitat Loss to Conversion			Conservation			Unconserved		Risk Index	
Slope Class	Developed	Agriculture	%	GAP 1 & 2	GAP 3	%	Natural	%	CRI	NRI
Upper Flats	4,650,893	3,895,314	47%	554,022	1,767,240	13%	7,261,374	40%	3.68	15.43
Lower Slopes	8,628,345	5,805,477	32%	1,853,859	5,407,177	16%	22,872,940	51%	1.99	7.79
Lower Flats	5,994,038	5,420,554	31%	2,292,300	4,374,005	18%	18,365,302	50%	1.71	4.98
All Slope classes	*23,301,667*	*17,766,124*	*26%*	*9,277,844*	*20,298,339*	*19%*	*84,646,567*	*55%*	*1.39*	*4.43*
Upper Slopes	3,998,269	2,579,339	13%	4,397,125	8,363,549	24%	33,027,928	63%	0.52	1.50
Water	30,122	65,440	3%	180,539	386,368	15%	3,119,023	82%	0.17	0.53

Figure 5.3. Geology Classes: Amount of conversion compared with the amount of securement. Each bar represents 100% of the historic area. Area to the left of the "0" axis indicates acreage converted, area to the right shows the remaining natural land by securement status (see also Figures 5.4-5.5).

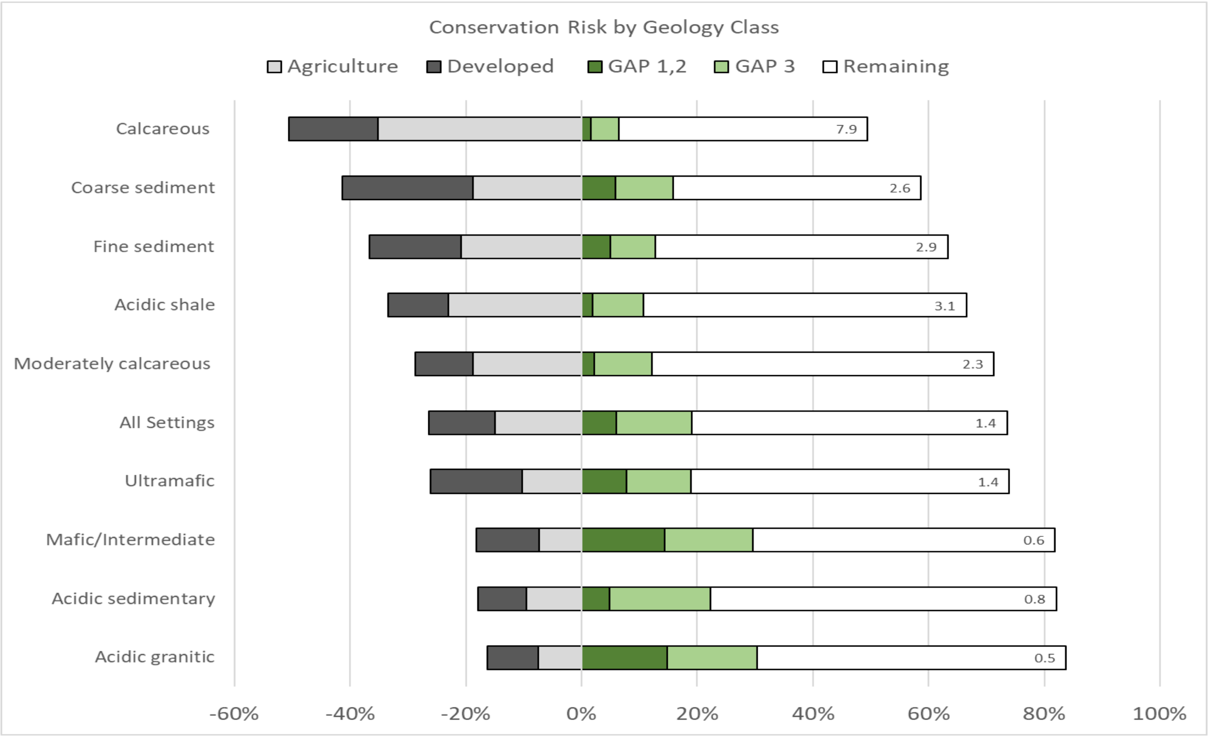
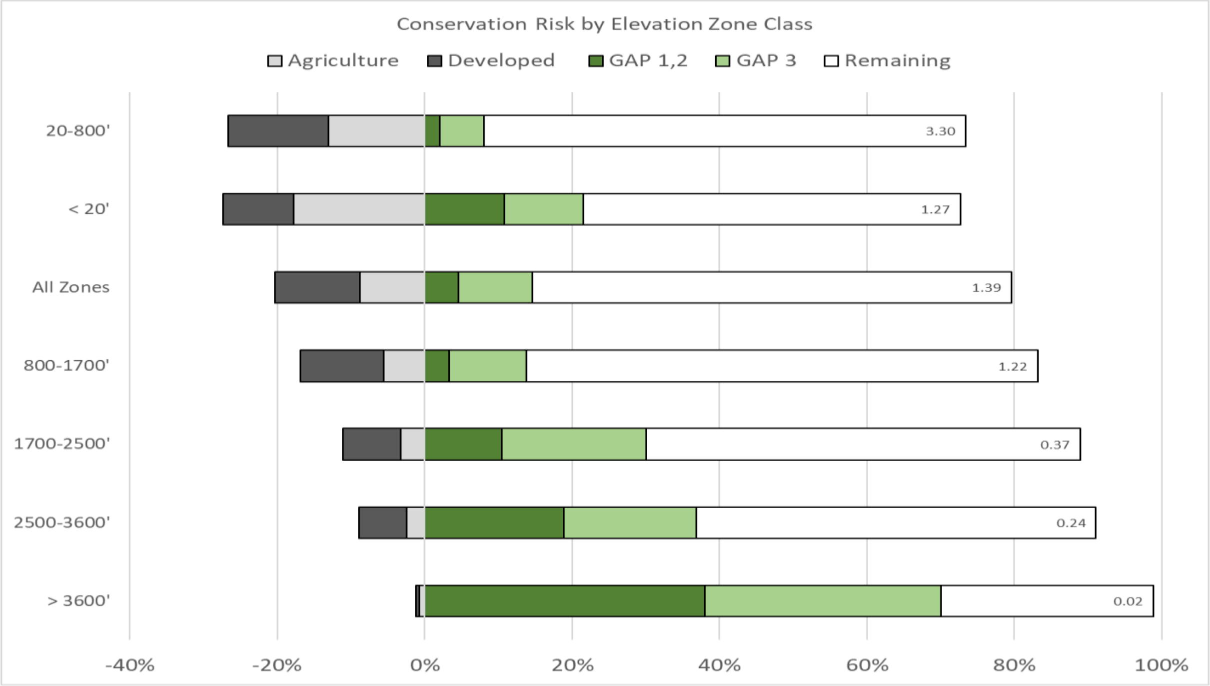
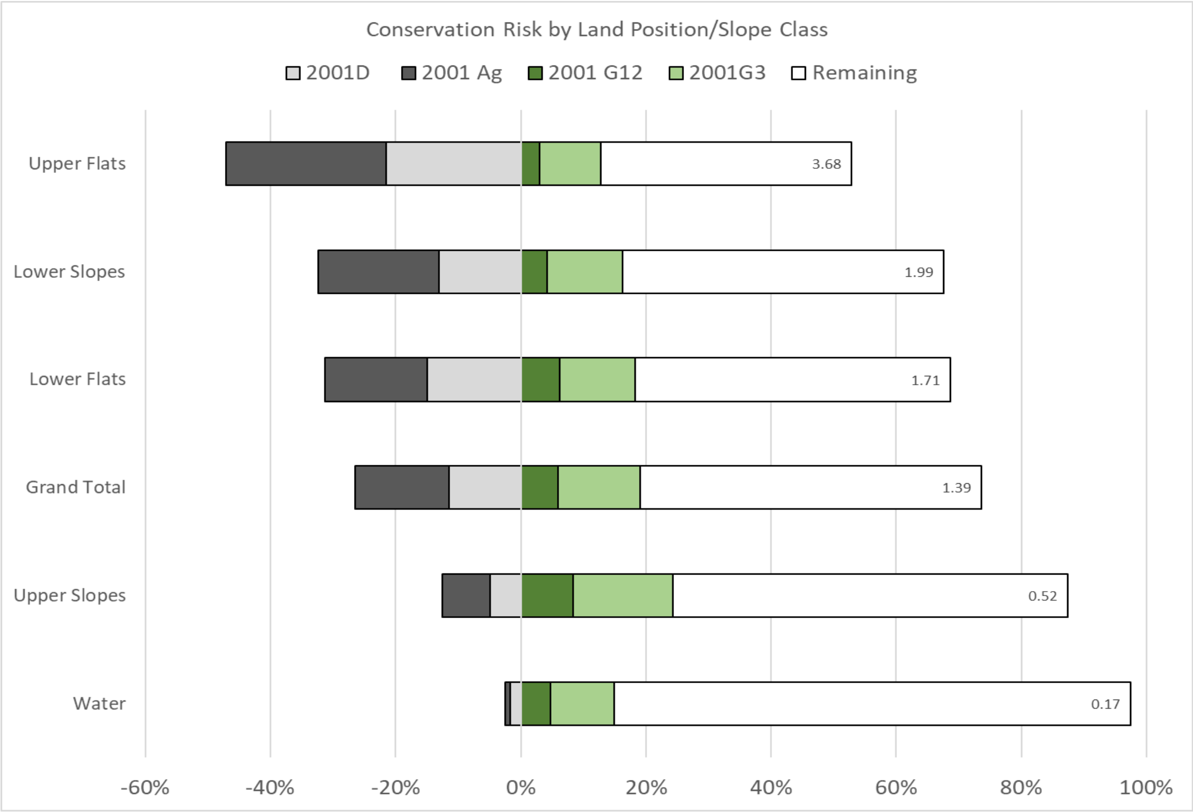


Figure 5.4. Elevation Zones: The amount of conversion compared with the amount of securement. Legend as for Figure 5.3 above. See also Figure 5.6



From a landform perspective, we have conversed slopes and converted flats (Table 5.16, Figure 5.5). Settings like upper flats (CRI 3.7), lower flats (CRI 1.7) and lower slopes (CRI 2) all have more conversion than conservation). In contrast, upper slopes (CRI 0.5) have more conservation than conversion to development or agriculture.

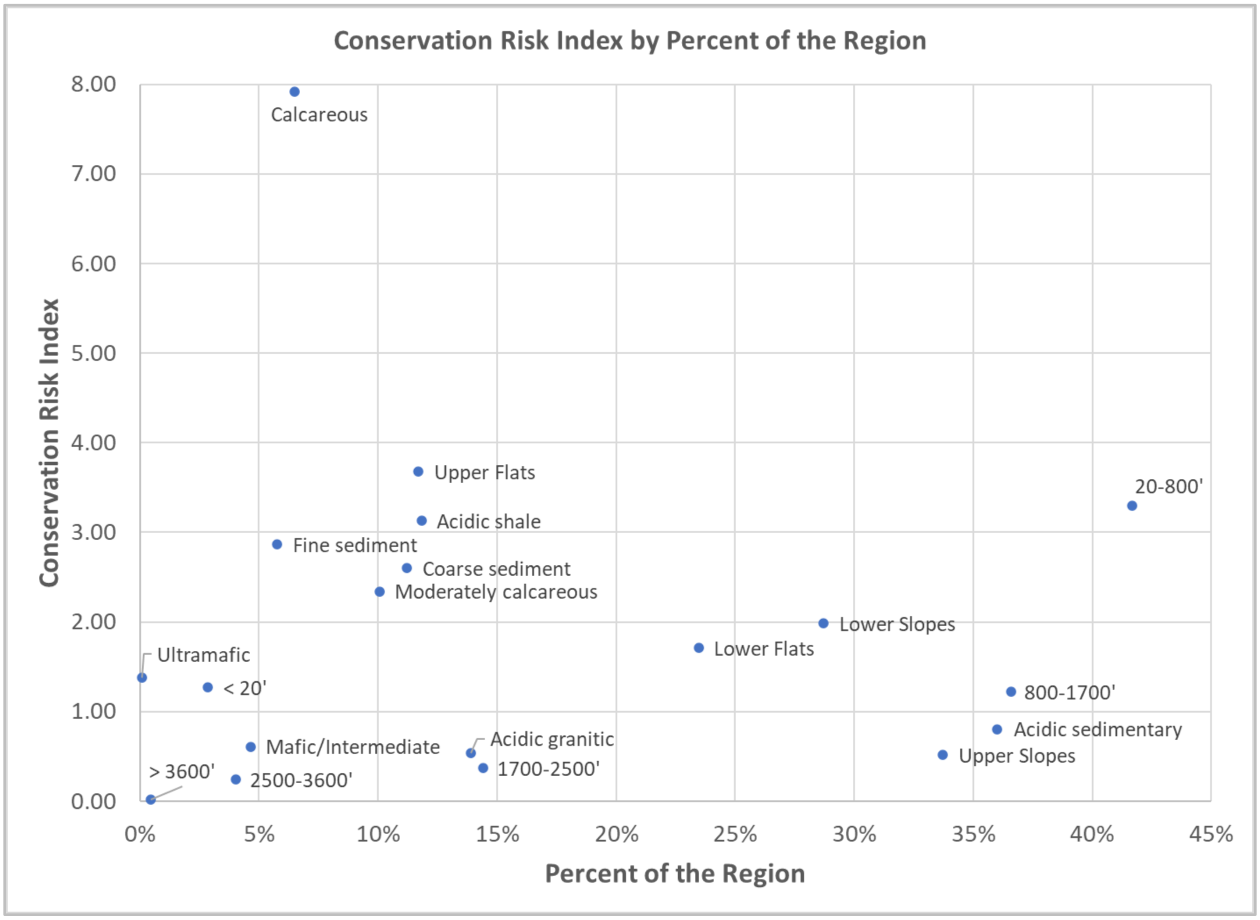
Figure 5.5. Landform Types: The amount of habitat conversion compared with the amount of habitat securement or protection. Legend as for figure 3 above. See also Figure 5.7.



We tested whether the ratio of conversion to conservation was simply a function of acreage, with small environments like alpine having more conservation, but we found that CRI was unrelated to the amount of each setting present in the region (Figure 5.6).

In summary, low elevation flat lands in calcareous, acidic shale, or coarse sand show a high conservation risk, and species associated with them are likely to face challenges. These settings had the highest amount of conversion to agriculture or development, and the least conservation. High elevation slopes in acidic granitic, mafic, or sedimentary soils were the opposite and are for the most part conserved. No setting except alpine, has enough area conserved explicitly for nature to offset the amount converted.

Figure 5.6. The conservation risk index of geological settings, elevation zones and landform types in relation to the percent of the region covered by that feature. Features below the 1.0 line have more securement than conversion, Features above the 1.0 line have more conversion than securement



Recent Trends in Habitat Conversion and Conservation (2011-2022)

For this section we focus on the 2012-2022 decade since the release of our first report (Anderson and Olivero 2011). We used the methods described above to understand the relative level of habitat conversion and land conservation securement within each geophysical setting, except that we restricted the conservation lands data (The Nature Conservancy. 2022) to conservation achieved since 2011 and used the NLCD landcover change data (Dewitz and U.S. Geological Survey, 2021) to identify changes in land cover or land use between 2011 – 2021. Below we summarize the results and compare the rate of conversion and conservation in the last 10 years to the average rate overall.

In contrast to the previous results for all years, this analysis shows that *on average for the last decade the amount of land conservation implemented has surpassed the amount of conversion to agriculture or development.* For every one acre of land conserved, 0.11 acres of habitat has been converted to development or agriculture, and for every one acre conserved for nature, 0.48 acres have been converted (Table 5.17).

Conservation and conversion were distributed relatively evenly across the region's geophysical settings with all setting showing Conservation Risk Indices less than one (CRI range 0.04-0.41, Table 5.17, Figure 5.7). This held true for the Nature Risk Index also with all setting except acidic shale and calcareous having NRI less than one (NRI range 0.06-0.79). Acid shale settings had the highest percentage of recent habitat loss to conversion (25%) and the lowest percent of new land conservation (60%) with 1.8 acres lost to conversion for every acre conserved for nature. Likely this reflects the boom in fracking that has resulted in thousands of new oil and gas wells situated in the Marcellus shale regions of Pennsylvania and Maryland before it was banned by the latter. Calcareous areas are still being converted faster than they are conserved for nature, but the rate is much slower (recent NRI 1.71 versus all years NRI 31.6)

Trends by elevation zone, were optimistic for wildlife and plants with CRI and NRI ratio less than one for evey elevation zone. Even the very low elevation zone with the most development (20-800') had more land conservation (78%) than conversion to development or agriculture (15%) an impressive trend.

Table 5.17. Recent trends in habitat conversion compared to percent of land conservation. The ratios of conversion to conservation are given in various combinations where CRI is the ratio of conversion to total conservation for nature or multiple uses (GAP 1-3) and NRI is the ratio of conversion to conservation explicitly for nature (GAP 1-2).

	Recent Trends: 2012-2022 (acres)									
	Habitat Loss to Conversion			Conservation			Habitat Gain	Total Change	Risk Index	
Geology	Developed	Agriculture	%CV	GAP 1 & 2	GAP 3	%CNMU	Ag to Natural	Acres Changed	CV/CNMU	CV/CN
Acidic shale	22,008	27,929	25%	26,390	95,302	62%	25,951	197,579	0.41	1.89
Fine sediments	13,964	10,379	18%	38,909	62,543	74%	11,070	136,865	0.24	0.63
Calcareous	5,962	14,194	17%	11,763	71,938	70%	15,714	119,571	0.24	1.71
Coarse sediments	29,501	13,875	15%	67,153	167,683	80%	14,068	292,280	0.18	0.65
Moderately Calcareous	15,173	17,019	13%	40,657	148,230	79%	18,228	239,306	0.17	0.79
All Classes	*166,415*	*146,144*	*10%*	*657,724*	*2,115,056*	*85%*	*158,732*	*3,244,071*	*0.11*	*0.48*
Mafic/Intermediate	8,554	6,057	7%	41,821	139,985	90%	5,572	201,988	0.08	0.35
Acidic granitic	17,765	19,817	7%	148,186	347,927	89%	21,360	555,055	0.08	0.25
Acidic sedimentary	53,269	36,811	6%	277,766	1,078,795	91%	46,690	1,493,331	0.07	0.32
Ultramafic	218	65	3%	5,078	2,655	96%	79	8,095	0.04	0.06
	Habitat Loss to Conversion			Conservation			Habitat Gain	Total Change	Risk Index	
Elevation	Developed	Agriculture	%CV	GAP 1 & 2	GAP 3	%CNMU	Ag to Natural	Acres Changed	CV/CNMU	CV/CN
Very Low ('20-800')	102,062	69,775	15%	252,898	630,779	78%	70,385	1,125,898	0.19	0.68
All Elevations	*166,415*	*146,144*	*10%*	*657,724*	*2,115,056*	*85%*	*158,732*	*3,244,071*	*0.11*	*0.48*
Low (800-1700')	45,416	55,049	8%	198,947	836,683	87%	58,158	1,194,253	0.10	0.50
Coastal (< 20')	5,424	1,296	8%	27,298	47,921	90%	1,545	83,484	0.09	0.25
Mid (1700-2500')	10,584	15,487	4%	108,669	457,758	92%	22,268	614,765	0.05	0.24
High (2500-3600')	2,831	4,385	4%	66,101	120,499	93%	6,179	199,995	0.04	0.11
Alpine (> 3600')	98	154	1%	3,811	21,415	98%	197	25,676	0.01	0.07
	Habitat Loss to Conversion			Conservation			Habitat Gain	Total Change	Risk Index	
Slope Class	Developed	Agriculture	%CV	GAP 1 & 2	GAP 3	%CNMU	Ag to Natural	Acres Changed	CV/CNMU	CV/CN
Upper Flats	29,328	23,094	16%	52,040	205,912	78%	19,776	330,150	0.20	1.01
Lower Slopes	54,705	55,060	12%	161,936	577,787	82%	52,435	901,923	0.15	0.68
Lower Flats	40,059	33,152	10%	167,669	462,049	85%	38,567	741,495	0.12	0.44
All Landforms	*166,415*	*146,144*	*10%*	*657,724*	*2,115,056*	*85%*	*158,732*	*3,244,071*	*0.11*	*0.48*
Upper Slopes	41,621	34,427	6%	269,206	822,573	90%	47,314	1,215,141	0.07	0.28
Water	702	411	2%	6,873	46,735	97%	640	55,361	0.02	0.16

Figure 5.7. Geology Classes: Conversion versus Conservation 2012-2022.

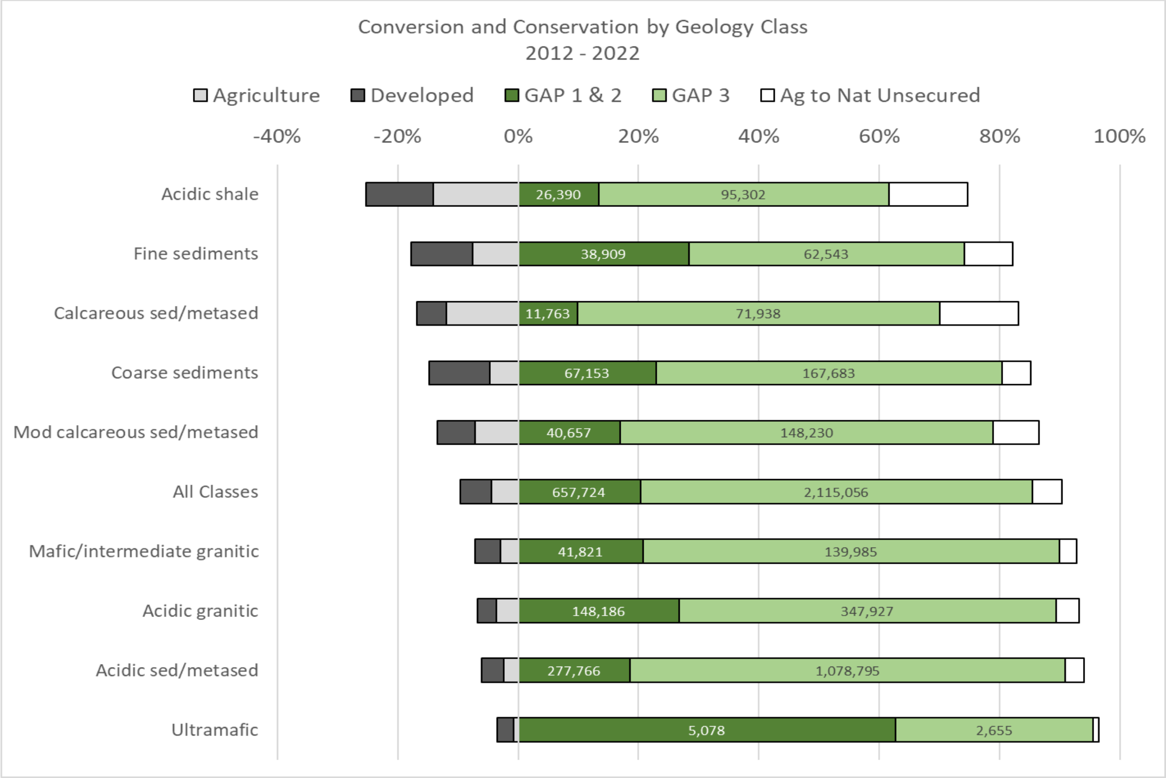


Figure 5.8. Elevation Zones: Conversion versus Conservation 2012-2022.

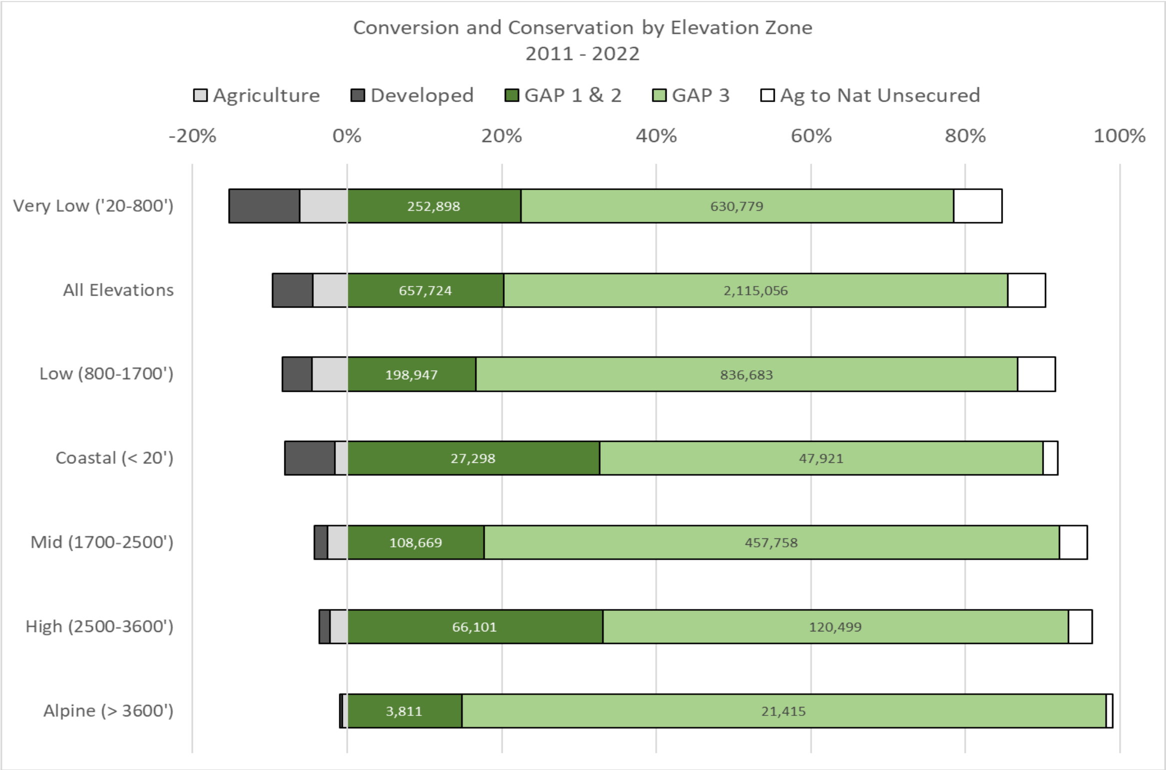
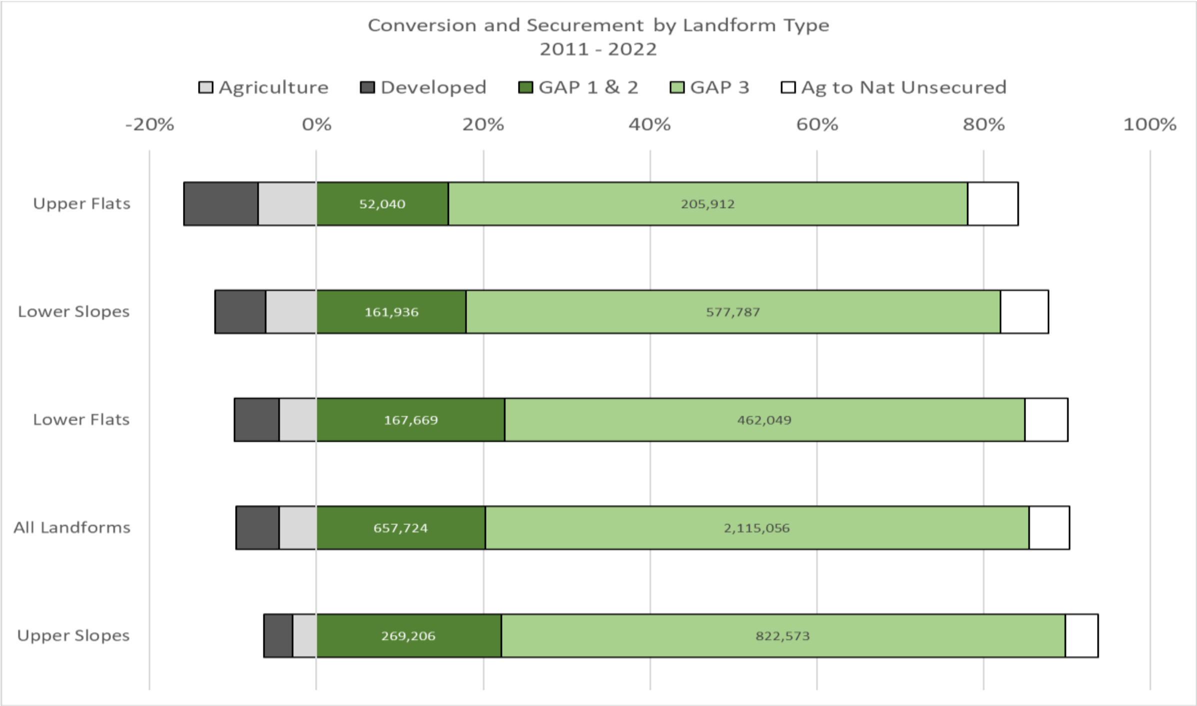


Figure 5.9. Slope Class: Conversion versus Conservation 2012-2022.



Slope patterns largely tracked the patterns seen in other setting with CRI and NRI all less than one, with the exception of the upper flats (equating generally to dry flat settings) where the conversion and conservation for nature were equal (NRI = 1.01, Figure 5.9)

In summary, the last decades has seen great progress in conservation. The combination of land conservation for nature and/or for multiple uses has surpassed habitat conversion across every geology type, elevation zone and slope class. Conservation explictly for nature shows the same trend with two exceptions: Shale has shown the most conversion and habitat conversion still surpassses land conservation about tow to one. Calcareous settings also show a roughly two-to-one ratio if habitat conversion to land conservation but this is a large drop from the 32 to 1 ration seen over the last century.

Fragmentation and Connectivity of Geophysical Settings

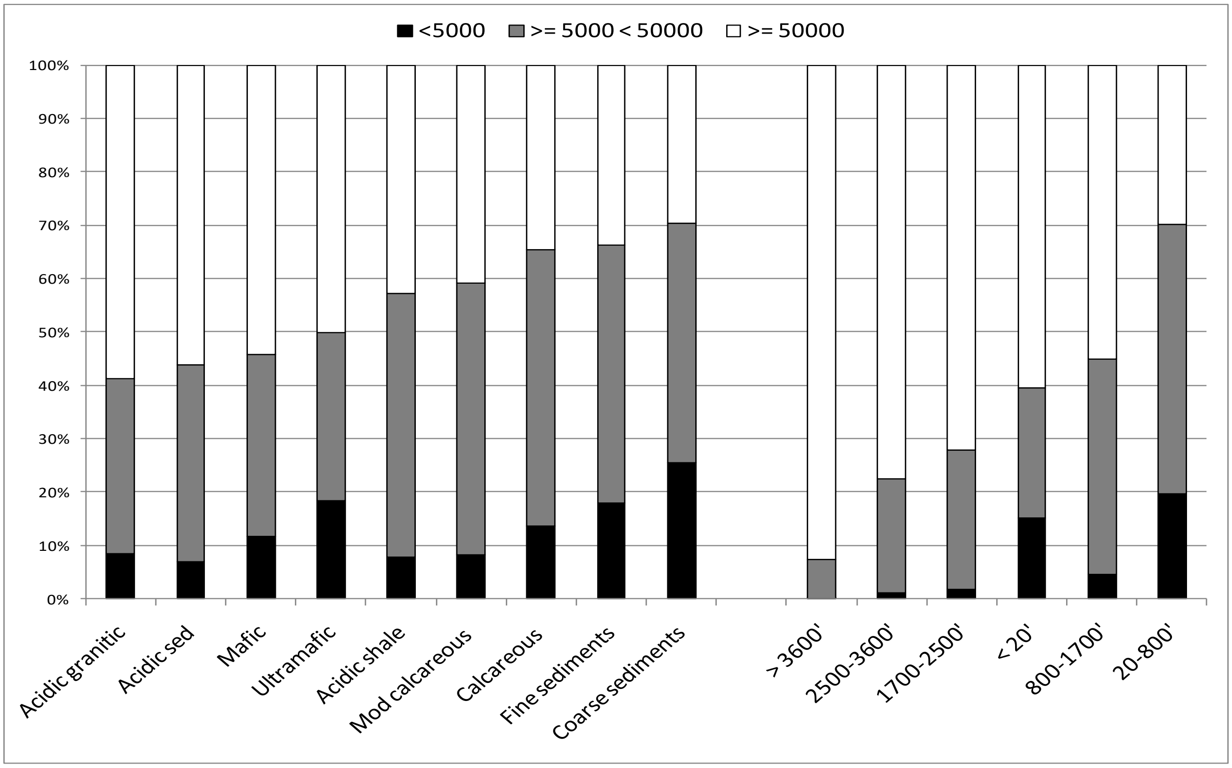
The region now supports 75 million people, 4 million more than in 2011. The infrastructure to support the human population include buildings and development, energy infrastructure, agricultural farmlands, mining and waste disposal areas, and at least 732,000 miles of permanent roads, pipelines, and transmission lines. In this section we examine the spatial distribution of these fragmenting features in relationship to the underlying geophysical settings to assess the degree of fragmentation present in each setting and how much it has changed over the last decade. We used two types of analysis to measure fragmentation. The first, a road bounded block analysis, was not repeated in 2022 as the major road network did not change enough for us to report on. We include the 2011 analysis as it provides a useful characterization of the region. The second, the local connectedness analysis, is very sensitive to changes in multiple fragmenting features including minor roads and building footprints. For this analysis, we were able to create and new resistance grid, run the analysis again and assess change over that last decade.

Fragmentation occurs when a contiguous area of natural land is subdivided into smaller patches, resulting in each patch having more edge habitat and less interior. Because edge habitat contrasts strongly with interior the surrounding edge habitat tends to isolate the interior region and contribute to its degradation. Thus, fragmentation can lead to an overall deterioration of ecological quality and a shift in associated species from interior specialists to edge generalists.

<u>Block Analysis</u> (from 2011) The regions 732 thousand permanent roads are the primary fragmenting features providing access into interior regions, and decreasing the amount of sheltered secluded habitat preferred by many species. Heavily-used paved roads create noisy disturbances that many species avoid, and the roads themselves may be barriers to the movement of small mammals, reptiles, amphibians and ground insects. To evaluate the extent and impact of roads, we examined the patterns created when major roads connect to encircle contiguous blocks of land. We defined a block as a distinct area of land surrounded on all sides by major roads (e.g. wide paved roads with significant traffic volume). The area of each block was calculated, the block was assigned to a size class, and the amount of each geophysical setting within each block was summarized to determine the size class distribution for blocks of each setting type (Map 5.3, Figure 5.4, Table 5.2). Our assumption was that the highest quality habitat is found in the central core of each block - the region greater than 100 meters from any major road, field or developed area – and that the effect of the fragmenting feature decreases with the size of the blocks.

Results of the overlay reveal progressively decreasing large blocks of natural land as the settings go from acidic bedrock to calcareous bedrock and then to surficial deposits. The same pattern can be seen from high elevation to low elevations (Figure 5.10). Only 30 percent of the coarse-grained sediment areas, and elevations between 20 and 800 feet were found in blocks over 50,000 acres compared to almost 60 percent for granitic settings, and 92 percent for alpine settings.

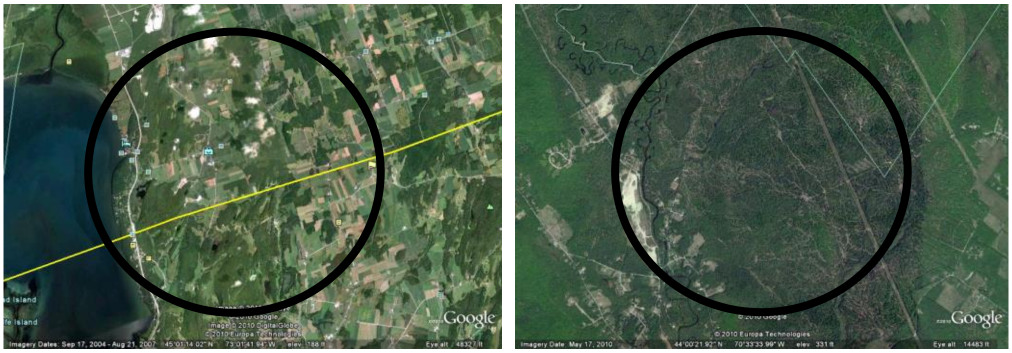
Figure 5.10: Percent of land acres within block size classes arranged by setting in order of decreasing large blocks (from 2011 report). The largest blocks (>50,000 acres) are shown in white



Connectivity. The opposite of fragmentation is connectivity, a measure of how easy it is for species and processes to freely move across the landscape. The metric we used to measure connectivity –local connectedness - was related to the forest block analysis of the previous section but goes beyond major roads to account for local roads, the relative density of all nearby roads, building footprints, land cover, oil and gas wells, solar farms and other land uses. The metric treats the landscape as having a gradient of permeability such that highly contrasting land cover types or dense areas of fragmenting features have reduced permeability between them, and highly similar or unfragmented ones have enhanced permeability. In applying the metric, we differentiated between developed lands, agricultural lands and natural cover, lumping together all types of natural cover including a variety of forest and wetland types.

This assessment of local connectivity was developed by Brad Compton at University of Massachusetts, based on a 30m NLCD (2001, 2011, 2021) land cover maps supplemented with major and minor road information from ESRI 2008 that as synthesized into a wall-to-wall resistance grid. For every 90 m grid cell in the region, a 3 km area around the cell was evaluated and the amount of resistance /permeability was calculated to create a wall-to-wall grid with cell values ranging from 0 to 100; “0” indicating complete impermeability (e.g. developed) and “100” indicating complete permeability (e.g. natural cover with no barriers, Figure 5.11). See Anderson et al 2012 for detail on the methods.

Figure 5.11: Aerial Photo Image of areas with different connectedness scores. The image on the left has a mean score of “10” for the area under the circle, close to the mean score of 14 for limestone settings. The image on the right has a mean score of “43” for the area under the circle, similar to the mean score of 42 for granitic settings. A pristine area with no roads, power-lines, development or farms would score “100.”

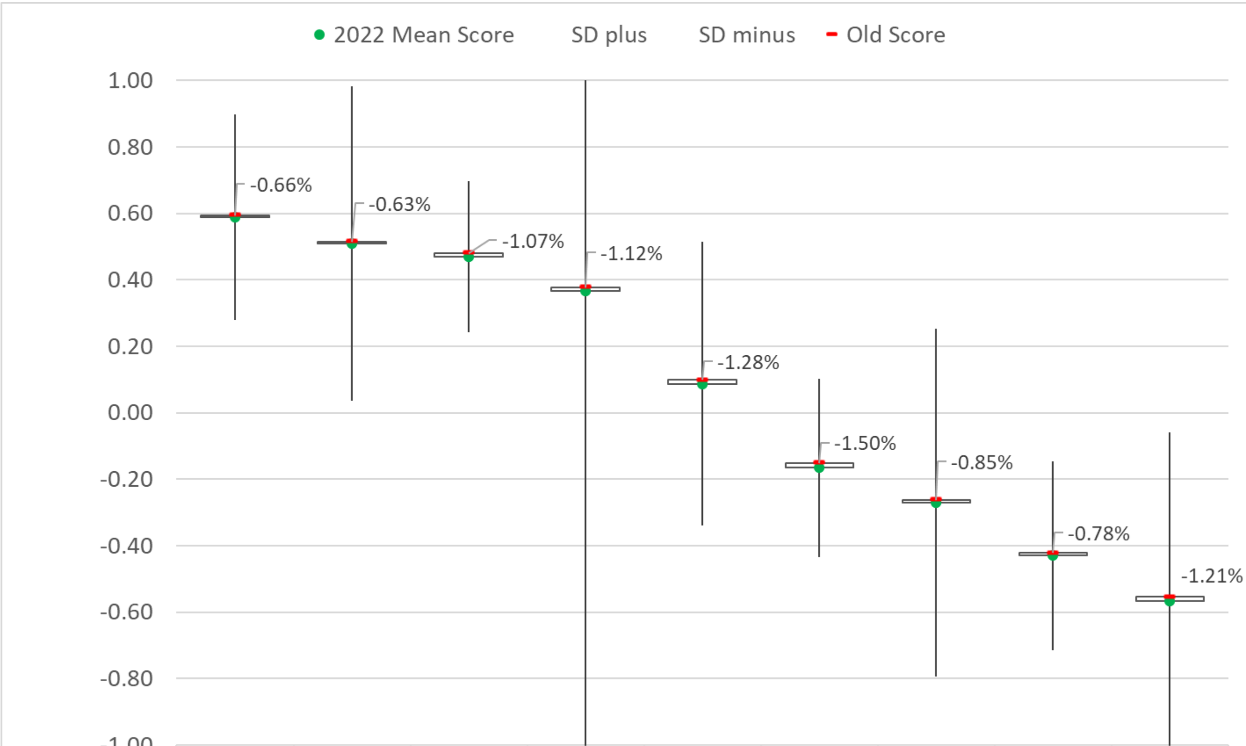


In 2022 we revised the resistance grid and reran the analysis using the following steps. We reclassified the 2011 and 2019 NLCD with the region-specific resistances. We identified all areas of change in resistance from the 2011 NLCD to the 2019 NLCD, then reran the neighborhood stats, kernel stats to calculate Local Connectedness for the areas within 3km of the changed cells. Compared the results from the 2011 and 2019 neighborhood stats. For the calculation of amount of change, we took the raw amount of change and divided by the standard deviation of the 2011 focal stats grid to put the scores into a standard normal distribution (Z-scores).

We added or subtracted the amount of change to the Local Connectedness grid, but because the methods were slightly different between the 2011 and 2019 NLCD dataset and we didn’t want to incorporate this data “noise” in the results. To account for this we only changed the scores when they were a change of at least 100 points in either direction on the 0.0 to 3.5 SD scale. Finally, we added areas of High Density Developed to the Developed Category on the Local Connectedness map.

Results of the analysis revealed that the region’s different geologic settings differ markedly in their degree of local connectedness. Calcareous areas have the lowest scores, averaging 14, suggesting that they have lost about 84 percent of their natural connectedness (Figure 5.12). Both surficial settings, coarse-grained and fine-grained, have scores averaging less than 20. Even the high scoring regions of granite and mafic materials, average only in the 40s, this highlights how pervasive fragmentation is across the region, although scores in the 40s can be fairly intact (Figure 5.12). Visually, areas with this score appear to have fairly contiguous cover, broken only by small patches of field, power-lines or minor roads (Figure 5.11).

Figure 5.12. Average connectedness scores for the nine geology types. Error bars show the one standard deviation above and below the mean. The new score is shown as a green dot and the old score as a red line. Labels show the change in the mean score over the last 10 years which corresponds to the width of the horizontal box.

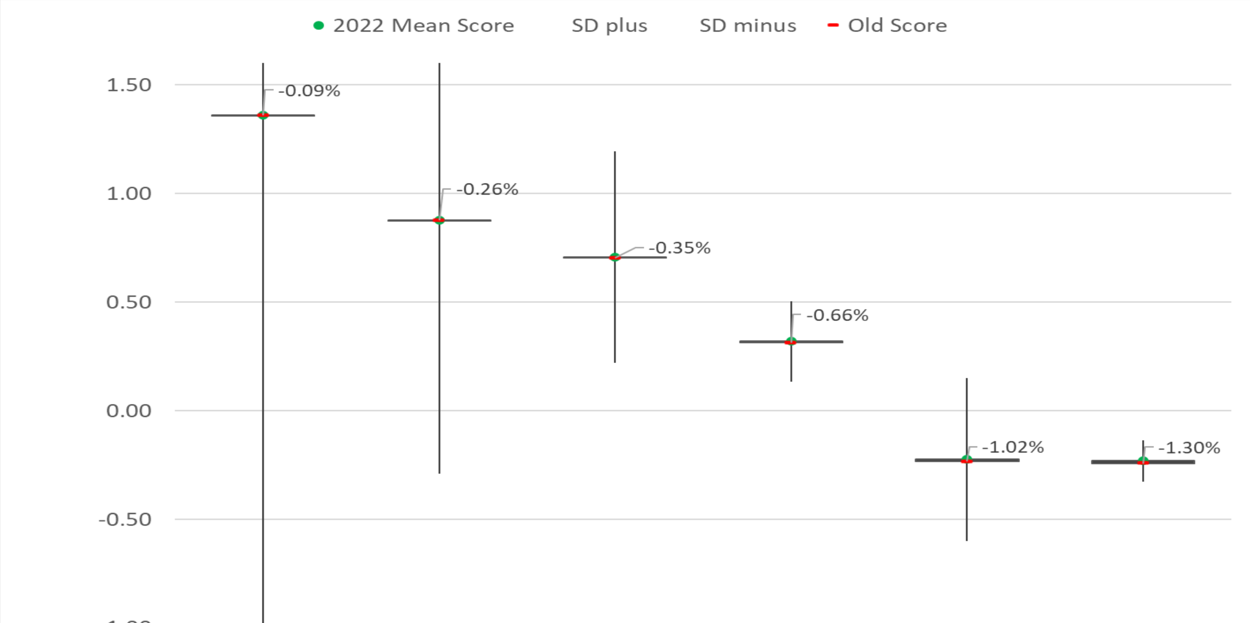


	Acidic granitic	Mafic/ Intermediate	Acidic Sedimentary	Ultramafic	Moderately Calcareous	Acidic shale	Fine sediments	Coarse sediments	Calcareous
2022 Mean Score	0.59	0.51	0.47	0.37	0.09	-0.17	-0.27	-0.43	-0.57
SD plus	0.90	0.98	0.70	4.96	0.51	0.10	0.25	-0.15	-0.06
SD minus	0.28	0.04	0.24	-4.23	-0.34	-0.43	-0.79	-0.71	-1.07
Old Score	0.60	0.52	0.48	0.38	0.10	-0.15	-0.26	-0.42	-0.55

Results of the analysis revealed that the region's different geologic settings differ markedly in their degree of local connectedness (Figure 5.12). Four settings had scores well below the average (0) for the region: calcareous (-0.5 SD), coarse sand (-0.43 SD), fine silts and clay (-0.27 SD) and acidic shale (-0.17 SD). The most connected settings were again those on granite (0.59 SD) or mafic (0.51 SD) bedrocks. The scores of all settings decreased over the last decade but the decrease was small, ranging from 0.66% in granite to a high of 1.5% in shale. Both calcareous and moderately calcareous settings showed a decrease of over 1%. These results reinforce the finding that shale and calcareous settings continue to fragment due to fracking or conversion.

Trend in elevation zone were more pronounced (Figure 5.13). Local connectedness was lower in the two lowest elevation zones which were below the mean score for the region. These two zones had the highest decrease in connectivity over the last decade: 20-80 feet (1.3%) and 0-20 feet (1.02%).

Figure 5.13. **Average connectedness scores for the elevation zone.** Error bars show the one standard deviation above and below the mean. The new score is shown as a green dot and the old score as a red line. Labels show the change in the mean score over the last 10 years which corresponds to the width of the horizontal box.

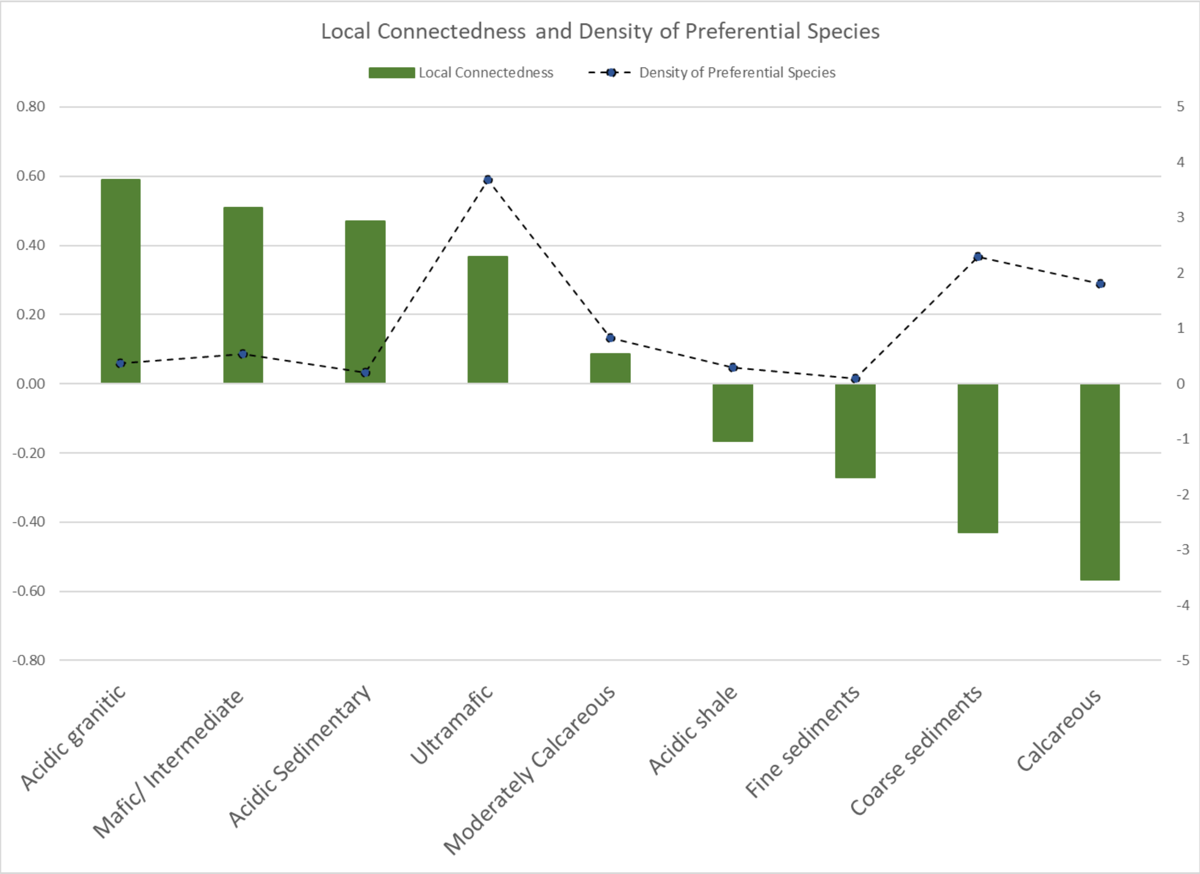


	> 3600'	2500-3600'	1700-2500'	800-1700'	< 20'	20-800'
2022 Mean Score	1.36	0.88	0.71	0.32	-0.22	-0.23
SD plus	6.17	2.05	1.19	0.50	0.15	-0.13
SD minus	-3.45	-0.29	0.22	0.13	-0.60	-0.32
Old Score	1.36	0.88	0.70	0.31	-0.23	-0.24

Synthesis of Species Data with Habitat Condition

Lastly, we examined how the density of restricted species described in the initial sections of this chapter, related to the conversion, fragmentation and connectivity scores. We found that with the exception of the extremely rare ultramafic settings, the more fragmented and least connected environments were the ones with the higher densities of restricted species (Figure 5.14). Coarse-grained sediment, calcareous bedrock and fine-grained sediment emerged as the three habitats of the highest concern, paralleling the results of the conversion to securement ratios.

Figure 5.14. Relationship between the average local connectedness score (left axis) and the density of preferential species (right axis). The two setting with the lowest connectedness score also had the second and third highest density of preferential species.



Individual Habitats

In this section we look at the conservation and conversion status of individual habitats. Forests and wetland habitats are covered in their own chapters, so here the focus is on non-forested communities like barrens, cliffs, dunes, and grasslands. We will also provide comprehensive detail on all the terrestrial habitats mapped in the Northeast Terrestrial Habitat Map (NETHM Ferree and Anderson 2013) which was completed in 2014 and not available for the 2011 report.

The terrestrial and wetland habitats defined and described in the NETHM follow the Northeast Terrestrial Wildlife Habitat Classification (Gawler et al. 2008) with modifications as necessary to enable consistent mapping in the Northeast. The NETHM is a comprehensive and standardized representation of natural habitats across fourteen states and four Canadian provinces (Map 5.3 and Figure 5.15. U.S. portion only). The habitats are equivalent in scale and concept to the NatureServe ecological system (Comer 2003), which was developed to provide a common base for characterizing vegetation habitats across states. The map was developed to promote an understanding of terrestrial and aquatic biodiversity patterns across the region, and not intended to replace state classifications, which often have more detail and nuance.

NatureServe's ecological system classification presents units that are readily identifiable by conservation and resource managers in the field (Comer 2010). Although based on dominant vegetation, they are defined as recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding. Each ecological system type is named based on biogeographic region, dominant cover type, and ecological setting such as an elevation zone, moisture regime, or disturbance process (e.g., Acadian Low-Elevation Spruce-Fir-Hardwood Forest). The classification includes all upland, wetland, and estuarine habitats, but does not include aquatic freshwater or marine habitats.

Many resources are available for those interested in exploring the Northeast Terrestrial Habitat Map:

Web Viewer https://maps.tnc.org/nehabitatmap/

Habitat Guides: Descriptions, distribution, synonyms, and ecological information about each habitat
http://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/hg/Pages/default.aspx

Methods Document: Full description of how the map was created (Ferree and Anderson 2013).
https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/Documents/HabitatMap_Methods.pdf

Data Download: GIS dataset
https://tnc.app.box.com/s/ujvjfelrfk0nqgslgli89lkgp7zxbwdy

Web Page on The Nature Conservancy's Conservation Gateway
https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/terrestrial/habitatmap/Pages/default.aspx

Map 5.2. The Northeast Terrestrial Habitat Map This dataset (Ferree and Anderson 2014) maps the distribution of 140 types of forests, wetlands, unique communities, and tidal systems across the Northeast. To explore the map and view the legend, go to **http://nature.ly/NEhabitat**

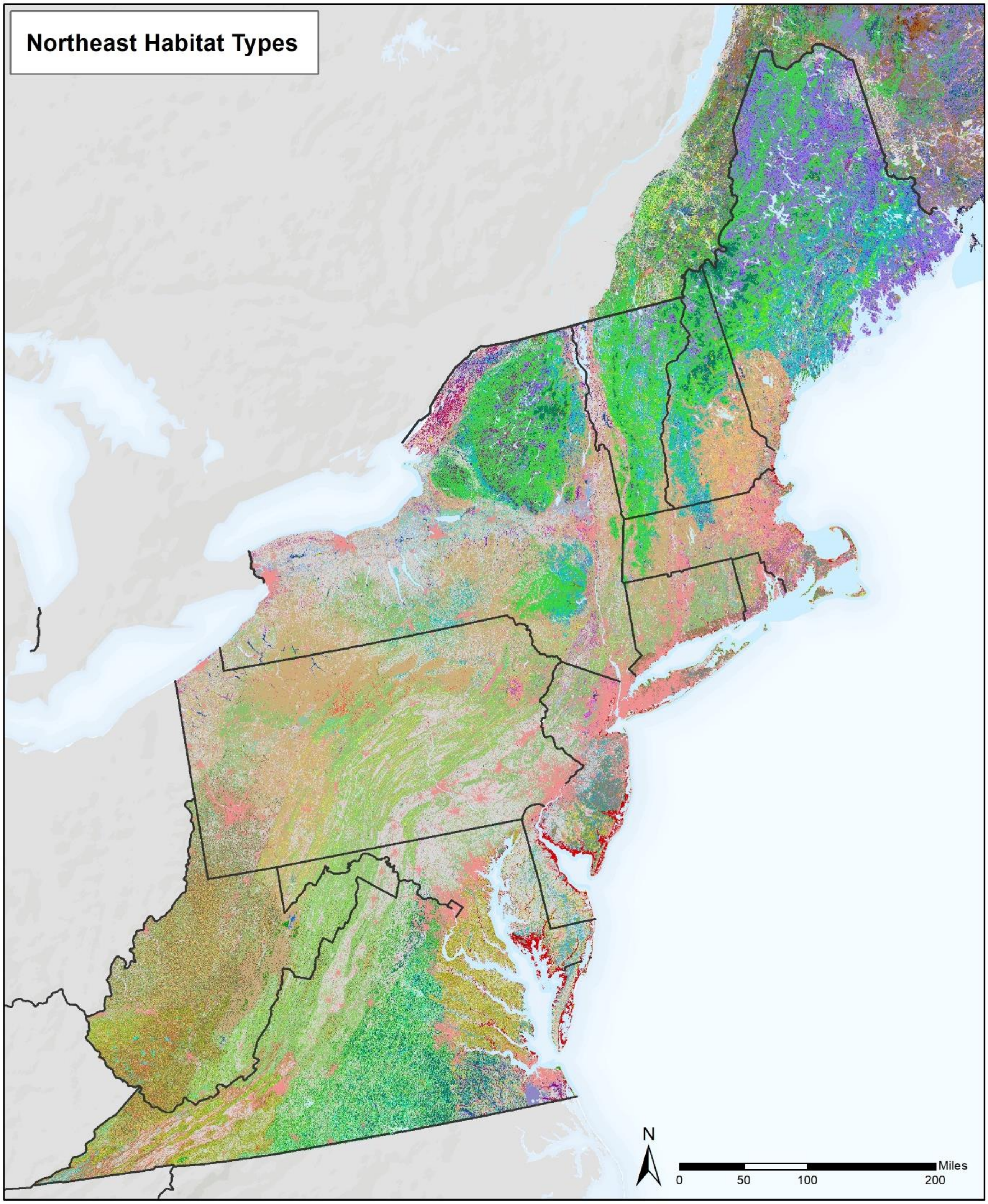


Figure 5.15. Legend for the Northeast Terrestrial Habitat Map

The mapping process was intensely data-driven, relying on comprehensive datasets of ecological variables (geology, landforms, precipitation, etc.) and more than 70,000 ecological community samples contributed by the State Natural Heritage Programs . Whenever possible, we used field-collected data combined with national datasets. Very briefly, the basic mapping steps were as follows:

- Compile foundation datasets for the entire region (landforms, geology, climate, land cover, etc.).
- Develop a list of ecological systems, and meet with appropriate state, federal, and NGO staff to understand the distribution, scale, and landscape pattern of ecological systems.
- Compile plot samples for ecological systems using State Natural Heritage data, forest inventory and analysis points, and other sources. Tag each sample with the appropriate ecological system.
- Develop models for the dominant matrix-forming forest types using regression tree analysis of tagged plot samples on the data sets of ecological information.
- Map the dominant forest types onto the landscape using landform-based units.
- Develop models for the wetland systems (swamps, marshes, bogs, etc.) and the patch-forming upland systems (barrens, glades, summits, cliffs, etc.).
- Assemble models into one region-wide map and develop legend.
-

<u>Habitat Types and Lexicon</u>
Natural habitats mapped within the NETHM can be grouped and sorted various ways, and default grouping schemes (Class, Formation, Macrogroup) are built into the dataset. The Northeast Lexicon project has also provided suggested classification schemes amendable to developing Wildlife Action Plans or evaluating conservation Success. We have crosswalked these to the three major groups.

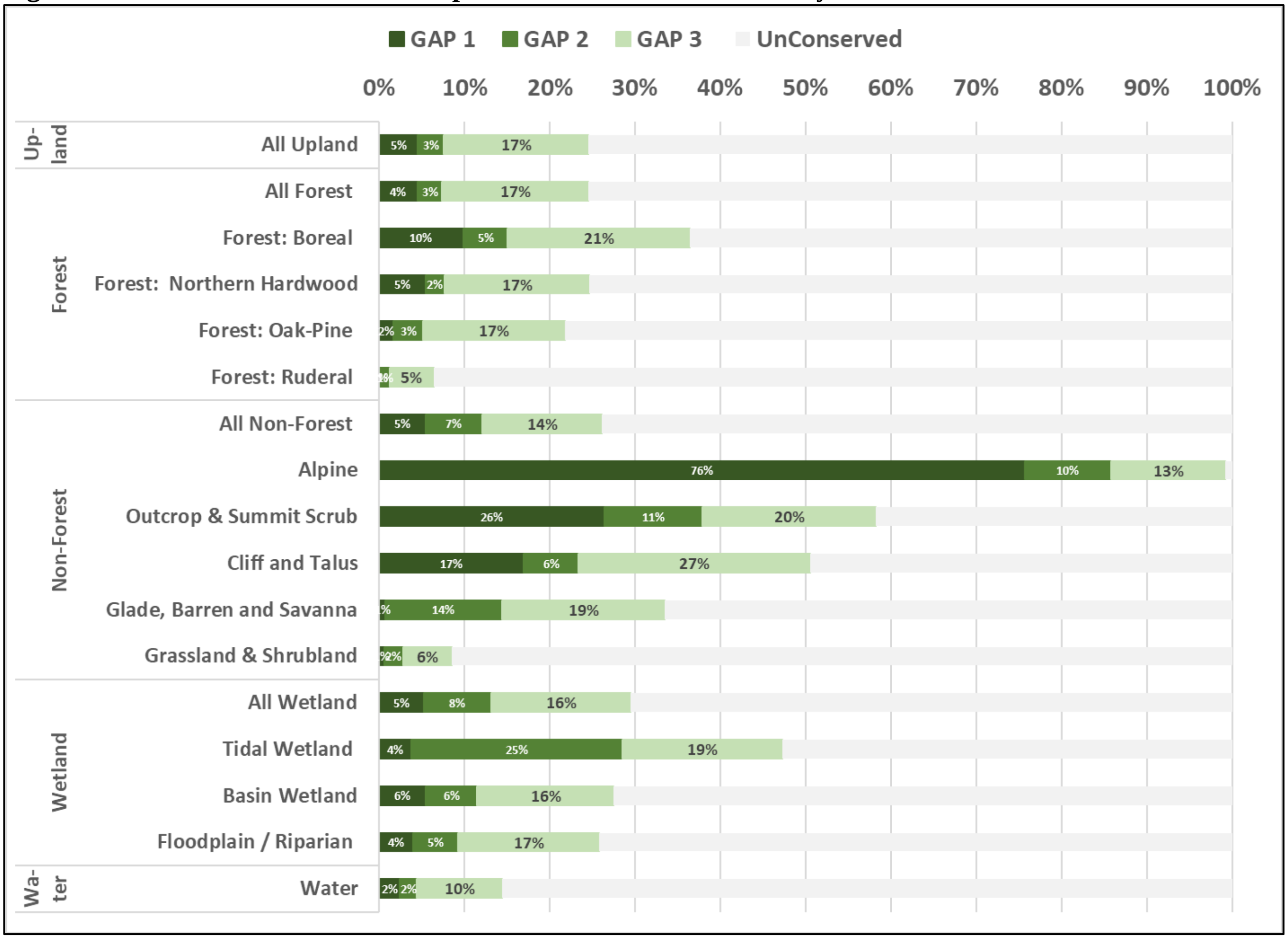
Upland Forest (Table 5.18): Dominant forest types that occupy large contiguous areas (generally >5,000 acres under natural conditions) and form the background matrix of a geographic region are mapped across their distribution. Other habitats tend to nest within the forest matrix where local conditions differ in moisture, soil depth, or disturbance regimes. An example of a matrix forest is the Acadian Low-Elevation Spruce-Fir-Hardwood Forest, which dominates at low elevations in northern Maine. Smaller scale, unusual upland forest types such as maritime forest, pine barrens, and clayplain forests are also included in the map. <u>Lexicon</u>: *Upland Forest, Boreal Forest, Northern Hardwood Forest, Oak-Pine Forest*.

Upland Non-Forested Habitat (Table 5.19): Patch-forming habitats occur under localized environmental conditions that are distinctly different from the surrounding landscape (e.g., Acidic Rocky Outcrop). The habitat often reflects extreme conditions in soil (bedrock or shifting sand), exposure (alpine winds, steep slopes), or disturbance regime (fire, mowing). Patch habitats tend to have high plant diversity and host some of New England's rarest species. <u>Lexicon</u>: *Alpine, Cliff and Talus, Glade, Barren, and Savannah, Grassland and Shrubland, Beach and Dune. (high elevation forest)*

Wetland (Table 5.20 & 5.21): **S**wamps, bogs, marshes, floodplains, and fens that form in annually flooded or permanently saturated conditions where water collects. These habitats are smaller than the matrix-forming forests and generally occupy 10 acres to 5,000 acres under natural conditions. An example is the North Atlantic Coastal Plain Basin Peat, which is a peat-accumulating forested wetland common to the coastal plain. <u>Lexicon:</u> *Basin Wetland, Floodplain/Riparian Wetland, Tidal Wetland*

Attention to these scales is an important part of understanding the distribution, securement, and resilience patterns of nature Attention to these scales is an important part of understanding the distribution, securement, and resilience patterns of nature.

Figure 5.16. Conservation Status of Upland and Wetland Habitats by Northeast Lexicon Names



Conservation Status

We overlaid the NETHW dataset with the Conservation Lands dataset to determine the current conservation status of each habitat as well as the patterns across habitat types (Figure 5.16). Conserving wildlife habitat is a shared responsibility but typically some states contain a disproportionate amount of the habitat and thus have greater responsibility towards its conservation (Table 5.18-5.21). For users interested in connecting the habitat types with the geophysical settings this information is often given at the individual habitat level (Tables 5.22-5.24) and we recommend reading through the descriptions in the Habitat Guides.

The 29 million acres of conserved land in the Northeast is spread relatively evenly across forests (26%) non forest (26%) and wetlands (29%). Within these groups there are some clear biases and gaps with are discussed in the forest and wetlands chapters, and later in this chapter for non-forested habitats.

Table 5.18. Conservation Status of Terrestrial Forests by Lexicon, Macrogroup and State

Northeast Habitats	RESPONSIBILITY % Habitat	% Conserved	ACRES Unconserved	GAP 1	GAP 2	GAP 3	Total Acres	% %UC	%GP1	%GP2	%GP3	Total
Upland	**100%**	**18%**	**118,117,158**	**4,530,132**	**3,306,932**	**18,485,111**	**144,439,333**	**82%**	**3%**	**2%**	**13%**	**100%**
Upland Forest	**100%**	**25%**	**70,206,416**	**4,168,205**	**2,693,749**	**15,925,865**	**92,994,235**	**75%**	**4%**	**3%**	**17%**	**100%**
Forest: Boreal	**100%**	**36%**	**5,216,473**	**812,276**	**427,242**	**1,748,295**	**8,204,287**	**64%**	**10%**	**5%**	**21%**	**100%**
Boreal Upland Forest		0%										
MA	0%	55%	561	688			1,249	45%	55%	0%	0%	100%
ME	80%	29%	4,698,564	244,682	214,297	1,417,286	6,574,829	71%	4%	3%	22%	100%
NH	7%	71%	167,529	99,071	167,247	139,851	573,699	29%	17%	29%	24%	100%
NY	8%	81%	120,560	414,993	4,425	78,561	618,539	19%	67%	1%	13%	100%
VA	0%	80%	1,263	1,418	1,915	1,809	6,404	20%	22%	30%	28%	100%
VT	5%	40%	221,380	35,915	24,695	88,981	370,971	60%	10%	7%	24%	100%
WV	1%	89%	6,575	15,509	14,664	21,803	58,551	11%	26%	25%	37%	100%
Cold-temperate Upland Forest		0%										
ME	0%	10%	40			5	45	90%	0%	0%	10%	100%
Forest: Northern Hardwood	**100%**	**25%**	**38,881,341**	**2,802,207**	**1,160,401**	**8,762,078**	**51,606,027**	**75%**	**5%**	**2%**	**17%**	**100%**
Northern Hardwood & Conifer		0%										
CT	1%	25%	470,338	8,042	37,067	112,593	628,040	75%	1%	6%	18%	100%
DC	0%	73%	639			1,764	2,404	27%	0%	0%	73%	100%
DE	0%	22%	86,561	495	2,399	21,843	111,298	78%	0%	2%	20%	100%
MA	4%	34%	1,326,450	113,069	102,884	477,326	2,019,729	66%	6%	5%	24%	100%
MD	2%	23%	656,653	1,753	23,184	174,916	856,506	77%	0%	3%	20%	100%
ME	17%	19%	7,136,729	146,754	188,920	1,323,468	8,795,872	81%	2%	2%	15%	100%
NH	8%	32%	2,694,338	136,626	221,140	911,153	3,963,257	68%	3%	6%	23%	100%
NJ	1%	31%	181,867	237	50,765	32,333	265,201	69%	0%	19%	12%	100%
NY	26%	29%	9,371,115	1,938,230	119,645	1,810,970	13,239,960	71%	15%	1%	14%	100%
PA	17%	26%	6,614,778	121,925	73,153	2,096,521	8,906,377	74%	1%	1%	24%	100%
RI	0%	38%	38,484	1,015	16,556	5,958	62,013	62%	2%	27%	10%	100%
VA	8%	16%	3,668,492	105,342	118,033	485,698	4,377,566	84%	2%	3%	11%	100%
VT	8%	25%	2,911,234	140,596	78,676	773,315	3,903,820	75%	4%	2%	20%	100%
WV	9%	17%	3,723,664	88,123	127,978	534,221	4,473,985	83%	2%	3%	12%	100%
Forest: Oak-Pine	**100%**	**22%**	**25,053,447**	**552,277**	**1,093,761**	**5,356,944**	**32,056,429**	**78%**	**2%**	**3%**	**17%**	**100%**
Central Oak-Pine		0%										
CT	4%	20%	954,235	19,843	54,200	170,065	1,198,344	80%	2%	5%	14%	100%
DC	0%	69%	697			1,538	2,235	31%	0%	0%	69%	100%
DE	0%	27%	59,819	1,159	3,078	17,505	81,562	73%	1%	4%	21%	100%
MA	2%	26%	442,676	19,524	34,138	100,037	596,374	74%	3%	6%	17%	100%
MD	4%	27%	889,370	2,439	30,574	304,275	1,226,657	73%	0%	2%	25%	100%
ME	0%	14%	100,805	557	6,365	9,623	117,349	86%	0%	5%	8%	100%
NH	0%	24%	45,399	1,488	2,324	10,303	59,514	76%	2%	4%	17%	100%
NJ	3%	31%	618,193	847	121,311	160,185	900,536	69%	0%	13%	18%	100%
NY	8%	13%	2,155,622	9,218	58,282	251,101	2,474,224	87%	0%	2%	10%	100%
PA	25%	28%	5,884,364	128,045	109,689	2,021,997	8,144,094	72%	2%	1%	25%	100%
RI	1%	23%	194,502	3,521	43,098	12,634	253,755	77%	1%	17%	5%	100%
VA	28%	27%	6,663,926	341,189	503,058	1,622,729	9,130,902	73%	4%	6%	18%	100%
VT	0%	14%	54,293	2,295	1,219	5,508	63,314	86%	4%	2%	9%	100%
WV	24%	10%	6,968,903	19,895	123,101	666,538	7,778,437	90%	0%	2%	9%	100%
Central Oak-Pine/Longleaf Pne		0%										
VA	0%	57%	251	326		2	579	43%	56%	0%	0%	100%
Southern Oak-Pine		0%										
VA	0%	29%	20,389	1,933	3,324	2,904	28,550	71%	7%	12%	10%	100%
WV	0%	0%	4				4	100%	0%	0%	0%	100%
Forest: Ruderal	**100%**	**6%**	**1,055,155**	**1,444**	**12,346**	**58,547**	**1,127,492**	**94%**	**0%**	**1%**	**5%**	**100%**
Plantation and Ruderal Forest		0%										
MD	0%	26%	753		5	261	1,018	74%	0%	0%	26%	100%
ME	0%	25%	361	24	0	98	483	75%	5%	0%	20%	100%
NH	0%	40%	43		4	24	72	60%	0%	6%	34%	100%
VA	100%	6%	1,053,821	1,420	12,336	58,107	1,125,685	94%	0%	1%	5%	100%
VT	0%	24%	176	0		56	233	76%	0%	0%	24%	100%

Table 5.19. Conservation Status of Terrestrial Non-Forest Habitats by Lexicon, Macrogroup and State

Northeast Habitats	RESPONSIBILITY		ACRES					%				
	% Habitat	% Conserved	Unconserved	GAP 1	GAP 2	GAP 3	Total Acres	%UC	%GP1	%GP2	%GP3	Total
Upland Non Forest	**26%**	**100%**	**2,814,894**	**207,508**	**253,186**	**534,760**	**3,810,348**	**74%**	**5%**	**7%**	**14%**	**100%**
Alpine	**100%**	**99%**	**66**	**6,194**	**834**	**1,092**	**8,185**	**1%**	**76%**	**10%**	**13%**	**100%**
Alpine		0%										
ME	44%	99%	32	1,763	747	1,084	3,624	1%	49%	21%	30%	100%
NH	51%	99%	34	4,065	62		4,160	1%	98%	1%	0%	100%
NY	3%	100%		277		8	285	0%	97%	0%	3%	100%
VT	1%	100%	0	89	26		115	0%	77%	22%	0%	100%
Cliff and Talus	**100%**	**51%**	**333,946**	**114,251**	**43,532**	**182,964**	**674,693**	**49%**	**17%**	**6%**	**27%**	**100%**
Cliff and Talus		0%										
CT	1%	41%	2,304	153	662	784	3,903	59%	4%	17%	20%	100%
DE	0%	100%				4	4	0%	0%	0%	100%	100%
MA	2%	54%	5,373	3,033	798	2,496	11,700	46%	26%	7%	21%	100%
MD	0%	49%	429	2	81	328	841	51%	0%	10%	39%	100%
ME	7%	53%	20,648	8,189	8,551	6,547	43,935	47%	19%	19%	15%	100%
NH	6%	70%	11,929	6,321	13,154	8,491	39,895	30%	16%	33%	21%	100%
NJ	1%	68%	1,309		1,395	1,360	4,064	32%	0%	34%	33%	100%
NY	21%	53%	68,315	52,577	3,575	20,141	144,608	47%	36%	2%	14%	100%
PA	32%	65%	75,806	28,832	1,899	108,226	214,762	35%	13%	1%	50%	100%
RI	0%	0%	3				3	100%	0%	0%	0%	100%
VA	8%	44%	30,176	6,285	6,119	11,778	54,357	56%	12%	11%	22%	100%
VT	8%	40%	33,935	8,130	1,810	12,896	56,770	60%	14%	3%	23%	100%
WV	15%	16%	83,719	729	5,488	9,913	99,850	84%	1%	5%	10%	100%
Glade, Barren and Savanna	**100%**	**34%**	**667,189**	**7,329**	**138,025**	**191,036**	**1,003,579**	**66%**	**1%**	**14%**	**19%**	**100%**
Pine Barren		0%										
CT	0%	55%	65		43	38	147	45%	0%	29%	26%	100%
MA	10%	47%	54,281	1,109	27,608	20,339	103,336	53%	1%	27%	20%	100%
ME	1%	40%	5,514	708	300	2,630	9,152	60%	8%	3%	29%	100%
NH	1%	36%	3,656	434	319	1,312	5,721	64%	8%	6%	23%	100%
NJ	33%	56%	143,972	118	85,439	96,948	326,476	44%	0%	26%	30%	100%
NY	8%	28%	59,911	296	9,899	12,823	82,929	72%	0%	12%	15%	100%
RI	1%	45%	3,320	104	2,401	185	6,010	55%	2%	40%	3%	100%
VT	0%	19%	430			103	534	81%	0%	0%	19%	100%
Glade, Barren and Savanna		0%										
CT	0%	48%	48	3	1	40	92	52%	3%	1%	44%	100%
DE	0%	70%	3			7	10	30%	0%	0%	70%	100%
MA	0%	28%	145	41	15		202	72%	20%	8%	0%	100%
MD	3%	22%	25,821	76	947	6,459	33,303	78%	0%	3%	19%	100%
ME	0%	16%	153	1		29	183	84%	0%	0%	16%	100%
NH	0%	25%	12			4	15	75%	0%	0%	25%	100%
NJ	0%	28%	104		12	29	144	72%	0%	8%	20%	100%
NY	3%	13%	24,199	57	2,499	1,182	27,937	87%	0%	9%	4%	100%
PA	12%	10%	110,872	156	905	11,229	123,161	90%	0%	1%	9%	100%
VA	12%	29%	89,177	3,871	6,978	25,277	125,303	71%	3%	6%	20%	100%
VT	0%	20%	2,762	244	51	404	3,461	80%	7%	1%	12%	100%
WV	15%	8%	142,728	113	608	11,990	155,439	92%	0%	0%	8%	100%
Serpentine Woodland (Canada)												
ME	0%	31%	18			8	26	69%	0%	0%	31%	100%
Grassland & Shrubland	**100%**	**9%**	**1,705,521**	**11,114**	**41,216**	**106,931**	**1,864,783**	**91%**	**1%**	**2%**	**6%**	**100%**
Coastal Grassland & Shrubland		0%										
CT	0%	24%	3,868	97	598	527	5,090	76%	2%	12%	10%	100%
DE	0%	54%	1,891	41	212	1,930	4,074	46%	1%	5%	47%	100%
MA	3%	39%	34,256	2,181	12,540	7,308	56,285	61%	4%	22%	13%	100%
MD	0%	81%	593		2,289	300	3,182	19%	0%	72%	9%	100%
ME	0%	12%	3,907	29	370	137	4,443	88%	1%	8%	3%	100%
NH	0%	29%	656		21	245	922	71%	0%	2%	27%	100%
NJ	1%	48%	5,186	624	1,296	2,880	9,985	52%	6%	13%	29%	100%
NY	2%	35%	18,820		4,193	5,962	28,975	65%	0%	14%	21%	100%
PA	0%	65%	149			276	425	35%	0%	0%	65%	100%
RI	0%	23%	5,345	73	1,038	480	6,936	77%	1%	15%	7%	100%
VA	1%	52%	5,210	1,993	3,145	618	10,966	48%	18%	29%	6%	100%
VT	0%	18%	5		0	1	6	82%	0%	4%	14%	100%
Ruderal Shrubland & Grassland		0%										
CT	0%	6%	4,812	16	70	199	5,098	94%	0%	1%	4%	100%
MA	1%	31%	12,371	69	3,513	2,066	18,020	69%	0%	19%	11%	100%
MD	0%	22%	3,830		29	1,044	4,902	78%	0%	1%	21%	100%
ME	1%	8%	20,795	374	419	1,045	22,634	92%	2%	2%	5%	100%
NH	0%	14%	3,542	54	187	327	4,110	86%	1%	5%	8%	100%
NJ	0%	0%	52				52	100%	0%	0%	0%	100%
NY	25%	3%	448,720	127	3,016	11,651	463,514	97%	0%	1%	3%	100%
PA	9%	13%	138,991	3,415	794	16,500	159,701	87%	2%	0%	10%	100%
RI	0%	17%	2,659	10	246	274	3,189	83%	0%	8%	9%	100%
VA	48%	6%	836,248	2,011	7,118	47,474	892,850	94%	0%	1%	5%	100%
WV	9%	4%	153,615		120	5,689	159,423	96%	0%	0%	4%	100%
Outcrop & Summit Scrub	**100%**	**58%**	**108,172**	**68,620**	**29,578**	**52,737**	**259,107**	**42%**	**26%**	**11%**	**20%**	**100%**
Outcrop & Summit Scrub		0%										
CT	0%	19%	74	0	14	3	91	81%	0%	15%	3%	100%
MA	2%	55%	2,261	1,304	254	1,186	5,005	45%	26%	5%	24%	100%
ME	25%	38%	40,139	6,292	5,892	12,052	64,375	62%	10%	9%	19%	100%
NH	21%	74%	13,782	10,517	19,098	9,929	53,327	26%	20%	36%	19%	100%
NY	25%	81%	12,238	41,105	868	10,181	64,392	19%	64%	1%	16%	100%
VA	0%	43%	48	14		22	83	57%	16%	0%	27%	100%
VT	24%	47%	32,502	7,440	2,544	18,441	60,926	53%	12%	4%	30%	100%
WV	1%	73%	851	1,874	364	110	3,198	27%	59%	11%	3%	100%
Rocky Coast		0%										
CT	0%	13%	413	5	40	18	477	87%	1%	8%	4%	100%
MA	1%	18%	2,155	41	68	362	2,626	82%	2%	3%	14%	100%
ME	1%	19%	2,549	13	280	307	3,148	81%	0%	9%	10%	100%
NH	0%	28%	153		5	53	211	72%	0%	2%	25%	100%
NY	0%	34%	119			62	182	66%	0%	0%	34%	100%
RI	0%	17%	888	15	152	9	1,064	83%	1%	14%	1%	100%

Table 5.20. Conservation Status of Basin Wetlands by Lexicon, Macrogroup and State

Northeast Habitats	RESPONSIBILITY % Habitat	% Conserved	ACRES Unconserved	GAP 1	GAP 2	GAP 3	Total Acres	% %UC	%GP1	%GP2	%GP3	Total
Wetland	**100%**	**29%**	**7,936,865**	**587,267**	**891,384**	**1,836,623**	**11,252,139**	**71%**	**5%**	**8%**	**16%**	**100%**
Basin Wetland	**100%**	**28%**	**6,625,246**	**505,931**	**548,249**	**1,460,228**	**9,139,653**	**72%**	**6%**	**6%**	**16%**	**100%**
Central Hardwood Swamp		0%										
CT	0%	16%	7,755	15	296	1,219	9,284	84%	0%	3%	13%	100%
MA	0%	24%	7,337	28	599	1,668	9,632	76%	0%	6%	17%	100%
MD	0%	14%	634		1	103	737	86%	0%	0%	14%	100%
ME	0%	3%	2,706		59	25	2,790	97%	0%	2%	1%	100%
NH	0%	26%	1,459	17	73	414	1,963	74%	1%	4%	21%	100%
NJ	0%	24%	4,796		154	1,347	6,296	76%	0%	2%	21%	100%
NY	1%	11%	109,856	171	4,749	8,326	123,101	89%	0%	4%	7%	100%
PA	0%	4%	1,631	10	4	58	1,702	96%	1%	0%	3%	100%
VA	0%	11%	19,053	210	196	2,012	21,470	89%	1%	1%	9%	100%
VT	0%	15%	13,397	477	567	1,401	15,842	85%	3%	4%	9%	100%
WV	0%	4%	145	4		2	150	96%	3%	0%	1%	100%
Coastal Plain Peat Swamp		0%										
CT	0%	42%	1,438	143	198	702	2,480	58%	6%	8%	28%	100%
DE	0%	70%	1,444	31	3,218	152	4,846	30%	1%	66%	3%	100%
MA	0%	50%	5,928	1,563	2,400	1,939	11,830	50%	13%	20%	16%	100%
MD	0%	57%	52	2	13	55	121	43%	1%	11%	45%	100%
ME	0%	20%	521		27	106	654	80%	0%	4%	16%	100%
NH	0%	62%	442	214	55	447	1,158	38%	18%	5%	39%	100%
NJ	0%	63%	13,086	5	10,465	11,811	35,367	37%	0%	30%	33%	100%
NY	0%	74%	26		59	12	97	26%	0%	62%	12%	100%
RI	0%	45%	959	91	677	22	1,750	55%	5%	39%	1%	100%
Coastal Plain Peatland		0%										
MA	0%	40%	566	30	149	191	936	60%	3%	16%	20%	100%
NJ	0%	83%	686	5	722	2,627	4,040	17%	0%	18%	65%	100%
NY	0%	57%	123		53	109	285	43%	0%	19%	38%	100%
VA	0%	100%	1	1,202	1,052		2,256	0%	53%	47%	0%	100%
Coastal Plain Swamp		0%										
DC	0%	69%	25			55	81	31%	0%	0%	69%	100%
DE	2%	24%	114,486	754	8,960	27,032	151,232	76%	0%	6%	18%	100%
MD	4%	28%	231,505	336	15,210	75,919	322,970	72%	0%	5%	24%	100%
NJ	5%	40%	266,275	496	82,670	95,341	444,782	60%	0%	19%	21%	100%
NY	0%	31%	12,505		3,137	2,605	18,246	69%	0%	17%	14%	100%
PA	0%	21%	4,065	67	188	804	5,124	79%	1%	4%	16%	100%
RI	0%	26%	473	49	115	3	640	74%	8%	18%	0%	100%
VA	5%	29%	303,455	2,979	87,302	32,938	426,675	71%	1%	20%	8%	100%
Emergent Marsh		0%										
CT	0%	32%	11,151	316	1,326	3,597	16,391	68%	2%	8%	22%	100%
DC	0%	40%	37			24	61	60%	0%	0%	40%	100%
DE	0%	32%	14,874	343	936	5,618	21,771	68%	2%	4%	26%	100%
MA	1%	34%	37,757	1,620	4,836	12,797	57,011	66%	3%	8%	22%	100%
MD	1%	27%	39,239	5	1,795	12,767	53,806	73%	0%	3%	24%	100%
ME	2%	21%	178,195	6,836	11,067	29,599	225,696	79%	3%	5%	13%	100%
NH	1%	31%	33,793	1,689	1,519	11,654	48,656	69%	3%	3%	24%	100%
NJ	1%	31%	67,980	380	15,432	15,013	98,806	69%	0%	16%	15%	100%
NY	2%	28%	161,618	21,885	9,246	30,761	223,511	72%	10%	4%	14%	100%
PA	1%	19%	39,637	686	850	7,559	48,733	81%	1%	2%	16%	100%
RI	0%	30%	3,587	63	1,120	321	5,091	70%	1%	22%	6%	100%
VA	1%	15%	89,723	305	2,573	13,432	106,033	85%	0%	2%	13%	100%
VT	0%	25%	29,516	1,629	2,089	6,219	39,454	75%	4%	5%	16%	100%
WV	0%	7%	6,303	14	143	306	6,766	93%	0%	2%	5%	100%
Northern Peatland		0%										
CT	0%	42%	346	48	44	162	599	58%	8%	7%	27%	100%
MA	0%	45%	2,725	305	604	1,313	4,948	55%	6%	12%	27%	100%
ME	4%	30%	252,881	20,531	21,701	67,298	362,411	70%	6%	6%	19%	100%
NH	0%	54%	4,739	1,561	955	3,054	10,310	46%	15%	9%	30%	100%
NJ	0%	97%	5		85	74	164	3%	0%	52%	45%	100%
NY	1%	57%	51,804	32,006	2,858	32,769	119,436	43%	27%	2%	27%	100%
PA	0%	54%	13,839	2,683	775	12,872	30,169	46%	9%	3%	43%	100%
RI	0%	69%	109	1	245		355	31%	0%	69%	0%	100%
VT	0%	69%	2,895	2,282	2,150	1,980	9,307	31%	25%	23%	21%	100%
Northern Swamp		0%										
CT	2%	24%	132,618	2,471	10,003	28,931	174,024	76%	1%	6%	17%	100%
DC	0%	27%	122			44	166	73%	0%	0%	27%	100%
DE	0%	50%	193		93	100	386	50%	0%	24%	26%	100%
MA	4%	33%	270,042	11,690	28,902	90,313	400,947	67%	3%	7%	23%	100%
MD	0%	23%	18,790	241	945	4,310	24,286	77%	1%	4%	18%	100%
ME	14%	20%	1,017,712	28,691	32,691	194,911	1,274,004	80%	2%	3%	15%	100%
NH	2%	30%	117,611	5,829	8,479	35,602	167,520	70%	3%	5%	21%	100%
NJ	2%	36%	97,052	140	24,616	30,074	151,882	64%	0%	16%	20%	100%
NY	21%	27%	1,411,137	255,727	39,840	238,577	1,945,281	73%	13%	2%	12%	100%
PA	3%	28%	173,635	3,520	6,245	58,134	241,534	72%	1%	3%	24%	100%
RI	1%	31%	50,365	1,402	17,447	4,203	73,416	69%	2%	24%	6%	100%
VA	0%	17%	26,597	253	425	4,904	32,179	83%	1%	1%	15%	100%
VT	1%	32%	77,028	7,198	6,936	21,424	112,586	68%	6%	6%	19%	100%
WV	0%	52%	13,216	1,612	8,627	4,139	27,594	48%	6%	31%	15%	100%
Southern Bottomland Forest		0%										
MD	0%	27%	2,707		106	900	3,712	73%	0%	3%	24%	100%
VA	4%	12%	310,298	8,533	5,029	30,690	354,550	88%	2%	1%	9%	100%
Wet Meadow / Shrub Marsh		0%										
CT	0%	26%	17,241	210	1,681	4,238	23,370	74%	1%	7%	18%	100%
DE	0%	43%	6,659	0	1,013	3,944	11,616	57%	0%	9%	34%	100%
MA	1%	34%	50,566	1,973	6,982	17,195	76,715	66%	3%	9%	22%	100%
MD	0%	45%	16,207	2	1,121	12,044	29,375	55%	0%	4%	41%	100%
ME	3%	21%	236,179	7,476	9,985	44,057	297,698	79%	3%	3%	15%	100%
NH	1%	31%	41,093	1,610	3,187	13,874	59,764	69%	3%	5%	23%	100%
NJ	1%	41%	40,020	159	15,951	12,223	68,353	59%	0%	23%	18%	100%
NY	3%	37%	185,010	59,746	6,369	42,822	293,946	63%	20%	2%	15%	100%
PA	0%	20%	31,925	800	588	6,483	39,796	80%	2%	1%	16%	100%
RI	0%	39%	3,130	104	1,601	301	5,135	61%	2%	31%	6%	100%
VA	1%	16%	72,522	968	2,466	10,403	86,359	84%	1%	3%	12%	100%
VT	0%	21%	33,430	1,484	1,182	6,412	42,508	79%	3%	3%	15%	100%
WV	0%	13%	2,557	6	23	341	2,928	87%	0%	1%	12%	100%

Table 5.21. Conservation Status of Floodplain and Tidal Wetlands by Lexicon, Macrogroup and State

Northeast Habitats	RESPONSIBILITY		ACRES					%				
	% Habitat	% Conserved	Unconserved	GAP 1	GAP 2	GAP 3	Total Acres	%UC	%GP1	%GP2	%GP3	Total
Wetland	**100%**	**29%**	**7,936,865**	**587,267**	**891,384**	**1,836,623**	**11,252,139**	**71%**	**5%**	**8%**	**16%**	**100%**
Floodplain / Riparian	**100%**	**26%**	**684,611**	**35,657**	**49,934**	**153,238**	**923,440**	**74%**	**4%**	**5%**	**17%**	**100%**
Large River Floodplain		0%										
CT	0%	32%	2,728		254	1,042	4,024	68%	0%	6%	26%	100%
DC	0%	96%	4		0	85	89	4%	0%	0%	96%	100%
DE	0%	60%	32		0	48	81	40%	0%	1%	60%	100%
MA	1%	41%	5,890	197	2,782	1,185	10,054	59%	2%	28%	12%	100%
MD	1%	49%	4,072	26	288	3,573	7,960	51%	0%	4%	45%	100%
ME	30%	25%	197,227	8,713	10,046	48,545	264,532	75%	3%	4%	18%	100%
NH	2%	23%	13,067	619	979	2,349	17,014	77%	4%	6%	14%	100%
NJ	1%	59%	3,988		2,871	2,983	9,842	41%	0%	29%	30%	100%
NY	32%	27%	203,701	19,192	17,120	39,927	279,939	73%	7%	6%	14%	100%
PA	11%	22%	75,943	2,133	1,950	17,480	97,506	78%	2%	2%	18%	100%
RI	0%	12%	17			2	19	88%	0%	0%	12%	100%
VA	15%	18%	107,953	2,270	3,390	18,824	132,435	82%	2%	3%	14%	100%
VT	6%	36%	33,783	2,456	7,016	9,309	52,564	64%	5%	13%	18%	100%
WV	1%	15%	10,142	6	182	1,557	11,887	85%	0%	2%	13%	100%
Coastal Plain Floodplain Swamps		0%										
DC	0%	100%				1	1	0%	0%	0%	100%	100%
DE	0%	39%	464	1	10	287	762	61%	0%	1%	38%	100%
MA	0%	0%	3				3	100%	0%	0%	0%	100%
MD	0%	32%	10,030	26	1,239	3,468	14,763	68%	0%	8%	23%	100%
NJ	0%	36%	4,001		1,288	1,009	6,298	64%	0%	20%	16%	100%
NY	0%	43%	334		222	30	587	57%	0%	38%	5%	100%
PA	0%	22%	594		13	152	759	78%	0%	2%	20%	100%
VA	0%	14%	10,639	18	282	1,381	12,320	86%	0%	2%	11%	100%
Tidal Wetland	**100%**	**47%**	**627,009**	**45,680**	**293,201**	**223,156**	**1,189,046**	**53%**	**4%**	**25%**	**19%**	**100%**
Tidal Marsh		0%										
CT	2%	37%	11,910	582	2,410	4,043	18,944	63%	3%	13%	21%	100%
DC	0%	52%	58			62	120	48%	0%	0%	52%	100%
DE	7%	61%	33,354	6,045	21,357	24,624	85,380	39%	7%	25%	29%	100%
MA	6%	44%	37,729	1,786	12,631	15,019	67,166	56%	3%	19%	22%	100%
MD	21%	46%	133,131	519	24,609	87,528	245,788	54%	0%	10%	36%	100%
ME	3%	31%	23,563	252	4,705	5,424	33,945	69%	1%	14%	16%	100%
NH	1%	24%	5,461	307	299	1,149	7,216	76%	4%	4%	16%	100%
NJ	19%	66%	78,637	10,873	124,489	14,318	228,317	34%	5%	55%	6%	100%
NY	4%	27%	35,432		9,412	4,025	48,869	73%	0%	19%	8%	100%
PA	0%	32%	1,107	417	39	74	1,637	68%	25%	2%	5%	100%
RI	1%	30%	6,035	57	2,221	267	8,580	70%	1%	26%	3%	100%
VA	20%	45%	127,880	19,513	59,768	27,122	234,283	55%	8%	26%	12%	100%
Tidal Swamp		0%										
DC	0%	89%	9			72	81	11%	0%	0%	89%	100%
DE	1%	38%	7,197	500	963	2,903	11,563	62%	4%	8%	25%	100%
MA	0%	100%				2	2	0%	0%	0%	100%	100%
MD	7%	39%	51,385	754	10,609	21,264	84,012	61%	1%	13%	25%	100%
NJ	4%	47%	21,922	846	14,337	4,621	41,726	53%	2%	34%	11%	100%
NY	0%	38%	930		379	199	1,507	62%	0%	25%	13%	100%
PA	0%	17%	1,065	113	46	54	1,278	83%	9%	4%	4%	100%
VA	6%	27%	50,203	3,116	4,928	10,385	68,633	73%	5%	7%	15%	100%

Non-Forested Habitat: Distribution and Protection

The Northeast is a forested region and non-forested upland habitats are relatively rare. They form and persist in localized environmental conditions that are distinctly different from the surrounding landscape. The factors can be edaphic, ecologic or reflect past disturbances such as:

Edaphic

- Nutrient poor shallow-to-bedrock soil (outcrops, summit shrub, glade, barren),
- Shifting sand (beach, dune),
- Steep unstable slopes (cliff and talus)
- High elevation cold exposed summits (alpine).

Disturbance

- Abandoned mowed grasslands (ruderal grasslands)
- Recently burned areas (pine barrens, sandplain grasslands)

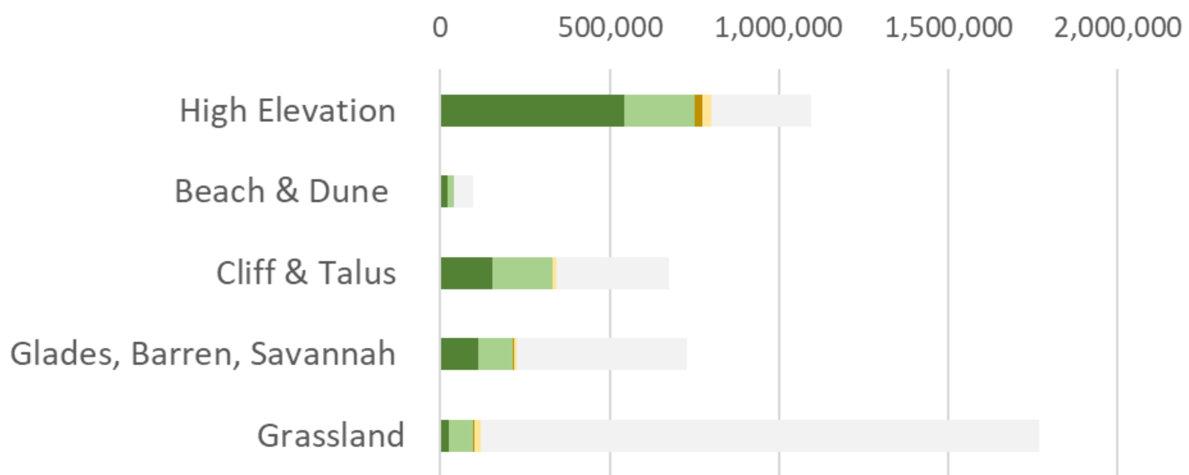
These condition or processes tend to occur in discrete patches where the dominance of trees is limited allowing diverse grass, herb and shrub communities to develop. Non-forested habitats tend to have high plant diversity and host some of New England's rarest species.

In this section we examine the non-forested habitats with respect to their conservation status and recent conservation trends by overlaying the conserved lands dataset on the NETHM. Users should keep in mind that many of these patch-forming habitats are very small and difficult to map accurately. Additionally, the disturbance dependent types are ephemeral and subject to change over time. Although this overlay can reveal some actual trends, the occurrences should be ground-checked for more accurate information.

It is helpful to cross check the edaphically defined habitats with the geophysical setting it is associated with (Table 5.19) as the trend for the individual habitat is likely to follow the trend for the setting. For example, the calcareous cliffs mapped in the NETHP appear to be well conserved (38%) but they occur within a geophysical setting the is highly converted and still losing ground.

Results of the habitat overlay correspond closely to the geophysical analysis. High elevation habitats comprise over 750,000 thousand acres of conservation land including 50,000 new acres in the last decade (Figure 5.17). That includes almost 100% of the northeast Alpine habitat (Figure 18). Beach and dune habitats were mostly conserved before 2001 when large coastal National Wildlife Refuges were established. These systems are now threatened by sea level rise and recent conservation activity has been minimal (but see climate change chapter).

Figure 5.17. Conservation Status of Non-Forested Habitats by Acres. The colors show the conservation status across all years, with the last decade highlighted in brown and tan. A breakdown my percent and individual habitat is shown in Figure 18.

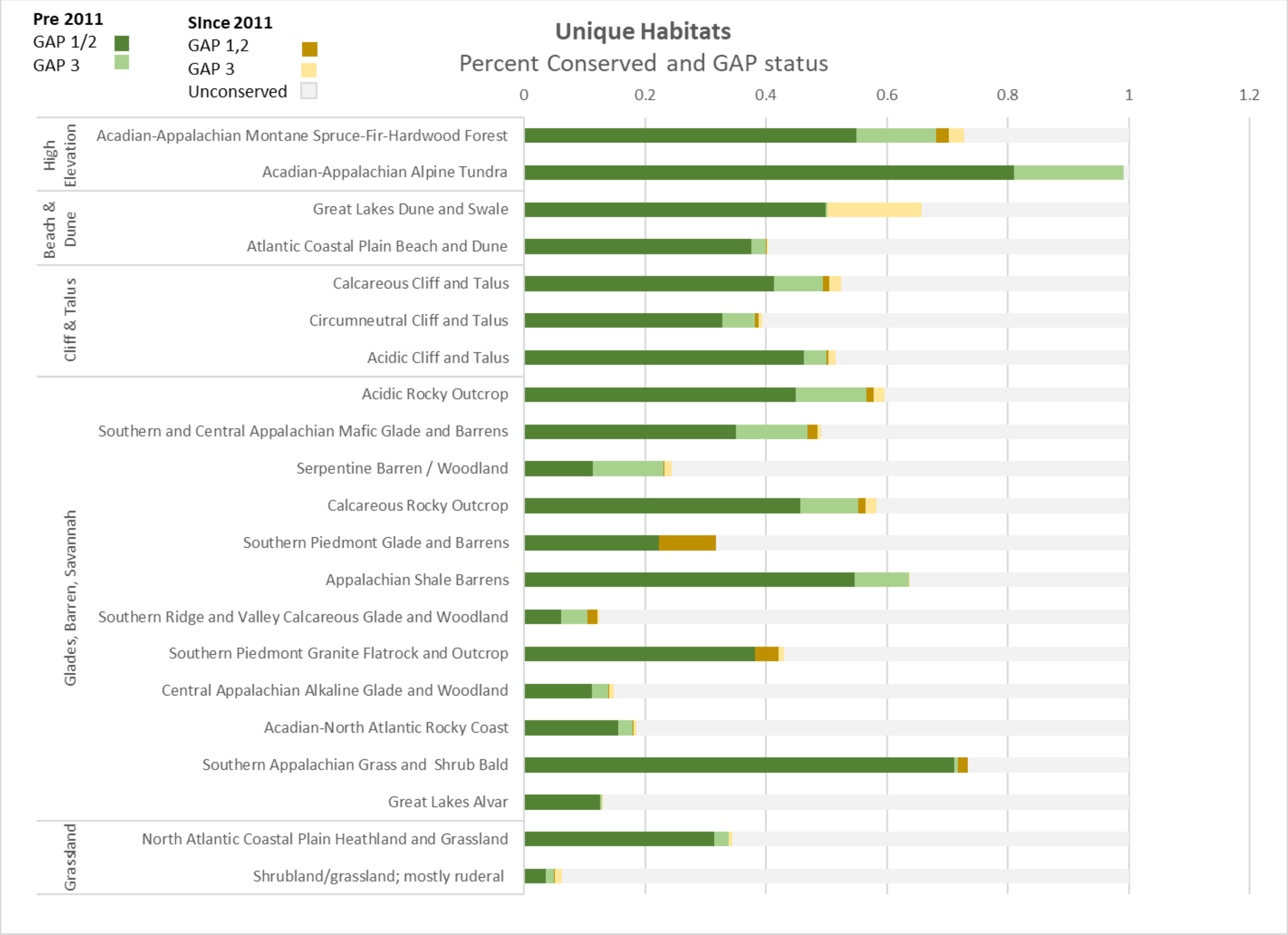


	Grassland	Glades, Barren, Savannah	Cliff & Talus	Beach & Dune	High Elevation
GAP1&2 Pre2001	18,436	93,825	140,078	21,750	475,336
GAP1&2 Pre2011	7,455	17,009	14,765	1,379	65,748
GAP 3 Pre 2001	53,948	76,597	161,217	15,525	128,778
GAP 3 Pre 2011	15,985	25,027	14,030	937	80,158
GAP1&2 2012-2022	3,255	3,942	2,940	55	22,264
GAP 3 2012-2022	20,085	7,770	7,717	452	27,265
UnSecured	1,647,167	504,212	333,946	58,354	296,493

Cliff and talus communities account for 240,000 acres of conserved habitat with 10,000 of that conserved in the last decade (Figure 5.17) This translates to almost 50% of the habitat being conserved. Glades, Barrens and Savannahs account for about the same acreage as cliffs but are not as well conserved although slightly more we put under conservation during the last decade (Figure 5.18). This is a mixed collection of small habitat types including two types of rocky outcrops which are over 50% conserved and three types of calcareous glades and alvars which are less than 20% conserved. Shale barrens and Southern Appalachian grass balds have the highest level of conservation with both over 60%.

Grasslands are the most problematic habitat in the non-forested group. Small edaphic and sometimes fire-dependent grasslands of the coastal plain have over 30% of their habitat under conservation. The region’s more widespread grasslands (1.79 million acres) are classified as ruderal habitat, being comprised of pastures, abandoned fields, recently cut forests or recent cool burns. Five percent of that is under conservation but it is not known whether the intents of the owners or easement holders are to maintain that land as grassland or allow it to convert to forest.

Figure 5.18. Conservation of Non-Forested Habitat by Percent Conserved and Individual Habitat Type



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Appendix 5.1: Crosswalk Tables linking Northeast Lexicon, Individual Habitats and Geophysical Settings

Forested Upland Habitats

Table 5.1.1. Crosswalk between the Northeast Lexicon Project and the NETHM forest types

		Elevation			Geology								
LEXICON	HABITAT	Very High Elevation	High Elevation	Coastal	Shale	Sedimentary	Granite	Mafic	Calcareous	Moderately Calcareous	Serpentine	Sand	Loam
Forest: Northern Hardwood	Appalachian (Hemlock)-Northern Hardwood Forest					1	1						
	Laurentian-Acadian Northern Hardwood Forest					1	1						
	Laurentian-Acadian Northern Pine-(Oak) Forest					1	1						
	Laurentian-Acadian Pine-Hemlock-Hardwood Forest					1	1						
	Laurentian-Acadian Red Oak-Northern Hardwood Forest					1	1						
	North-Central Interior Beech-Maple Forest					1	1						
	Northeastern Coastal and Interior Pine-Oak Forest			1								1	
	South-Central Interior Mesophytic Forest								1	1			
	Southern and Central Appalachian Cove Forest								1	1			
	Southern Appalachian Northern Hardwood Forest				1	1	1		1				
	Southern Atlantic Coastal Plain Mesic Hardwood Forest											1	1
	Southern Piedmont Mesic Forest						1						1
Forest: Boreal	Acadian Low Elevation Spruce-Fir-Hardwood Forest					1	1	1					
	Acadian Sub-boreal Spruce Flat					1	1						
	Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest		1				1	1					
	Boreal Highland/Northern Balsam Fir Forest					1	1	1					
	Central and Southern Appalachian Spruce-Fir Forest		1			1	1						
	Cold Temperate Northern/Higher Elevation Conifer Forest					1							
Forest: Oak-Pine	Allegheny-Cumberland Dry Oak Forest and Woodland					1				1			
	Central and Southern Appalachian Montane Oak Forest		1			1	1						
	Central Appalachian Pine-Oak Rocky Woodland					1	1						
	Coastal Plain Maritime Forest			1								1	
	Dry Oak-Pine Forest, Central Apps and Southern Piedmont					1	1	1					
	Glacial Marine and Lake Mesic Clayplain Forest												
	North Atlantic Coastal Plain Hardwood Forest											1	
	Northeastern Interior Dry-Mesic Oak Forest					1	1						
	Piedmont Hardpan Woodland and Forest						1	1					
	Southern Appalachian Montane Pine Forest and Woodland					1	1						
	Southern Appalachian Oak Forest					1	1						
	Southern Ridge and Valley / Cumberland Dry Calcareous Forest								1	1			
	Coastal Plain Maritime Forest			1								1	
	Southern Appalachian Low Elevation Pine Forest					1							
	Southern Atlantic Coastal Plain Upland Longleaf Pine Woodland											1	
Forest: Ruderal	Early Seral (Intolerant) Forest-- Canada												
	Old Field Forest												
	Plantation Forest												

Non-Forested Upland Habitats

Table 5.1.2. Crosswalk between the Northeast Lexicon Project and the NETHM non-forested habitats.

		Elevation			Geology									Soil			
LEXICON	HABITAT	Very High Elevation	High Elevation	Coastal	Shale	Sedimentary	Granite	Mafic	Calcareous	Moderately Calcareous	Serpentine	Sand	Loam	Silt	Muck	Enriched	Peat
Agricultural	Agriculture																
Alpine	Acadian-Appalachian Alpine Tundra	1															
Cliff and Talus	Acidic Cliff and Talus						1	1									
	Calcareous Cliff and Talus								1	1							
	Circumneutral Cliff and Talus									1							
Glade, Barren and Savanna	North Atlantic Coastal Plain Pitch Pine Barrens											1					
	Northeastern Interior Pine Barrens											1					
	Appalachian Shale Barrens				1												
	Central Appalachian Alkaline Glade and Woodland								1	1							
	Great Lakes Alvar								1	1							
	Serpentine Barren / Woodland										1						
	Southern and Central Appalachian Mafic Glade and Barrens							1									
	Southern Piedmont Glade and Barrens						1	1									
	Southern Ridge and Valley Calcareous Glade and Woodland								1	1							
Beach and Dune	Atlantic Coastal Plain Beach and Dune											1					
	Great Lakes Dune and Swale											1					
Grassland & Shrubland	North Atlantic Coastal Plain Heathland and Grassland											1					
	Shrubland/grassland; mostly ruderal shrublands, regenerating clearcuts					1	1	1									
Outcrop & Summit Scrub	Acidic Rocky Outcrop						1										
	Calcareous Rocky Outcrop								1	1							
	Southern Appalachian Grass and Shrub Bald					1	1										
	Southern Piedmont Granite Flatrock and Outcrop						1										
	Acadian-North Atlantic Rocky Coast						1										
Urban/Suburban Built	Developed																
Upland Total		1	3		1	10	10	1	8	1	2	10	2	1			

Wetland Habitats

Table 5.1.3. Crosswalk between the Northeast Lexicon Project and the NETHM wetland habitats.

CLASS		Soil						Topography		
LEXICON	**HABITAT**	**Sand**	**Loam**	**Silt**	**Muck**	**Enriched**	**Peat**	**Floodplain**	**Riparian**	**Tidal**
Basin Wetland	Atlantic Coastal Plain Blackwater/Brownwater Stream Flood	1								
	Central Atlantic Coastal Plain Non-riverine Swamp and Wet	1								
	North Atlantic Coastal Plain Basin Swamp and Wet Hardwoo	1								
	North Atlantic Coastal Plain Pitch Pine Lowland	1								
	Glacial Marine and Lake Wet Clayplain Forest			1						
	North-Central Interior Wet Flatwoods			1						
	Piedmont Upland Depression Swamp			1						
	Laurentian-Acadian Freshwater Marsh				1					
	Piedmont-Coastal Plain Freshwater Marsh				1					
	North-Central Appalachian Acidic Swamp				1					
	Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp				1					
	Laurentian-Acadian Wet Meadow-Shrub Swamp				1					
	Piedmont-Coastal Plain Shrub Swamp				1					
	Central Interior Highlands and Appalachian Sinkhole and Depression Pond					1				
	Laurentian-Acadian Alkaline Conifer-Hardwood Swamp					1				
	North-Central Interior and Appalachian Rich Swamp					1				
	Laurentian-Acadian Alkaline Fen					1				
	North Atlantic Coastal Plain Basin Peat Swamp						1			
	Atlantic Coastal Plain Northern Bog						1			
	Atlantic Coastal Plain Peatland Pocosin and Canebrake						1			
	Acadian Maritime Bog						1			
	Boreal-Laurentian Bog						1			
	Boreal-Laurentian-Acadian Acidic Basin Fen						1			
	Atlantic Coastal Plain Northern Bog						1			
	North-Central Interior and Appalachian Acidic Peatland						1			
	High Allegheny Headwater Wetland									
Floodplain / Riparian	Riparian Forest, southeast Virginia								1	
	Southern Piedmont Lake Floodplain Forest							1		
	Laurentian-Acadian Large River Floodplain							1		
	North-Central Appalachian Large River Floodplain							1		
	North-Central Interior Large River Floodplain							1		
	Piedmont-Coastal Plain Large River Floodplain							1		
Tidal Wetland	Atlantic Coastal Plain Embayed Region Tidal Freshwater/Brackish Marsh									1
	Tidal Salt Marsh, Estuarine Marsh									1
	Coastal Plain Tidal Swamp									1
Wetland Total		6		3	6	4	9	5	2	3

Appendix 5.2: Geophysical Settings and Preferential Species

Table 5.2.1. Preferential Species for Sand and other Coarse-Grained Sediments. The table gives examples of the 295 total species.

Coarse Sand							
Vascular plant			Common Name	IV	% AE	RANK	Count
	Dicot						
		Helianthemum dumosum	Bushy Rockrose	138.9	0.88	G3	158
		Linum intercursum	Sandplain Flax	125.6	0.84	G4	149
		Coreopsis rosea	Rose Coreopsis	115.1	0.62	G3	185
		Polygonum glaucum	Seabeach knotweed	102.5	0.63	G3	164
		Sabatia kennedyana	Plymouth Gentian	91.16	0.43	G3	212
		Stachys hyssopifolia	Hyssop-leaved Hedge-nettle	81.41	0.59	G4	137
		Amelanchier nantucketensis	Nantucket Juneberry	79.44	0.74	G3	108
		Bidens bidentoides	Delmarva Beggar-ticks	46.35	0.49	G3	95
		Amaranthus pumilus	Seabeach Amaranth	44.01	0.77	G2	57
		Gentiana autumnalis	Pine Barren Gentian	41.85	0.93	G3	45
	Monocot						
		Helonias bullata	Swamp Pink	139.9	0.70	G3	201
		Rhynchospora scirpoides	Bald Rush, Beak-rush	85.11	0.67	G4	127
		Sagittaria teres	Quill-leaf Arrowhead	64.11	0.50	G3	127
		Muhlenbergia torreyana	Pine Barren Smoke Grass	51.15	0.93	G3	55
		Juncus caesariensis	New Jersey Rush	50.08	0.89	G2	56
		Rhynchospora knieskernii	Knieskern's Beaked-rush	49.29	0.93	G2	53
		Eriocaulon parkeri	Estuary Hatpins	45.83	0.35	G3	131
		Scleria reticularis	Nut-rush	45.67	0.38	G3	119
		Lachnanthes caroliana	Carolina Redroot	44.66	0.72	G4	62
		Narthecium americanum	Bog Asphodel	42.71	0.91	G2	47
	Ferns						
		Schizae pusilla	Curly Grass Fern	41.85	0.93	G3	45
		Thelypteris simulata	Bog Fern	9.34	0.25	G4	38
		Isoetes hyemalis	Winter Quillwort	6.16	0.51	G2	12
Vertebrates							
	Herptiles						
		Hyla andersonii	Pine Barrens Treefrog	465	0.93	G4	500
		Ambystoma mabeei	Mabee's salamander	11.88	0.74	G4	16
		Necturus punctatus	Dwarf Waterdog	5.3	0.53	G4	10
		Crotalus horridus pop. 2	Timber Rattlesnake - Coastal Plain Popu	24.83	0.80	G4	31
	Mammals						
		Corynorhinus rafinesquii macrotis	Rafinesque's eastern big-eared bat	24.9	0.83	G3	30
	Fish						
		Etheostoma vitreum	Glassy Darter	13.74	0.76	G4	18
		Enneacanthus chaetodon	Blackbanded Sunfish	7.37	0.82	G4	9
Invertebrates							
	Insects						
		Enallagma recurvatum	Pine Barrens Bluet	71.62	0.53	G3	134
		Papaipema sulphurata	Decodon Stem Borer Moth	52.05	0.61	G2	85
		Neonympha helicta	Helicta Satyr	49.29	0.93	G3	53
		Enallagma pictum	Scarlet Bluet	46	0.46	G3	100
		Enallagma laterale	New England Bluet	43.35	0.22	G3	195
		Apharetra dentata	A noctuid moth	41.96	0.58	G4	72
		Catocala herodias gerhardi	Gerhard's Underwing Moth	37.73	0.62	G3	61
		Psectraglaea carnosa	Pink Sallow	36.17	0.52	G3	69
		Callophrys irus	Frosted elfin	31.15	0.12	G3	255
		Oncocnemis riparia	A noctuid moth	25.69	0.78	G4	33

Table 5.2.2. Preferential Species for Calcareous Bedrock areas. The table gives examples of the 255 total preferential G1-G4 species.

Calcareous					
Vascular plant	**Common Name**	**IV**	**% AE**	**RANK**	**Count**
Dicot					
Salix serissima	Autumn Willow	48.28	0.50	G4	96
Paxistima canbyi	Canby's Mountain-lover	27.73	0.45	G2	61
Clematis addisonii	Addison's Leatherflower	27.62	0.81	G2	34
Arabis patens	Spreading Rockcress	26.43	0.52	G3	51
Echinacea laevigata	Smooth Coneflower	23.78	0.52	G2	46
Delphinium exaltatum	Tall Larkspur	23.55	0.67	G3	35
Helenium virginicum	Virginia Sneezeweed	21.32	0.89	G2	24
Penstemon hirsutus	Hairy Beardtongue	18.83	0.61	G4	31
Lithospermum latifolium	American Gromwell	18.5	0.37	G4	50
Actaea racemosa	Black Cohosh	18.25	0.73	G4	25
Euphorbia purpurea	Darlington's Glade Spurge	17.73	0.29	G3	61
Monocot					
Cypripedium reginae	Showy Lady's-slipper	78.26	0.43	G4	182
Potamogeton hillii	Hill's Pondweed	75.53	0.62	G3	121
Carex grayi	Asa Gray's Sedge	66.97	0.52	G4	129
Carex trichocarpa	Hairy Sedge	59.72	0.57	G4	104
Carex schweinitzii	Schweinitz' Sedge	58.88	0.51	G3	116
Carex tetanica	Rigid Sedge	53.28	0.56	G4	96
Carex formosa	Handsome Sedge	52.77	0.59	G4	89
Carex sterilis	Dioecious Sedge	35.19	0.42	G4	83
Trillium nivale	Snow Trillium	34.61	0.45	G4	77
Cypripedium arietinum	Ram's Head Lady's-slipper	34.07	0.34	G3	99
Vertebrates					
Fish					
Notropis ariommus	Popeye Shiner	20.06	0.48	G3	42
Acipenser fulvescens	Lake Sturgeon	17.97	0.62	G3	29
Notropis anogenus	Pugnose Shiner	10.95	0.73	G3	15
Mammals					
Myotis sodalis	Indiana Bat	89.05	0.31	G2	285
Myotis leibii	Eastern Small-footed Myotis	74.43	0.30	G3	251
Myotis grisescens	Gray Myotis	8.09	0.62	G3	13
Herptiles					
Ambystoma jeffersonianum	Jefferson Salamander	97.41	0.29	G4	337
Clemmys muhlenbergii	Bog Tutle	79.59	0.49	G3	163
Invertebrates					
Anthropods					
Pseudotremia fulgida	Greenbrier Valley Cave Millipede	22.97	0.79	G3	29
Trichopetalum weyeriensis	Grand Caverns Blind Cave Millipede	18.39	0.80	G3	23
Kleptochthonius henroti	Greenbrier Valley Cave Pseudoscorpion	10.09	0.78	G2	13
Trichopetalum whitei	Luray Caverns Blind Cave Millipede	10.02	0.72	G3	14
Insects					
Stylurus scudderi	Zebra Clubtail	41.78	0.29	G4	146
Pseudanophthalmus grandis	A Cave Beetle	36.85	0.82	G3	45
Calephelis borealis	Northern Metalmark	30.38	0.46	G3	66
Euphyes dion	Dion Skipper	28.78	0.63	G4	46
Mussel					
Alasmidonta undulata	Triangle Floater	67.76	0.16	G4	432
Io fluvialis	Spiny Riversnail	22.13	0.54	G2	41
Fontigens tartarea	Organ Cavesnail	17.32	0.72	G2	24
Alasmidonta heterodon	Dwarf Wedge Mussel	16.04	0.13	G1	128

Table 5.2.3. Preferential Species for Acidic Sedimentary Bedrock areas. The table gives examples of the 159 total preferential G1-G4 species.

Acidic Sedimentary					
Vascular plant	**Common Name**	**IV**	**% AE**	**RANK**	**Count**
Dicot					
Actaea podocarpa	Mountain Bugbane	22.2	0.25	G4	90
Solidago uliginosa	Bog Goldenrod	21.8	0.36	G4	60
Plantago cordata	Heartleaf Plantain	19.22	0.33	G4	59
Solidago simplex var. racemosa	Lake Ontario Goldenrod	15.88	0.44	G3	36
Astragalus alpinus	Alpine Milk-vetch	13.34	0.58	G3	23
Lobelia dortmanna	Water Lobelia	13.08	0.50	G4	26
Heuchera alba	White Alumroot	12.62	0.32	G2	39
Salix myricoides	Blueleaf Willow	12.04	0.32	G4	38
Sorbus decora	Northern Mountain-ash	10.88	0.30	G4	36
Astragalus alpinus var. brunetianus	Alpine Milkvetch	10.6	0.53	G3	20
Monocot					
Stenanthium gramineum	Eastern Featherbells	36.7	0.32	G4	115
Trisetum melicoides	Bristle Grass	12.98	0.42	G4	31
Carex squarrosa	Squarrose Sedge	12.1	0.27	G4	45
Cleistes bifaria	Spreading Pogonia	10.82	0.37	G4	29
Spiranthes casei	Case's Ladies'-tresses	8.18	0.39	G4	21
Carex aestivalis	Summer Sedge	7.84	0.16	G4	48
Juncus militaris	Bayonet Rush	7.12	0.51	G4	14
Carex ormostachya	Necklace Spike Sedge	6.86	0.40	G4	17
Lygodium palmatum	Climbing Fern	65.26	0.26	G4	247
Asplenium pinnatifidum	Lobed Spleenwort	20.06	0.35	G4	57
Ferns					
Asplenium bradleyi	Bradley's Spleenwort	8.5	0.34	G4	25
Vertebrates					
Herptiles					
Aneides aeneus	Green Salamander	72.22	0.45	G3	159
Plethodon nettingi	Cheat Mountain Salamander	41.98	0.52	G2	81
Plethodon punctatus	Cow Knob Salamander	26.26	0.56	G3	47
Plethodon sherando	Big Levels Salamander	5.7	0.38	G2	15
Crotalus horridus	Timber Rattlesnake	117	0.16	G4	738
Sistrurus catenatus catenatus	Eastern Massasauga	27.7	0.43	G3	65
Mammals					
Neotoma magister	Allegheny Woodrat	117.5	0.24	G3	494
Sylvilagus obscurus	Appalachian Cottontail	19.16	0.37	G4	52
Sorex dispar	Rock Shrew	15.74	0.30	G4	53
Microtus chrotorrhinus	Rock Vole	6.56	0.21	G4	32
Fish					
Etheostoma tippecanoe	Tippecanoe Darter	9.5	0.38	G3	25
Etheostoma maculatum	Spotted Darter	7.34	0.32	G2	23
Clinostomus elongatus	Redside Dace	5.7	0.38	G3	15
Invertebrates					
Insects					
Stylurus amnicola	Riverine Clubtail	19.16	0.37	G4	52
Lycaena epixanthe	Bog Copper	16.22	0.27	G4	59
Cicindela patruela	Barrens Tiger Beetle	13.04	0.34	G3	38
Lanthus parvulus	Northern Pygmy Clubtail	12.46	0.34	G4	37
Ophiogomphus mainensis	Maine Snaketail	10.08	0.39	G4	26
Mussels					
Cambarus veteranus	A Crayfish	39.44	0.58	G2	68
Stygobromus pizzinii	Pizzini's Cave Amphipod	8.24	0.29	G3	28
Fusconaia subrotunda	Longsolid	20.58	0.40	G3	51
Epioblasma torulosa rangiana	Northern Riffleshell	18.04	0.47	G2	38
Quadrula cylindrica	Rabbitsfoot	16.56	0.52	G3	32

Table 5.2.4. Preferential Species for Moderately Calcareous Bedrock areas. The table gives examples of the 135 total preferential G1-G4 species.

Moderately Calcareous							
Vascular plant			**Common Name**	**IV**	**% AE**	**RANK**	**Count**
	Dicot						
		Panax quinquefolius	American Ginseng	68.54	0.17	G3	394
		Viola appalachiensis	Appalachian Blue Violet	36.63	0.39	G3	93
		Polemonium vanbruntiae	Bog Jacob's-ladder	20.01	0.18	G3	111
		Aconitum reclinatum	White Monkshood	19.14	0.35	G3	54
		Scutellaria saxatilis	Rock Skullcap	14.42	0.23	G3	62
		Lathyrus ochroleucus	Pale Vetchling	13.31	0.32	G4	41
		Aconitum uncinatum	Blue Monkshood	12.31	0.30	G4	41
		Polygonum robustius	Robust Knotweed	11.02	0.50	G4	22
		Cardamine rotundifolia	American Bittercress	10.01	0.91	G4	11
		Ceratophyllum echinatum	Prickly Hornwort	9.66	0.37	G4	26
	Monocot						
		Carex oronensis	Orono Sedge	27.51	0.45	G2	61
		Platanthera hookeri	Hooker Orchis	16.2	0.14	G4	120
		Carex Lupuliformis	False Hop Sedge	14.12	0.11	G3	132
		Scirpus pedicellatus	Stalked Bulrush	10.48	0.37	G4	28
		Potamogeton vaseyi	A Pondweed	9.9	0.11	G4	90
		Cyperus houghtonii	Houghton's Umbrella-sedge	9.13	0.21	G4	43
		Listera australis	Southern Twayblade	7.84	0.33	G3	24
	Ferns						
		Botrychium oneidense	Blunt-lobe Grape Fern	25.34	0.34	G4	74
		Isoetes engelmannii	Appalachian Quillwort	11.29	0.59	G4	19
Vertebrates							
	Fish						
		Ichthyomyzon bdellium	Ohio Lamprey	38.89	0.49	G3	79
		Etheostoma percnurum	Duskytail Darter	20.75	0.83	G1	25
		Percina macrocephala	Longhead Darter	16.77	0.36	G3	47
		Percina copelandi	Channel Darter	16.06	0.24	G4	66
	Mammals						
		Myotis septentrionalis	Northern Myotis	54.99	0.14	G4	389
		Sylvilagus transitionalis	New England Cottontail	29.95	0.21	G3	145
	Herptiles						
		Cryptobranchus alleganiensis	Hellbender	36.47	0.31	G3	117
		Emydoidea blandingii	Blanding's Turtle	249.5	0.20	G4	1261
		Glyptemys insculpta	Wood Turtle	159.6	0.07	G3	2427
		Clonophis kirtlandii	Kirtland's Snake	5.1	0.51	G2	10
Invertebrates							
	Anthropods						
		Nesticus tennesseensis	A Cave Cobweb Spider	11.56	0.72	G3	16
	Insects						
		Lycaeides melissa samuelis	Karner Blue	43.1	0.39	G2	110
		Tachopteryx thoreyi	Gray Petaltail	18.07	0.23	G4	77
		Pieris virginiensis	West Virginia White	12.04	0.27	G3	44
		Rhionaeschna mutata	Spatterdock Darner	9.34	0.13	G4	74
	Mussel						
		Pleurobema oviforme	Tennessee Clubshell	62.46	0.59	G2	106
		Fusconaia barnesiana	Tennessee Pigtoe	56.93	0.46	G2	123
		Alasmidonta varicosa	Brook Floater	53.37	0.17	G3	307
		Lampsilis cariosa	Yellow Lampmussel	45.61	0.12	G3	371

Table 5.2.5. Preferential Species for Acidic Granitic Bedrock areas. The table gives examples of the 112 total preferential G1-G4 species.

Granitic					
Vascular plant	**Common Name**	**IV**	**% AE**	**RANK**	**Count**
Dicot					
Hottonia inflata	Featherfoil	30.32	0.20	G4	148
Utricularia resupinata	Northeastern Bladderwort	23.4	0.39	G4	60
Hudsonia ericoides	Golden Heather	15.64	0.74	G4	21
Minuartia glabra	Appalachian Sandwort	14.68	0.19	G4	77
Cardamine micranthera	Small Anthered-bittercress	13.28	0.32	G2	42
Geum peckii	Mountain Avens	12.92	0.34	G2	38
Vaccinium boreale	Alpine Blueberry	12.88	0.23	G4	57
Atriplex glabriuscula	Smoothish Orache	12.04	0.39	G4	31
Corydalis sempervirens	Pale Corydalis	11.44	0.72	G4	16
Paronychia argyrocoma var. albimontana	Silverling	10.44	0.65	G3	16
Monocot					
Isotria medeoloides	Small whorled poginia	40.28	0.21	G2	192
Potamogeton confervoides	Algae-like Pondweed	37.92	0.27	G3	138
Arethusa bulbosa	Arethusa	37.08	0.20	G4	187
Scirpus longii	Long's Bulrush	33.08	0.38	G2	87
Triphora trianthophora	Nodding Pogonia	25.36	0.20	G3	129
Calamagrostis pickeringii	Pickering's Reed Bentgrass	19.56	0.58	G4	34
Carex wiegandii	Wiegand Sedge	14.96	0.22	G3	69
Rhynchospora macrostachya	Large-spiked Beak-rush	11.64	0.55	G4	21
Potamogeton bicupulatus	Snail-seed Pondweed	7.92	0.21	G4	38
Carex cumulata	Piled up Sedge	7.72	0.13	G4	58
Cyperus granitophilus	Granite-loving Flatsedge	5.04	0.84	G3	6
Ferns					
Isoetes acadiensis	Acadian Quillwort	6.24	0.57	G3	11
Vertebrates					
Fish					
Phenacobius teretulus	Kanawha Minnow	23.32	0.49	G3	48
Notropis bifrenatus	Bridle Shiner	21.92	0.10	G3	213
Percina rex	Roanoke Logperch	5.92	0.16	G1	38
Herptiles					
Plethodon hubrichti	Peaks of Otter Salamander	9.24	0.84	G2	11
Invertebrates					
Insects					
Williamsonia lintneri	Ringed Bog Haunter	51.2	0.49	G2	105
Zanclognatha martha	Pine Barrens Zanclognatha	19.12	0.28	G4	68
Callophrys hesseli	Hessel's hairstreak	15.88	0.28	G3	57
Neonympha mitchellii	Mitchell's Satyr	15.16	0.63	G2	24
Williamsonia fletcheri	Ebony Boghaunter	9.92	0.16	G3	63
Somatochlora georgiana	Coppery Emerald	7.92	0.61	G3	13
Mussel					
Margaritifera margaritifera	Eastern Pearlshell	15.36	0.19	G4	79

Table 5.2.6. Preferential Species for Mafic or Intermediate Bedrock areas. The table gives examples of the 57 total preferential G1-G4 species.

Mafic							
Vascular plant			**Common Name**	**IV**	**% AE**	**RANK**	**Count**
	Dicot						
		Houstonia longifolia	Longleaf Bluet	25.62	0.35	G4	73
		Pycnanthemum torrei	Torrey's Mountainmint	18.58	0.33	G2	57
		Hydrastis canadensis	Golden Seal	17.12	0.17	G4	98
		Limosella australis	Mudwort	14.5	0.19	G4	75
		Juglans cinerea	Butternut	14.26	0.11	G3	129
		Bidens eatonii	Eaton's Beggarticks	13.54	0.33	G2	41
		Ranunculus allegheniensis	Allegheny Crowfoot	10.72	0.28	G4	38
		Pycnanthemum clinopodioides	Basil Mountainmint	10.48	0.25	G1	42
		Megalodonta beckii	Beck Water-marigold	10.38	0.13	G4	77
		Adlumia fungosa	Allegheny Vine	10.12	0.10	G4	98
	Monocot						
		Carex polymorpha	(variable) Sedge	25.74	0.21	G3	121
		Platanthera flava	Pale Green Orchis	9.34	0.15	G4	61
		Carex meadii	Mead's Sedge	6.84	0.19	G4	36
		Poa fernaldiana	Wavy Bluegrass	6.32	0.23	G2	28
		Paspalum laeve	Field Beadgrass	5.92	0.33	G4	18
		Triglochin gaspensis	Gaspe Arrow-grass	5.64	0.94	G3	6
		Dryopteris goldiana	Goldie's Fern	20.34	0.13	G4	161
	Ferns						
		Huperzia appalachiana	Appalachian Fir-clubmoss	16.18	0.34	G4	47
Invertebrates							
	Insects						
		Gomphus abbreviatus	Spine-crowned Clubtail	9.88	0.10	G3	102
	Mussels						
		Ligumia nasuta	Eastern Pond Mussel	13.18	0.07	G4	197

Table 5.2.7. Preferential Species for Acidic Shale Bedrock areas. The table gives examples of the 38 total preferential G1-G4 species.

Acidic Shale					
Vascular plant (43)	**Common Name**	**IV**	**% AE**	**RANK**	**Count**
Dicot (26)					
Trifolium virginicum	Kate's Mountain Clover	149.03	0.87	G3	171
Arabis serotina	Shale Barren Rockcress	69.63	0.77	G2	91
Oenothera argillicola	Shale Barren Evening-primrose	61.58	0.58	G3	106
Taenidia montana	Mountain Parsley	38.03	0.54	G3	71
Phlox buckleyi	Swordleaf Phlox	27.22	0.50	G2	54
Prunus alleghaniensis	Alleghany Plum	19.19	0.23	G4	83
Penstemon canescens	Gray Beardtongue	19.13	0.47	G4	41
Clematis viticaulis	Millboro Leatherflower	15.74	0.87	G2	18
Helianthus laevigatus	Smooth Sunflower	14.74	0.82	G4	18
Scutellaria parvula var. missouriensis	Shale Barren Skullcap	10.11	0.37	T4	27
Antennaria virginica	Shale Barren Pussytoes	8.6	0.43	G4	20
Monocot (10)					
Allium oxyphilum	Lillydale Onion	16.04	0.57	G2	28
Vertebrates					
Fish					
Notropis semperasper	Roughhead Shiner	28.62	0.84	G2	34
Noturus gilberti	Orangefin Madtom	5.39	0.23	G2	23
Invertebrates					
Insect					
Euchloe olympia	Olympia Marble	40.52	0.63	G4	64
Pyrgus wyandot	Appalachian grizzled skipper	20.76	0.65	G1	32
Mussel					
Pleurobema collina	James Spinymussel	176.47	0.63	G1	279
Elliptio lanceolata	Yellow Lance	21.89	0.30	G2	73
Elliptio producta	Atlantic Spike	9.46	0.43	G3	22
Fusconaia masoni	Atlantic Pigtoe	8.9	0.30	G2	30

Table 5.2.8. Preferential Species for Ultramafic Bedrock areas. The table gives examples of the 18 total preferential G1-G4 species.

Ultramafic							
Vascular plant			**Common Name**	**IV**	**% AE**	**RANK**	**Count**
	Dicot						
		Symphyotrichum depauperatum	Serpentine Aster	42.9	0.89	G2	48
		Talinum teretifolium	Roundleaf Fameflower	26.92	0.69	G4	39
		Moehringia macrophylla	Largeleaf Sandwort	19.95	0.74	G45	27
		Packera anonyma	Small's Ragwort	14.95	0.65	G45	23
		Sanguisorba canadensis	Canada Burnet	10.89	0.19	G45	56
		Ageratina aromatica	Lesser Snakeroot	6.92	0.17	G45	40
		Helenium brevifolium	Shortleaf Sneezeweed	5.97	0.40	G4	15
	Monocot						
		Fimbristylis annua	Annual Fimbry	14.96	0.68	G45	22
		Dichanthelium oligosanthes	Heller's Witchgrass	12.92	0.32	G45	41
		Sporobolus heterolepis	Northern Dropseed	8.946	0.33	G45	27
		Deschampsia cespitosa	Tufted Hairgrass	8.942	0.31	G45	29
		Lilium grayi	Gray's Lily	5.94	0.20	G3	30
	Ferns						
		Adiantum viridimontanum	Green Mountain Maidenhair-fern	6.986	1.00	G2	7
Invertebrates							
	Insects						
		Anthocharis midea	Falcate Orangetip	5.98	0.60	G4	10

Table 5.2.9. Preferential Species for Fine-grained Mud and Silt Deep Surficial Sediment. The table gives examples of the 10 total preferential G1-G4 species.

Fine Sediment							
Vascular plant			**Common Name**	**IV**	**% AE**	**RANK**	**Count**
	Dicot						
		Kalmia angustifolia	Sheep Laurel	24.3	0.71	G45	34
		Verbena scabra	Sandpaper Vervain	11.05	0.58	G45	19
		Lilaeopsis carolinensis	Carolina Lilaeopsis	10.35	0.80	G3	13
		Stewartia ovata	Mountain Camellia	9.1	0.51	G4	18
		Lobelia elongata	Elongated Lobelia	6.65	0.95	G4	7
	Monocot						
		Rhynchospora alba	White Beakrush	7.1	0.39	G45	18
		Schoenoplectus subterminalis	Water Bulrush	6.4	0.12	G4	52
Vertebrates							
	Herptiles						
		Siren intermedia	Lesser Siren	9.25	0.62	G45	15
		Crotalus horridus atricaudatus	Canebrake Rattlesnake	5.45	0.50	G45	11

Table 5.2.10. Preferential Species for the Very High Elevation zone (>3600'). The table gives examples of the 31preferential G1-G4 species. It has the highest density of preferential species in the Northeast.

>3600' Very High Elevation					
Vascular plant (19)	**Common Name**	**IV**	**% AE**	**RANK**	**Count**
Dicot					
Vaccinium boreale	Alpine Blueberry	39.86	0.70	G4	57
Betula minor	Dwarf White Birch	25.93	0.93	G3	28
Geum peckii	Mountain Avens	23.91	0.63	G2	38
Solidago cutleri	Cutler's Alpine Goldenrod	17.95	0.94	G4	19
Prenanthes boottii	Boott's Rattlesnake Root	15.96	0.94	G2	17
Heuchera alba	White Alumroot	15.9	0.41	G2	39
Ilex collina	Long-stalk Holly	12.93	0.45	G3	29
Monocot					
Poa fernaldiana	Wavy Bluegrass	25.93	0.93	G2	28
Vertebrates					
Herptiles (5)					
Plethodon nettingi	Cheat Mountain Salamander	63.8	0.79	G2	81
Plethodon punctatus	Cow Knob Salamander	25.88	0.55	G3	47
Birds (1)					
Catharus bicknelli	Bicknell's Thrush	51.77	0.54	G4	95

Table 5.2.11. Preferential Species for the High Elevation zone (2500'-3600'). The table gives examples of the 72 preferential G1-G4 species.

2500' to 3600' High Elevation					
Vascular plant (35)	**Common Name**	**IV**	**% AE**	**RANK**	**Count**
Dicot					
Trifolium stoloniferum	Running Buffalo Clover	35.93	0.63	G3	57
Aconitum reclinatum	White Monkshood	30.98	0.57	G3	54
Vaccinium macrocarpon	Large Cranberry	22.3	0.60	G4	37
Euphorbia purpurea	Darlington's Glade Spurge	17.85	0.29	G3	61
Sorbus decora	Northern Mountain-ash	15.32	0.43	G4	36
Paronychia argyrocoma	Silverling	13.74	0.21	G4	67
Solidago roanensis	Roan Mountain Goldenrod	11.62	0.58	G4	20
Monocot					
Lilium grayi	Gray's Lily	17.43	0.58	G3	30
Listera smallii	Kidneyleaf Twayblade	15.49	0.57	G4	27
Cleistes bifaria	Spreading Pogonia	10.45	0.36	G4	29
Carex aestivalis	Summer Sedge	10.09	0.21	G4	48
Ferns					
Huperzia appalachiana	Appalachian Fir-clubmoss	18.11	0.39	G4	47
Thelypteris simulata	Bog Fern	11.28	0.30	G4	38
Vertebrates					
Mammals (2)					
Sylvilagus obscurus	Appalachian Cottontail	16.02	0.31	G4	52
Sorex dispar	Long-tailed Or Rock Shrew	13	0.25	G4	53
Invertebrates					
Invertebrates (27)					
Neonympha mitchellii	Mitchell's Satyr	19.55	0.81	G2	24

Table 5.2.12. Preferential Species for the Coastal zone (0’-20’). The table gives examples of the 177 preferential G1-G4 species

0' to 20' Coastal							
Vascular plant (119)			**Common Name**	**IV**	**% AE**	**RANK**	**Count**
	Dicot						
		Polygonum glaucum	Seabeach knotweed	145.5	0.89	G3	164
		Bidens bidentoides	Delmarva Beggar-ticks	86.47	0.91	G3	95
		Limosella australis	Mudwort	64.64	0.86	G4	75
		Amaranthus pumilus	Seabeach amaranth	52.68	0.92	G2	57
		Plantago cordata	Heartleaf Plantain	49.57	0.84	G4	59
		Helianthemum dumosum	Bushy Rockrose	47.81	0.30	G3	158
		Cardamine longii	Long's Bitter Cress	42.8	0.78	G3	55
		Bidens hyperborea	Estuary Beggarticks	42.21	0.88	G2	48
		Bidens eatonii	Eaton's Beggarticks	38.62	0.94	G2	41
		Amelanchier nantucketensis	Nantucket Juneberry	33.72	0.31	G3	108
	Monocot						
		Eriocaulon parkeri	Estuary Hatpins	117.4	0.90	G3	131
		Sagittaria subulata	River-arrowhead	34.56	0.82	G4	42
		Carex hormathodes	Marsh Straw Sedge	34.38	0.76	G4	45
		Carex mitchelliana	Mitchell's Sedge	34.09	0.68	G3	50
		Rhynchospora scirpoides	Bald Rush, Beak-rush	33.61	0.26	G4	127
		Helonias bullata	Swamp Pink	33.31	0.17	G3	201
		Iris prismatica	Slender Blue Flag	33.29	0.41	G4	81
		Juncus megacephalus	Big-head Rush	23.55	0.94	G4	25
		Phragmites australis ssp. americanus	Common Reed	19.91	0.55	T4	36
		Fuirena pumila	Dwarf Umbrella-grass	16.41	0.21	G4	79
	Ferns						
		Schizaea pusilla	Curly Grass Fern	12.38	0.28	G3	45
Vertebrates							
	Herptiles (10)						
		Caretta caretta	Loggerhead	76.29	0.94	G3	81
		Dermochelys coriacea	Leatherback	15.07	0.94	G2	16
		Crotalus horridus pop. 2	Timber Rattlesnake - Coastal Plain Popula	14.2	0.46	G4	31
		Lepidochelys kempii	Kemp's Or Atlantic Ridley	10.36	0.94	G1	11
	Birds						
		Charadrius melodus	Piping plover	466.9	0.90	G3	518
		Sterna dougallii	Roseate Tern	176.8	0.92	G4	193
		Sternula antillarum	Least Tern	172	0.83	G4	207
		Falco peregrinus	Peregrine Falcon	86.55	0.22	G4	386
		Calidris canutus	Red Knot	79.11	0.94	G4	84
		Ammodramus caudacutus	Saltmarsh Sharp-tailed Sparrow	79.06	0.93	G4	85
		Ammodramus maritimus	Seaside Sparrow	40.50	0.94	G4	43
		Rallus elegans	King Rail	24.46	0.31	G4	78
		Laterallus jamaicensis	Black rail	23.43	0.87	G4	27
	Fish						
		Acipenser brevirostrum	Shortnose sturgeon	35.09	0.70	G3	50
		Acipenser oxyrinchus	Atlantic sturgeon	15.01	0.88	G3	17
Invertebrates							
	Invertebrates						
		Papaipema sulphurata	Decodon Stem Borer Moth	24.06	0.28	G2	85
		Problema bulenta	Rare skipper	21.55	0.86	G2	25
		Cicindela puritana	Puritan tiger beetle	10.67	0.27	G1	40
		Euphyes dukesi	Dukes' Skipper	10.36	0.94	G3	11
		Spartiniphaga inops	Spartina Borer	10.24	0.79	G3	13
	Mussel						
		Leptodea ochracea	Tidewater mucket	36.26	0.27	G3	133

Table 5.2.13. Preferential Species for the Cliffs and Steep Slopes. The table gives examples of the preferential G1-G4 species.

Cliff and Steep Slopes							
Vascular plant			**Common Name**	**IV**	**% AE**	**Rank**	**Count**
	Dicot						
		Clematis occidentalis	Purple Clematis	34.72	0.27	G45	128
		Arabis missouriensis	Green Rock-cress	26.56	0.18	G45	144
		Campanula rotundifolia	American Harebell	22.47	0.42	G45	53
		Arabis serotina	Shale Barren Rockcress	22.09	0.24	G2	91
		Solidago simplex var. monticola	Sticky Goldenrod	18.71	0.65	T4	29
		Geum peckii	Mountain Avens	18.62	0.49	G2	38
		Paxistima canbyi	Canby's Mountain-lover	18.39	0.30	G2	61
		Juglans cinerea	Butternut	17.71	0.14	G3	129
		Oenothera argillicola	Shale Barren Evening-primrose	16.94	0.16	G3	106
		Thuja occidentalis	Northern White Cedar	8.48	0.16	G45	52
	Monocot						
		Carex eburnea	Ebony Sedge	17.51	0.36	G45	49
		Carex scirpoidea	Bulrush Sedge	15.61	0.40	G45	39
		Poa fernaldiana	Wavy Bluegrass	14.72	0.53	G2	28
		Luzula spicata	Spiked Woodrush	13.78	0.63	G45	22
		Calamagrostis stricta ssp. inexpansa	Bentgrass	11.59	0.28	GU	41
		Melica nitens	Three-flower Melic Grass	11.53	0.25	G45	47
		Agrostis borealis	Boreal Bentgrass	10.73	0.40	GU	27
		Hierochloe alpina	Alpine Sweet Grass	10.72	0.38	GU	28
		Carex aestivalis	Summer Sedge	10.52	0.22	G4	48
		Milium effusum	Tall Millet Grass	10.28	0.14	G45	72
	Ferns						
		Dryopteris fragrans	Fragrant Cliff Fern	21.48	0.41	G45	52
		Woodsia glabella	Smooth Cliff Fern	17.67	0.54	G45	33
		Huperzia appalachiana	Appalachian Fir-clubmoss	16.53	0.35	G4	47
		Cheilanthes eatonii	Eaton's Lipfern	13.72	0.49	G45	28
		Diplazium pycnocarpon	Glade Fern	12.22	0.16	G45	78
		Pellaea atropurpurea	Purple Cliffbrake	10.53	0.22	G45	47
Vertebrates							
	Birds						
		Falco peregrinus	Peregrine Falcon	127.26	0.34	G4	374
		Aquila chrysaetos	Golden Eagle	18.69	0.60	G45	31
	Mammals						
		Neotoma magister	Allegheny Woodrat	124.06	0.25	G3	494
		Corynorhinus townsendii virginianus	Virginia Big-eared Bat	15.26	0.21	G45	74
		Microtus chrotorrhinus	Rock Vole	8.68	0.27	G4	32
		Sorex dispar	Long-tailed Or Rock Shrew	6.47	0.12	G4	53
	Reptiles						
		Crotalus horridus	Timber Rattlesnake	205.62	0.28		738
		Eumeces anthracinus	Coal Skink	10.46	0.19	G45	54

Appendix 5.3 Other Species names used in the text

Common Name	**Standard name**
Allegheny Woodrat	*Neotoma magister*
Alpine Azalea	*Loiseleuria procumbens*
Anarta Noctuid Moth	*Anarta melanopa*
Annual Fimbry	*Fimbristylis annua*
Appalachian Azure	*Celastrina neglectamajor*
Appalachian Firmoss	*Huperzia appressa*
Appalachian grizzled skipper	*Pyrgus Wyandot*
Appalachian Trail Lichen	*Ramalina petrina*
Appalachian Woodsia	*Woodsia appalachiana*
Black Rail	*Laterallus jamaicensis*
Black-stem Spleenwort	*Asplenium resiliens*
Bog Copper	*Lycaena epixanthe*
Bog Fern	*Thelypteris simulate*
Bryohaplocladium microphyllum	*Bryohaplocladium microphyllum*
Cambarus crayfish	*Cambarus veteranus*
Carolina sphagnum	*Sphagnum carolinianum*
Cave Salamander	*Eurycea lucifuga*
Cheat Mountain Salamander	*Plethodon netting*
Chowanoke Crayfish	*Orconectes virginiensis*
Coastal Barrens Buckmoth	*Hemileuca maia maia*
Common Loon	*Gavia immer*
Copperbelly Water Snake	*Nerodia erythrogaster neglecta*
Copperhead	*Agkistrodon contortrix*
Creek Heelsplitter	*Lasmigona compressa*
Crested Coralroot	*Hexalectris spicata var. spicata*
Currant Spanworm	*Itame ribearia*
Deer's Hair Sedge	*Trichophorum caespitosum*
Depressed Glyph	*Glyphyalinia virginica*
Eastern Spadefoot	*Scaphiopus holbrookii*
Elongated Lobelia	*Lobelia elongate*
Fence Lizard	*Sceloporus undulates*
Roundleaf fameflower	*Talinum teretifolium*
Golden Darter	*Etheostoma denoncourti*
Gray Myotis	*Myotis grisescens*
Green Mountain madenhair-fern	*Adiantum viridimontanum*
Ground Skink	*Scincella lateralis*
Hart's-tongue Fern	*Asplenium scolopendrium var.americanum*
Holsinger's Cave Isopod	*Caecidotea holsingeri*
Indian Milk-vetch	*Astragalus australis*
Indian's dream	*Aspidotis densa*
Inland Silverside	*Menidia beryllina*
James Spinymussel	*Pleurobema collina*
Joyful Holomelina moth	*Holomelina laeta*
Kanawha Minnow	*Phenacobius teretulus*
Lake Erie Water Snake	*Nerodia sipedon insularum*
Largeleaf Sphagnum	*Sphagnum macrophyllum*
Lilypad Clubtail	*Arigomphus furcifer*
Lined Topminnow	*Fundulus lineolatus*
Loggerhead	*Caretta caretta*

Maritime Shrew	*Sorex maritimensis?*
Mountain Spleenwort	*Asplenium montanum*
Mud Salamander	*Pseudotriton montanus*
Narrowleaf Peatmoss	*Sphagnum angustifolium*
NE beach tiger beetle	*Cicindela patruela consentanea*
New England Siltsnail	*Cincinnatia winkleyi*
Northern Appressed Clubmoss	*Lycopodiella subappressa*
Northern Clearwater Crayfish	*Orconectes propinquus*
Northern flying squirrel	*Glaucomys sabrinus*
Northern Monk's-hood	*Aconitum noveboracense*
Northern Red-bellied Cooter	*Pseudemys rubriventris pop 1*
Northern Redbelly Dace	*Phoxinus eos*
Organ Cavesnail	*Fontigens tartarea*
Pennsylvania ostrich fern	*Matteuccia struthiopteris var. pens*
Peregrine Falcon	*Falco peregrines*
Philadelphia Vireo	*Vireo philadelphicus*
Pine Barren Gentian	*Gentiana autumnalis*
Pink Papershell	*Potamilus ohiensis*
Piping Plover	*Charadrius melodus*
Plains Clubtail	*Gomphus externus*
Prairie Vole	*Microtus ochrogaster*
Price's Cave Isopod	*Caecidotea pricei*
Pseudanophthalmus Cave beetles	*Pseudanophthalmus spp.*
Pseudanophthalmus delicatus	*Pseudanophthalmus delicates*
Purple Sedge	*Carex purpurifera*
Rafinesque's Big-eared Bat	*Corynorhinus rafinesquii*
Red Peatmoss	*Sphagnum rubellum*
Red-breasted Nuthatch	*Sitta Canadensis*
Red-cockaded Woodpecker	*Picoides borealis*
Roughhead shiner	*Notropis semperasper*
Seabeach knotweed	*Polygonum glaucum*
Serpentine aster	*Symphyotrichum depauperatum*
Shalebarren Pussytoes	*Antennaria virginica*
Shenandoah Salamander	*Plethodon Shenandoah*
Silverling	*Paronychia argyrocoma var. albimontana*
Slenderhead Darter	*Percina phoxocephala*
Slimy Salamander	*Plethodon glutinosus*
Slimy Sculpin	*Cottus cognatus*
Small Yellow Lady's-slipper	*Cypripedium calceolus var. parviflo*
Small's ragwort	*Packera anonyma*
Smooth Cliff Brake	*Pellaea glabella ssp. Glabella*
Smooth Softshell	*Apalone mutica*
Southern Leopard Frog	*Rana sphenocephala*
Spiny Riversnail	*Io fluvialis*
Swamp Fly-honeysuckle	*Lonicera oblongifolia*
Tidewater interstitial amphipod	*Stygobromus araeus*
Timber Rattlesnake	*Crotalus horridus*
Virginia Big-eared Bat	*Corynorhinus townsendii virginianus*
Virginia Northern Flying Squirrel	*Glaucomys sabrinus fuscus*
Virginia Pigtoe	*Lexingtonia subplana*
White Mountain Fritillary	*Boloria chariclea montinus*
Wood Turtle	*Glyptemys insculpta*

CHAPTER

Streams and Rivers

6

Condition and Conservation Status

Feb 2023

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Stream and River Conservation: The region contains over 200,000 miles of streams and rivers, draining three major basins and supporting thousands of species. In total, 23% of all stream miles are locally conserved including 18% of critical stream riparian area of which 75% is still in natural cover. However, only 6% of stream miles meet upstream watershed conservation targets needed to achieve integrated protection. Thus 75% of locally protected streams and rivers do not have enough conserved upstream watershed to protect them from accumulated upstream impacts and overall 94% of streams and rivers do not meet integrated protection. Integrated protection varies by stream type with streams (7%) achieving the most followed by rivers (2%), tidal streams and rivers (1%), and big rivers (0%).

Loss versus Conservation: Riparian areas have lost more habitat through conversion (25%) to agriculture and development than has been conserved (18%), equivalent to 1.4 acres converted for every acre conserved. Over the last decade, however, riparian conservation surpassed habitat conversion almost 4 to 1 reversing the historic trend. Eight states have designated Tier 3 Outstanding National Resource Waters that prohibit new or increased discharge and two more states have designated other waters with medium level water quality protection. Three states have instream flow statues and eight have instream flow requirements. Over 1,500 miles of federally designated Wild and Scenic Rivers provide protection for habitat and connectivity.

Connectivity and Hydrologic Alteration: Historically 74% of all stream and river were embedded in huge, connected networks over 5,000 miles. Today, only 3% of miles are in these huge networks. The region's 14,000 dams fragment perennial stream networks into segments averaging 7 dams per 100 miles, not including the 15,000 small dams on tiny headwater streams. As a result, 86% of river miles are in networks less than a quarter of their pre-dam size, and 21% are less than 25 miles long. Further, 48% of streams and rivers are considered significantly altered in their hydrology, with alteration greatest on big rivers (66%). In the last decade, 346 dams have been removed, opening a minimum of 3,500 miles. Accounting for retrofitted or partially passable dams that increases to over 5,000 miles of newly connected stream and river habitat.

Impervious Surfaces and Nutrient Enrichment: All indicators of stream quality decline with increasing watershed imperviousness and nutrient enrichment. Over the last twenty years, streams and rivers highly impacted by impervious surfaces have increased from 21% to 24%, while undisturbed miles were reduced from 40% to 34%. Additionally, 75% of all miles now exceed EPA nitrogen criteria and 94% of all miles exceed EPA phosphorus criteria. Perhaps as a result, only 8% of the region's streams and rivers are predicted to be in good biological condition as measured by their benthic organisms.

Stream Biota: Nearly 500 non-indigenous aquatic species have been observed in the region and over 300, have established populations (mostly fish and plants). Brook trout have been a focus of conservation and 37% of their recognized strongholds have been secured with conservation land. Over the last decade, conservation has surpassed conversion in every identified brook trout strategy area, including in their identified strongholds (179 to 1) and areas to restore persistent populations (54 to 1).

Streams and rivers are flowing water ecosystems. For centuries, people have depended on them for drinking water, food, transportation, recreation, and more. As we work to balance human needs for water with the needs of stream biota, an assessment of their conservation status and condition is imperative. Here we examine these with respect to fragmentation, hydrologic alteration, nutrients, and biota.

Northeast streams and rivers range from tiny headwater streams to huge mainstem tidal rivers. Major streams and river types vary widely in their associated biota and these relationships described in the Northeast Aquatic Habitat Classification (NEAHC, Olivero and Anderson 2008), the Northeast Aquatic Habitat Guide (Anderson et al. 2013), and Eastern U.S. Stream Classification (McManamay et al. 2018).

Stream and rivers can be grouped into size classes based on their upstream drainage area which correlates with predictable changes in velocity, sediment, and biotic composition as they grow (Vannote et al. 1980, Figure 6.1.). For this report, we crosswalked the classes from the NEAHC to the three SWAP 2022 habitat lexicon target reporting types: Streams & Rivers, Big Rivers, and Tidal Streams & Rivers (Table 6.1.)

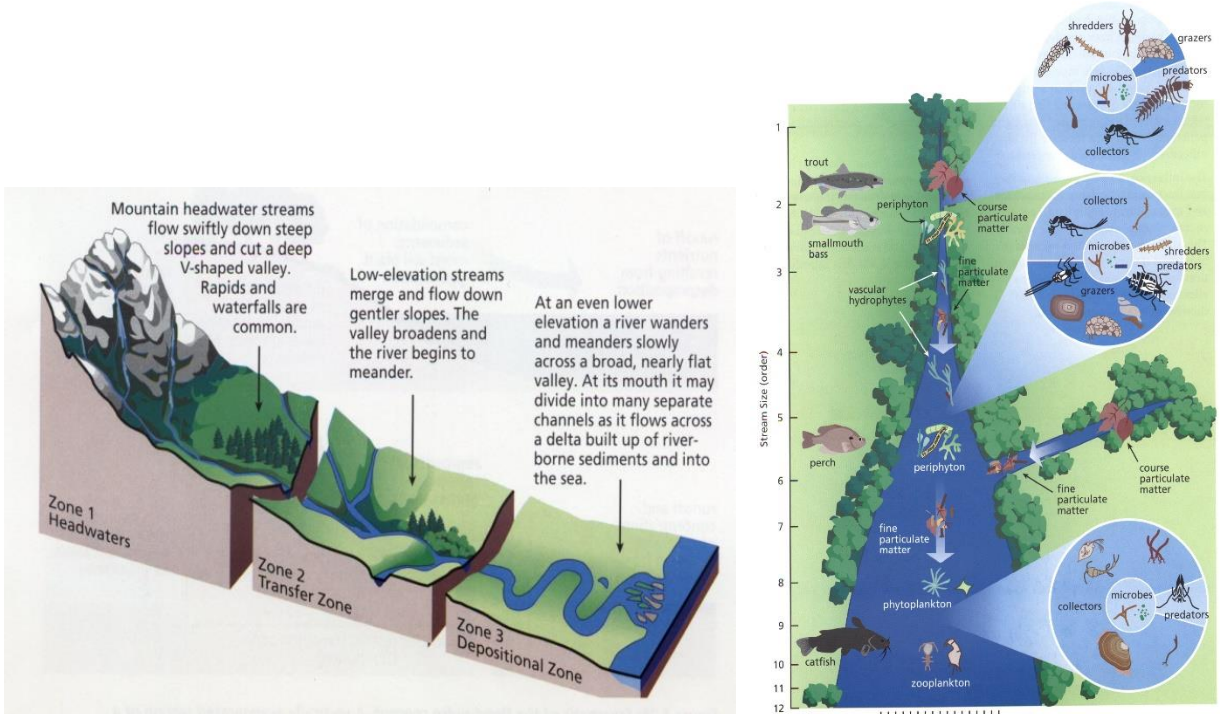
Table 6.1. Stream and River Size Classes

Lexicon Aquatic Habitat Types		**NEAHC Habitat Name**	**Upstream Drainage Area**
Streams & Rivers	Streams	Headwater	<10 sq.km
		Creek	10-100 sq.km.
	Rivers	Small Tributary	100-500 sq.km
		Medium Tributary	500-2,500 sq.km
		Mainstem River	2,500-10,000 sq.km
Big Rivers		Freshwater and Tidal Large to Great Rivers	>10,000 sq.km
Tidal Streams & Rivers		Tidal Streams	<100 sq.km.
		Tidal Rivers	100-10,000 sq.km

As streams increase in size, they increase in fish diversity and their species composition changes (Vannote et al., 1980). In this region, fish of small, cold, clear streams with rocky substrates include brook trout and slimy sculpin. In larger streams, cool water fish communities develop that include species such as blacknose dace, golden shiner, and white sucker. As rivers broaden and flatten, warm water fish communities occur until, in the lower tidal sections of large rivers the fish communities include a variety of anadromous, diadromous, and estuarine species (Anderson et al. 2013). Size based freshwater ecosystems further subdivide into variants based on variation in gradient, geology, and temperature class.

The biota associated with the physical variation is described in the full Northeast Stream Classification and Habitat Guide (Anderson et al. 2013). The region's freshwater ecosystems support over 300 species of freshwater and anadromous fish, over 100 species of freshwater mussels, over 100 species of freshwater snails, 36 species of crayfish, 91 species of amphibians, over 500 caddisfly, mayfly, stonefly, dragonfly or damselfly species, and a myriad of aquatic plants, algae, sponges, worms, other invertebrates and microscopic life (NatureServe 2022).

Figure 6. 1. River Continuum Concept (Vannote et al. 1980).



Basemap**:** We used the national dataset Medium Resolution 1:100,000 National Hydrography Dataset NHDPlusV21 data (USGS 2016) to map the extent of river and stream habitats and quantify the abundance of each type. The USGS National Hydrography Dataset (NHD) is a comprehensive national hydrography basemap that includes naturally occurring and constructed bodies of surface water. Its standard unique reach identifiers (COMID) relate to multiple federal and state databases used for reporting in the following sections of this chapter and in many other regional and national contexts.

Our analysis of distribution and trends is based on all streams and rivers with an *upstream drainage area of one square mile or larger*. Smaller streams are often intermittent and inconsistently mapped in the source data (e.g.,1:100,000 USGS topo quads) from which the NHD Medium Resolution was developed. This mapping threshold has been used in other regional scale studies (Anderson et al. 2013, Martin et al. 2017) to provide consistent and comparable metrics across the region's 14 states. As a result, the total miles of smallest headwater streams may be an underestimate in some places. Additionally, our estimate of river length do not include miles of the lakes, reservoirs, and ponds that some rivers pass through. These lentic systems are treated separately in the Lakes and Ponds chapter. The exception to this, are connectivity metrics in this chapter where we do add the centerlines for lotic systems to measure the length of the connected "freshwater network" between dams.

Distribution and Abundance

The region contains over 200,000 miles of streams and rivers that drain three major basins, the North Atlantic, Great Lakes, or Ohio-Mississippian (Map 6.1). Major river systems include the Penobscot, Kennebec, Merrimack, Connecticut, Hudson, Delaware, Susquehanna, Potomac, James, Roanoke, Allegheny, Monongahela, New River, and Ohio River.

The area includes portions of six freshwater ecoregions (Map 6.1, Abell et al. 2008).

1. Laurentian Great lakes,
2. Northeast US and Southeast Canada Atlantic Drainages,
3. Chesapeake Bay,
4. Teays-Old Ohio,
5. Appalachian Piedmont,
6. Tennessee.

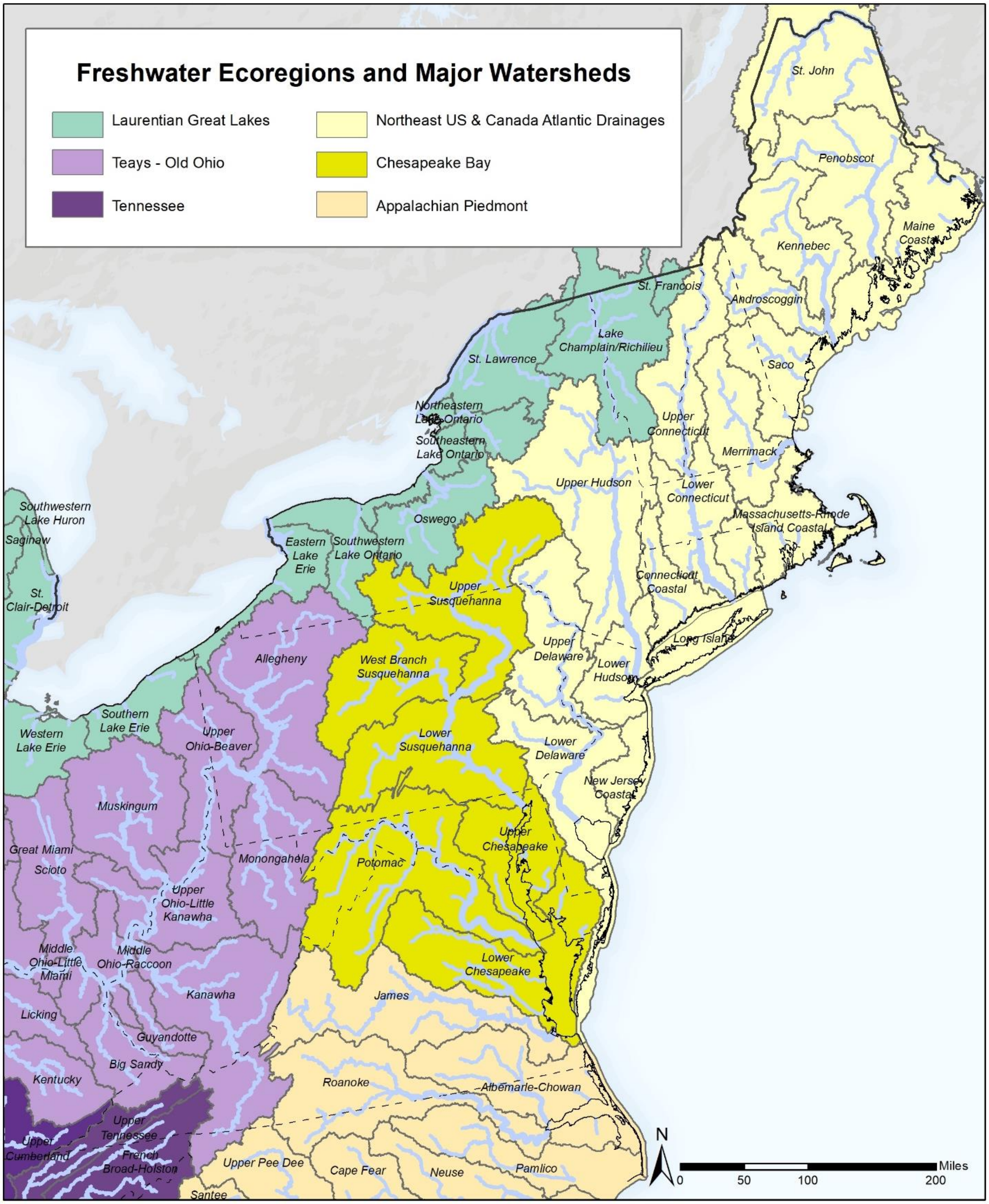
Only the Chesapeake Bay Ecoregions is fully within the NEAFWA region. The ecoregions differ in their freshwater fauna, physiography, and major river systems (Abell et al. 2008). The region is subdivided into 49 6-digit hydrologic units (HUC6) representing USGS delineated watersheds. Thirty-nine of these are primarily within the Northeast states and ten cross into adjacent states not covered here.

Headwater and creeks, make up 80% of all stream miles in the region. Small to mainstem rivers account for another 15% and tidal streams and rivers make up 4%. Big rivers account for 1% (Table 6.2, Map 6.2).

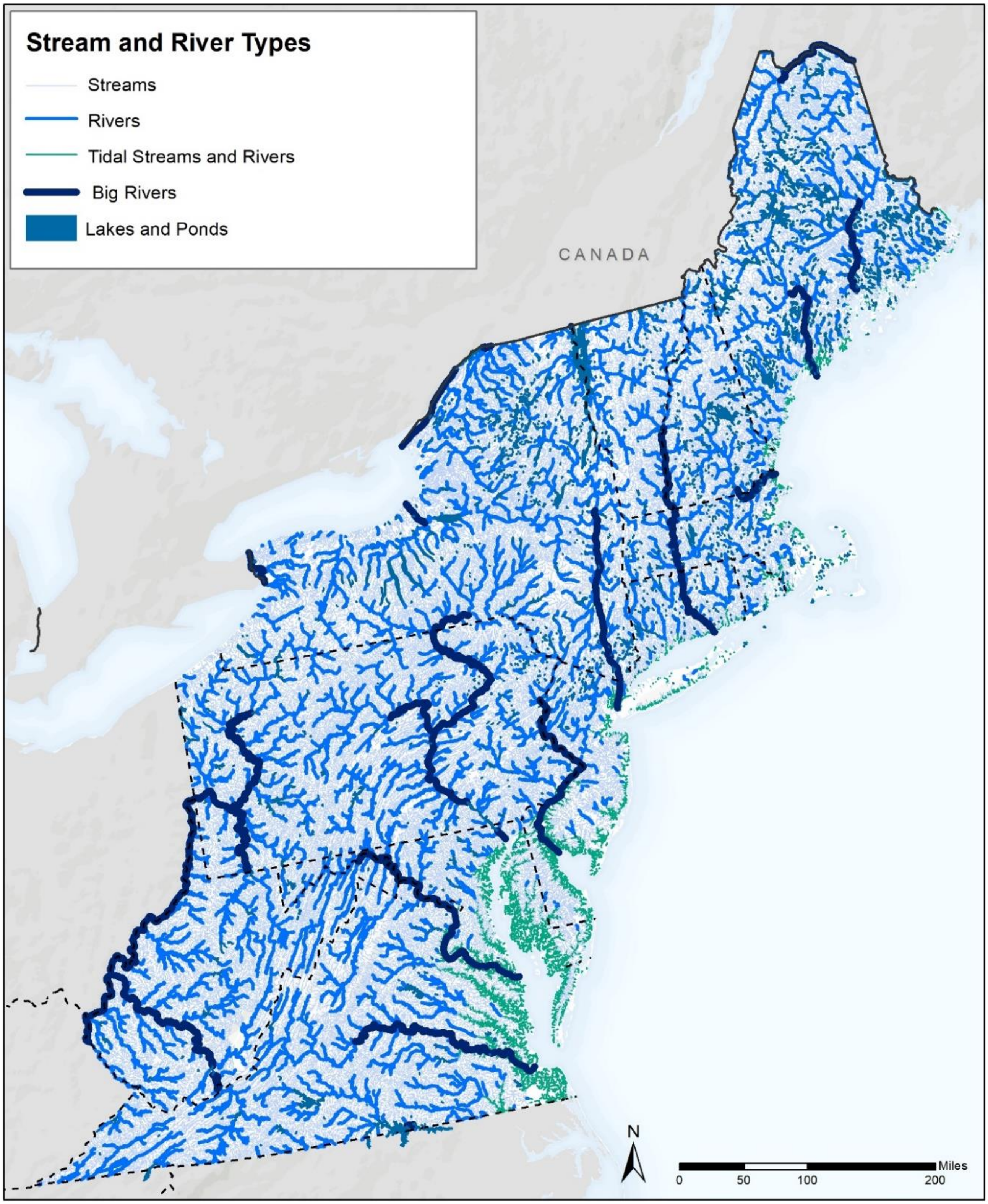
Table 6.2. Miles of Stream and River Types by State and Region *(Source NHD Medium Resolution 1:100,000). All stream and river arcs with >1 sq.mi. drainage area)*

MILES AND TYPES	CT	DC	DE	MA	MD	ME	NH	NJ	NY	PA	RI	VA	VT	WV	Total Miles
Headwaters	1,869	5	802	2,590	4,004	9,287	3,151	2,540	18,072	19,926	380	15,434	2,270	10,576	90,907
Creeks	1,470	3	383	1,967	2,182	9,021	2,605	1,870	15,307	14,063	217	11,290	3,067	7,268	70,712
Total Streams	**3,339**	**8**	**1,185**	**4,557**	**6,186**	**18,308**	**5,756**	**4,410**	**33,379**	**33,989**	**597**	**26,725**	**5,337**	**17,843**	**161,619**
Small Rivers	289	9	31	516	489	1,946	664	453	3,534	3,741	52	3,058	751	2,199	17,733
Medium Rivers	163		10	242	174	858	253	66	1,817	1,562	32	1,584	347	1,289	8,398
Mainstem Rivers	15				30	507	157	20	637	604		620	77	520	3,188
Total Rivers	**467**	**9**	**42**	**758**	**693**	**3,312**	**1,075**	**540**	**5,988**	**5,907**	**84**	**5,261**	**1,175**	**4,009**	**29,319**
1. TOTAL STREAMS AND RIVERS	**3,806**	**17**	**1,226**	**5,315**	**6,879**	**21,620**	**6,831**	**4,950**	**39,367**	**39,895**	**681**	**31,986**	**6,512**	**21,852**	**190,938**
Freshwater Big Rivers	10			89	70	191	45	38	189	642		146	41	517	1,976
Tidal Big Rivers	60	5	23	28	61	69		53	165	30		168			662
2. TOTAL BIG RIVERS	**69**	**5**	**23**	**117**	**131**	**260**	**45**	**90**	**354**	**673**	**0**	**314**	**41**	**517**	**2,638**
Tidal Streams	125	4	458	221	1,771	338	47	750	223	17	32	2,165			6,152
Tidal Rivers	80	8	126	86	632	170	26	332	67	34	28	679			2,268
3. TOTAL TIDAL STREAMS AND RIVERS	205	12	583	307	2,403	509	73	1,082	291	51	60	2,845	0	0	8,420
NORTHEAST TOTAL ALL STREAM AND RIVER TYPES	**4,081**	**35**	**1,833**	**5,739**	**9,413**	**22,388**	**6,949**	**6,122**	**40,011**	**40,619**	**740**	**35,144**	**6,552**	**22,370**	**201,996**

Map 6.1. Freshwater ecoregions and major rivers of the northeast United States.



Map 6.2. Streams and River Types. Major habitat types used in this report include 1. Streams (<100 sq.km drainage), 2. Rivers (100 sq.km – 10,000 sq.km), 3. Big Rivers (> 10,000 sq.km), and 4. Tidal Streams and Rivers.



Conservation Status of Streams and Rivers

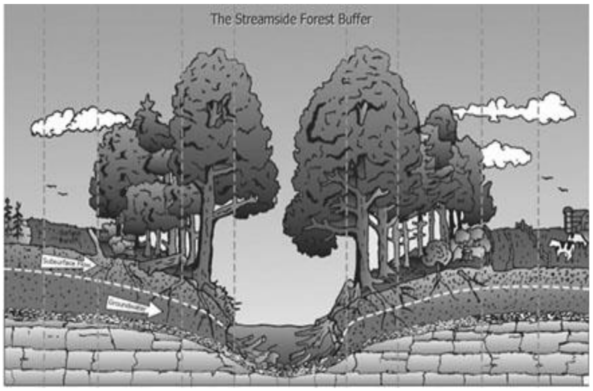
Conservation status is a measure of how well protected ecosystems are against future threats like conversion, fragmentation, or degradation. We define conservation as the establishment and implementation of mechanisms that help freshwater systems avoid future impacts to key ecological attributes for 25 years or more, have a high probability of renewal and enforceability, or have completely alleviated the potential for a future threat (Higgins et al. 2021). Key ecological attributes include habitat, water quality, hydrologic regime, and biotic composition (Karr 1991, Higgins et al. 2021). Assessing the degree of protection involves translating land conservation and policy to spatial extent. For this study we were able to assess three attributes, habitat conservation and water quality protection at a stream reach level, and flow protection at the state level.

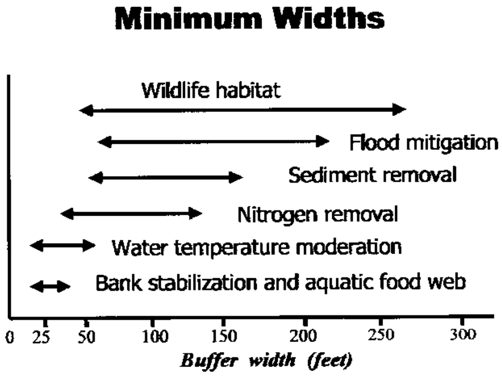
Habitat Conservation in the Riparian Zone

The riparian zone is the land area directly adjacent to a stream or river and subject to its influence. This dynamic zone is an ecologically rich environment supporting many rare and common species and numerous natural communities. Vegetated riparian zones also support adjacent aquatic systems through bank stabilization, water temperature moderation, nutrient filtering, and they are important sources of dissolved particulate and coarse organic matter (Figure 6. 2).

In this section, we assessed the riparian zone of each stream and river by creating a standard 100 m (~300 ft.) buffer on either side of each stream and river centerline line and/or 100 m landward from both shorelines of wider rivers mapped as polygons in the NHD basemap. The 100 m distance was chosen to encompass a broad range of the types of riparian functions noted for eastern riparian zones as one moves landward from the water interface (Palone et al. 1997).

Figure 6. 2. Riparian Zone Conceptual Model (Welsch 1991, Palone et al. 1997).





Land Cover Change in the Riparian Zone

Natural vegetated buffers along streams provide a suite of benefits to aquatic systems, while agricultural and urban development in the riparian zone is associated with elevated levels of nitrogen, phosphorus, sediment, pesticides, and bacteria in streams. We calculated the amount of agriculture and developed land within each 100 m riparian buffer zone by overlaying the 2011 and 2019 National Land Cover dataset (Dewitz and U.S. Geological Survey 2021).

Results of the overlay indicate that 75% of stream riparian land is in natural cover, 13% in agriculture, and 12% in developed cover (Table 6.3). The amount of riparian land in natural cover decreased with increasing stream size from a high of 76% for streams to a low of 64% for big rivers. Development showed the opposite pattern from natural cover, increasing from a low of 11% for headwaters to a high of 27% for big rivers. The percent of agricultural cover had a narrow range of variation across stream sizes, from a high of 13% for streams and rivers to low of 7% for tidal streams and rivers. New England and New York (80%) had slightly more natural riparian areas than the Mid-Atlantic (72%) and slightly less agriculture 11% vs. 14%). The pattern was similar for development: New England (10%), Mid-Atlantic (13%).

Table 6.3. Acres of Riparian Land by Cover Type and Conservation Status

Stratification	Agr. Acres	Dev. Acres	GAP 1 and 2 Acres	GAP 3 Acres	Unconserved Natural Acres	Total Acres
Tidal Streams & Rivers	-38,428	-99,262	50,326	71,678	272,686	532,379
Streams	-1,634,884	-1,359,216	641,517	1,590,091	7,246,420	12,472,128
Rivers	-275,923	-292,401	111,351	245,302	1,207,100	2,132,077
Big Rivers	-15,977	-46,253	11,161	21,865	75,842	171,099
NORTHEAST REGION	-1,965,213	-1,797,132	814,354	1,928,937	8,802,048	15,307,683
MID-ATLANTIC SUBREGION	-1,261,310	-1,162,910	306,261	1,108,790	4,933,107	8,772,378
NEW ENGLAND SUBREGION	-703,903	-634,222	508,093	820,148	3,868,941	6,535,305

Conservation in the Riparian Zone

To evaluate the conservation land in the nearshore riparian zone, we overlaid the TNC 2022 Conservation Lands data set on the 100 m riparian buffer zone. Results indicate that over 2.7 million acres of riparian buffer land was conserved, equivalent to 18% of all the riparian land in the region. Most of this (81%) was associated with small headwaters and creeks, which makes sense as these numerically dominate the region. Nearly 6% of riparian land was in GAP 1-2 land conserved for nature. New England and New York had 20% of their riparian land conserved with 8% conserved for nature, and the Mid-Atlantic had 16% conserved with 4% conserved for nature.

The **Conservation Risk Index (CRI)** is a measurement of the amount of natural land converted to development or agriculture in relation to the amount of land conserved, allowing us to evaluate if conservation is outpacing the loss to agricultural or developed land. CRI is calculated as the amount of agriculture and developed land divided by the amount of GAP 1-3 conservation land, and the stricter Nature Risk Index (NRI) is similar only divided solely by GAP 1-2 land conserved for nature. A ratio greater than one indicates more habitat loss than conserved and a ratio less than one indicates more conservation than conversion to development or agriculture.

Results across all streams and rivers indicate that riparian land was 25% converted to development or agriculture and 18% conserved, equivalent to 1.4 acres converted for every 1 acre conserved (CRI = 1.4, Table 6.4, Figure 6. 3). CRI was highest big rivers (1.9), followed by rivers (1.6), streams (1.3) and nearly equal in tidal streams and rivers (1.1). Big rivers had the highest overall loss to conversion (36%), whiles tidal streams and rivers had the largest proportion conserved (23%).

NRI ratios measuring conservation for nature (GAP 1-2) were much higher, with a regional average of 5 acres converted for every 1 acre conserved for nature (NRI = 4.6). Tidal rivers had the lowest NRI (2.7) while streams (4.7), rivers (5.1), and big rivers (5.6) had values at or above the regional mean (Table 6.4).

The Mid-Atlantic (1.7) had a higher CRI ratio than New England and New York (1.0). A few states such as ME, NH, and MA had ratios less than one indicating more conservation than conversion in the riparian zone. The NRI ratio showed similar patterns with the MidAtlantic (7.9) being higher than New England and New York (2.6) (Table 6.2, Figure 6. 3).

Table 6.4. Conservation Risk Index (CR) and% of Riparian Land Cover and Conservation Land

Stratification	Percent Converted (Dev & Ag)	Percent Protected (GAP 1 & 2)	Percent Conserved (GAP 1-3)	CRI	NRI
Tidal Streams & Rivers	25.9	9.5	22.9	1.1	2.7
Streams	24.0	5.1	17.9	1.3	4.7
Rivers	26.7	5.2	16.7	1.6	5.1
Big Rivers	36.4	6.5	19.3	1.9	5.6
NORTHEAST REGION	24.6	5.3	17.9	1.4	4.6
MID-ATLANTIC SUBREGION	27.6	3.5	16.1	1.7	7.9
NEW ENGLAND SUBREGION	20.5	7.8	20.3	1.0	2.6

Recent Trends in Riparian Shoreline Conservation

Over the last decade (2012-2022) there are some encouraging trends in riparian conservation. During this period conservation surpassed habitat conversion almost 4 to 1. Over 208,000 acres of riparian land was conserved and only 58,000 converted (CRI = 0.3), equivalent to 0.3 acres converted for every one conserved (Table 6.5, Figure 6. 4). The Mid-Atlantic (0.4) had a higher CRI ratio than New England and New York (0.1) but both were far below one. This pattern held true within every state except three: NY, DE, WV (Map 6.3). Although the trend is in the right direction, is has not yet reversed the overall trend of more habitat conversion than conservation in the riparian zone, and the way these two factors are distributed has stayed similar across stream and river types (Figure 6.4),

Figure 6. 3. The distribution of riparian land cover and conservation by stream type. In this chart, each bar represents the total area of riparian land in the habitat type. Land to the left of the center bar has been converted to development or agriculture; land to right of the center bar remains unconverted. Unconverted land is apportioned by conservation status and the% unconserved.

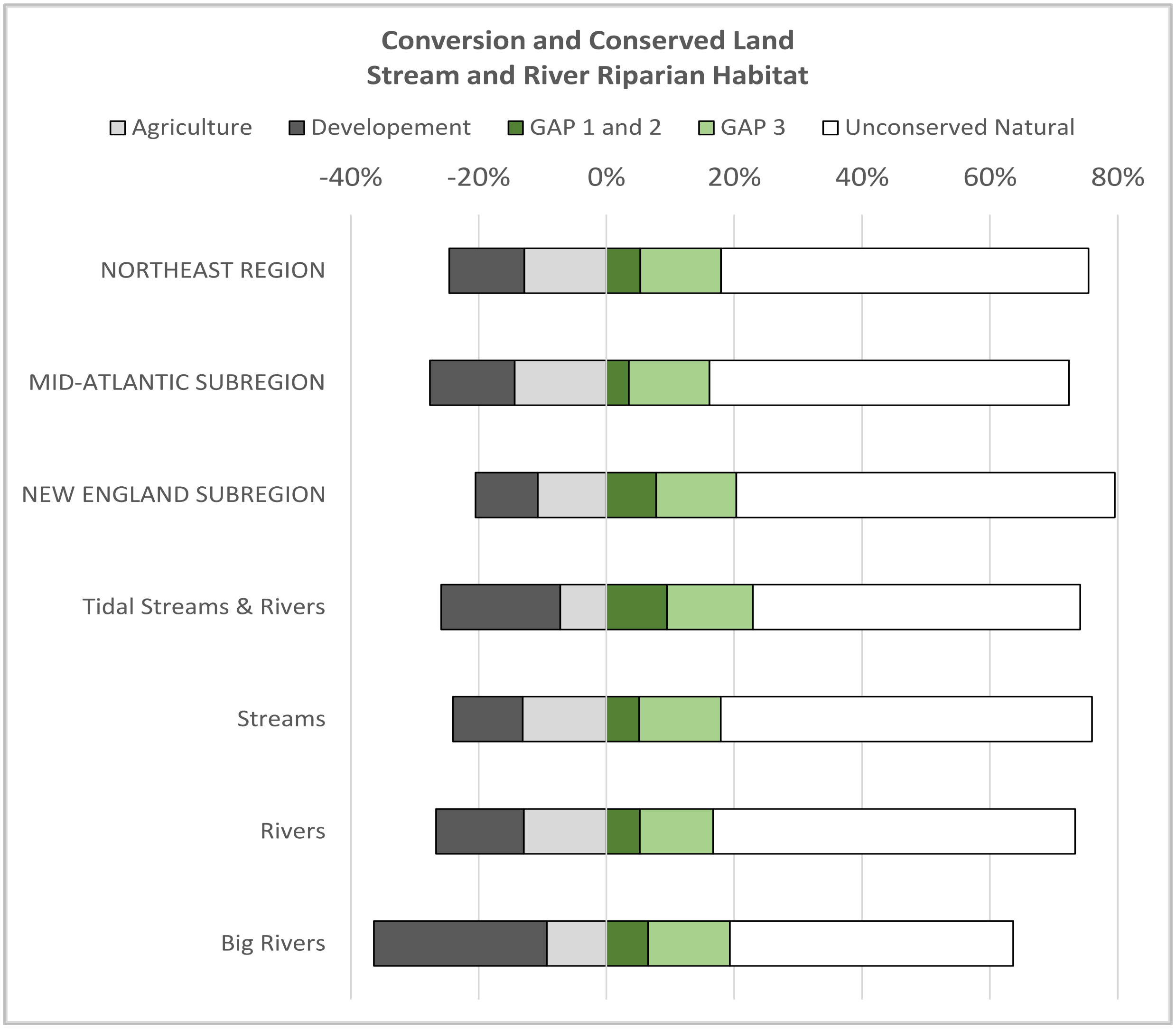


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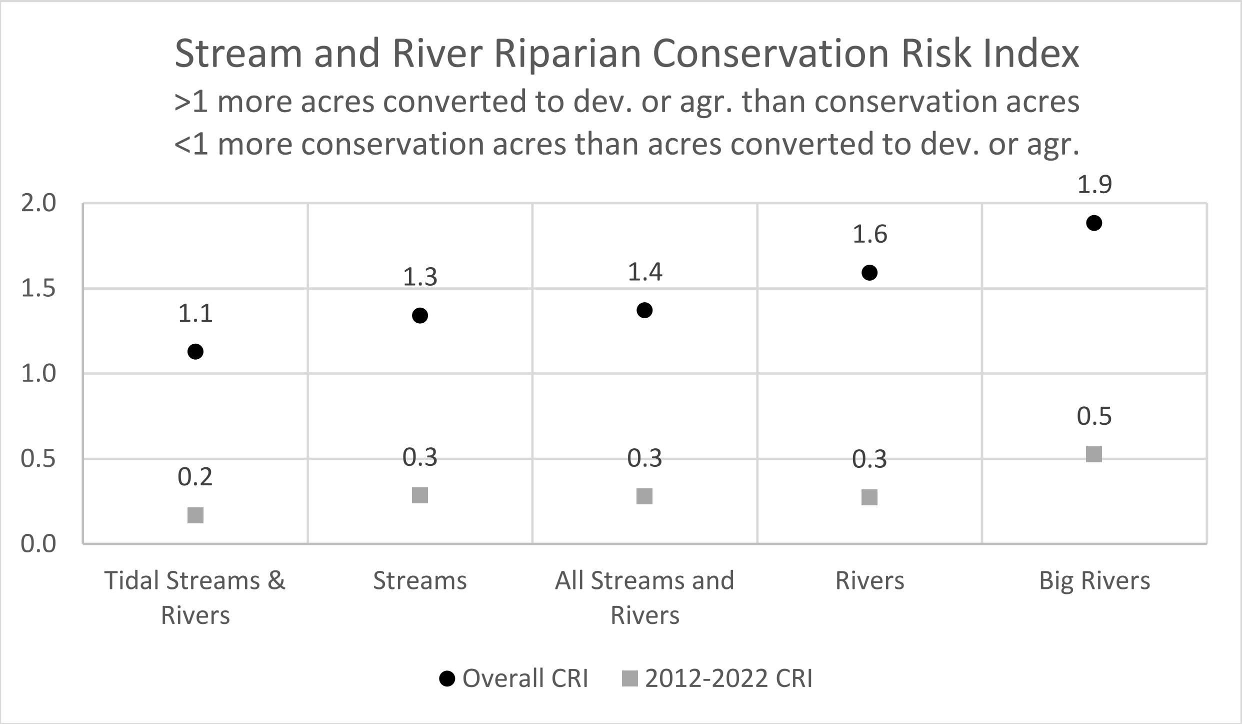
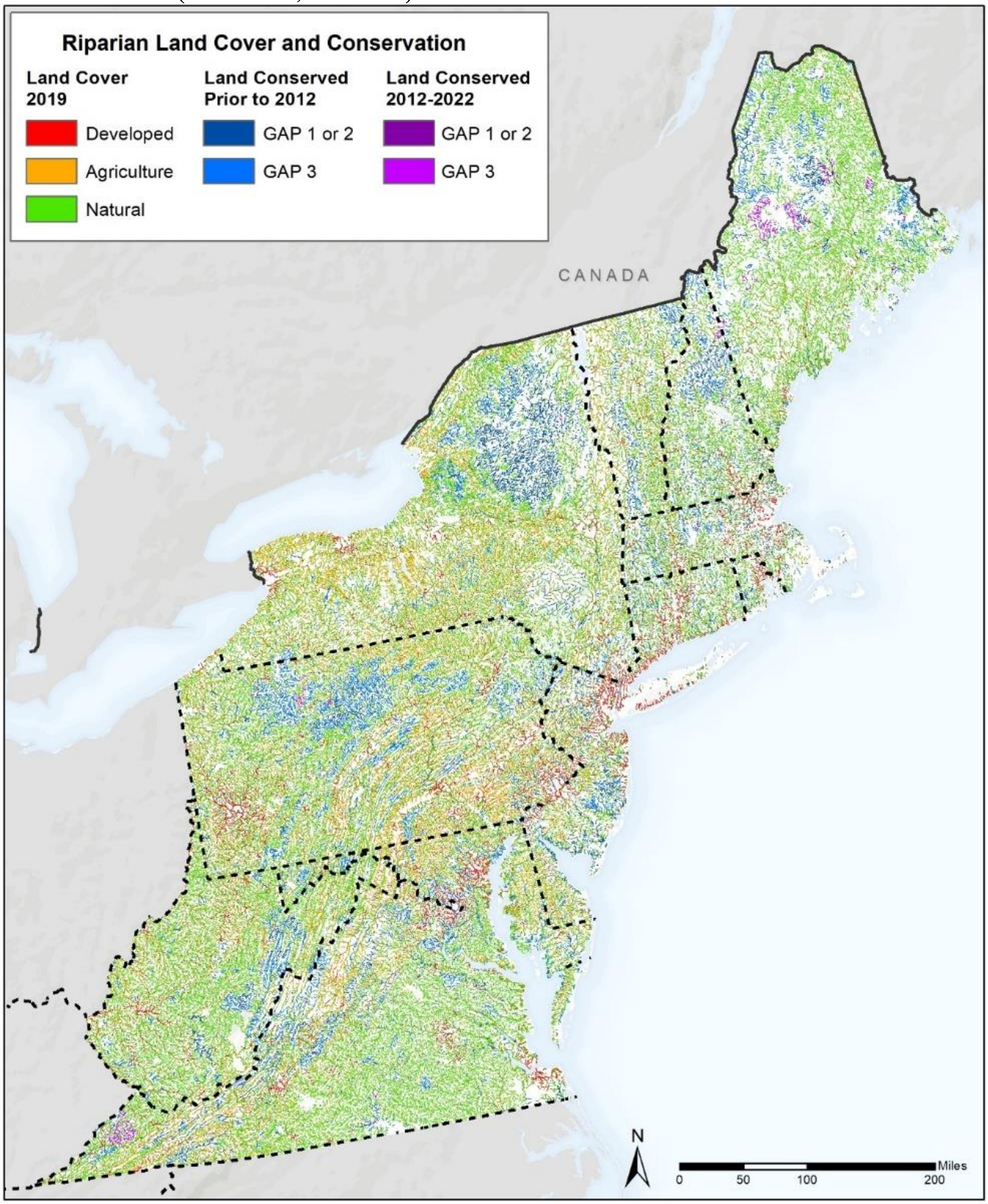
Table 6.5. Recent Trends 2012-2022. Conservation and Conservation in the Riparian Zone

Stratification	2012-2022 Loss Acres (Dev & Ag)	2012-2022 Conserved Acres	% of Total Area Lost 2012-2022	% of Total Area Conserved 2012-2022	2012-2022 CRI
Tidal Streams & Rivers	-1,599	9,470	0.3	1.8	0.2
Streams	-48,030	169,046	0.4	1.4	0.3
Rivers	-7,893	28,875	0.4	1.4	0.3
Big Rivers	-727	1,386	0.4	0.8	0.5
NORTHEAST REGION	-58,249	208,777	0.4	1.4	0.3
MID-ATLANTIC SUBREGION	-43,602	107,046	0.5	1.2	0.4
NEW ENGLAND SUBREGION	-14,647	101,731	0.2	1.6	0.1

Figure 6. 4. Conservation Risk Index (CRI): Overall and Last Decade. The CRI ratio represents the percent of habitat converted in the riparian buffer divided by the percent conserved. The CRI for all years compared to the CRI for the last decade only show that that although conservation is now outpacing habitat conversion, overall the riparian zone still has more land converted than conserved.



Map 6.3. Riparian Land Cover and Conservation. Riparian Land Cover (NLCD 2019) and Conservation Land (Before 2012, 2012-2022) Within 100m of Stream and Rivers

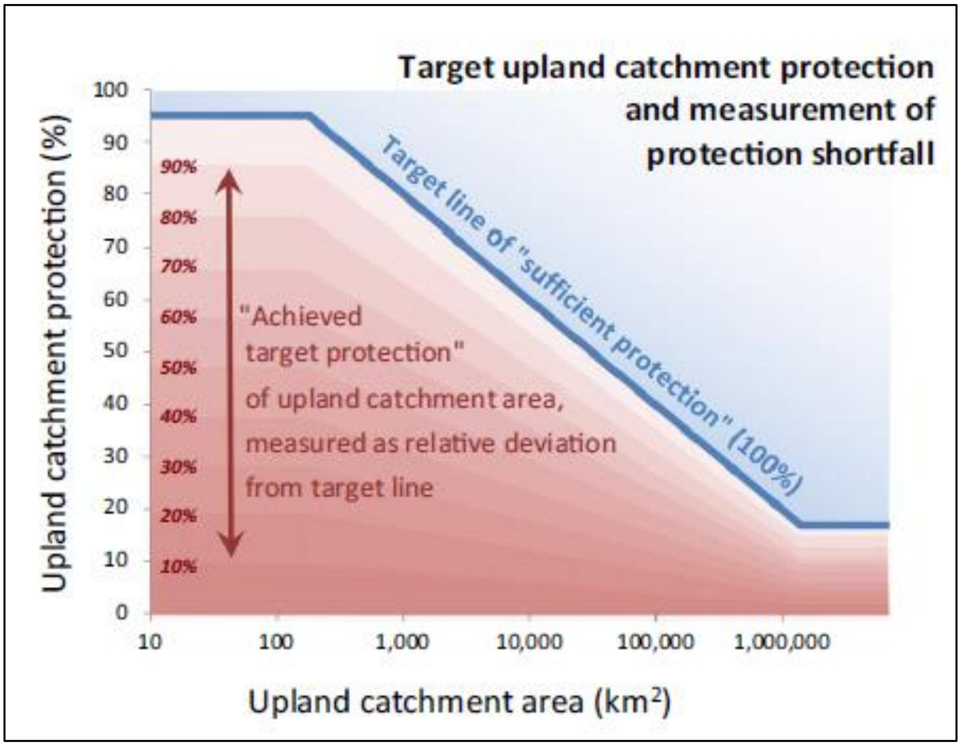


Integrated Protection Index

Miles of Streams and Rivers Achieving Local and Upstream Conservation Land Targets

In 2017, Abell and colleagues introduced an ***Integrated Protection Index (IPI)*** (Abell et al. (2017), which accounts for the protection of given reach as a function of both the *local protection*, the reach falling within conservation land, *and the degree of watershed conservation within a reach's upstream catchment*. The index asks the question: do our streams and rivers not only have local protection, but enough conserved upstream watershed area to likely protect them from the accumulated impacts of activities happening in their upstream watersheds. In the index, conserved reaches are assigned a target level of upstream watershed protection based on their upstream catchment size. For example, a small headwater stream might need 95% of its catchment conserved, while a very large river might need only 20% of its catchment conserved (Figure 6. 5). IPI can be used to determines how many rivers are meeting both their local and watershed goals.

Figure 6.5. Calculation of 'achieved target protection (From Abell et al. 2017). Once an area-based target line has been defined (blue line), every individual river reach can be assessed as to how far it deviates from the target (based on its individual values for 'upland protection' and catchment area).



We defined "locally conserved" as any NHDPlus flowline that intersected a conserved land (GAP 1-3). The boundaries of the region's conservation lands were expanded by 90 m to adjust for differing scales in the source data. The amount of conservation land upstream of every flowline was then accumulated and converted to a percent of the total upstream drainage area. All upstream calculations were based only on the upstream drainage area geography for which we had conservation land data. That is, drainage areas outside of the US or the 14 state NEAFWA footprint were not included in the 2022 calculations.

Following Abell et al. (2017), the "target area for upstream watershed conservation to achieve sufficient protection was calculated for every flowline as:

*Target Percentage = 100-((LOG10(watershed area [km2])-2)*20)*

This relationship is then capped at 95% at the high end and 17% at the low end to yield the declining line that will reach 100% at 100 km2 and 20% at 1 million km2. The IPI was then calculated for each locally protected stream reach by dividing the current percent of upstream conservation land by the target percentage and multiplying by 100. For example, if the target upstream watershed conservation for a stream reach was 80% and the actual upstream conservation was 20%, its IPI is 25 reflecting that it achieves 25% of its protection target.

Applying the IPI calculations to the region's streams and rivers revealed that although 23% of all streams and rivers miles in the region are locally protected, only 6% meet the upstream protection target amount to be considered achieving integrated protection. This highlights that nearly 75% of locally protected streams and rivers (17% out of 23%) do not have enough upstream conserved watershed area to protect them from accumulated impacts of activities that could happen in their upstream watersheds and overall 94% of all streams and rivers do not achieve integrated protection. Nearly 14% of locally protected reaches are getting close to reaching their upstream conservation target (IPI 80-99%). If these were counted as achieving their upstream target, the percentage of streams and rivers in the region achieving integrated protection would increase from 6% to 9%. However, most locally protected reaches are quite far from meeting their upstream watershed conservation land targets**,** as 49% meet less than 60% of target and 35% meet less than 40% of the target.

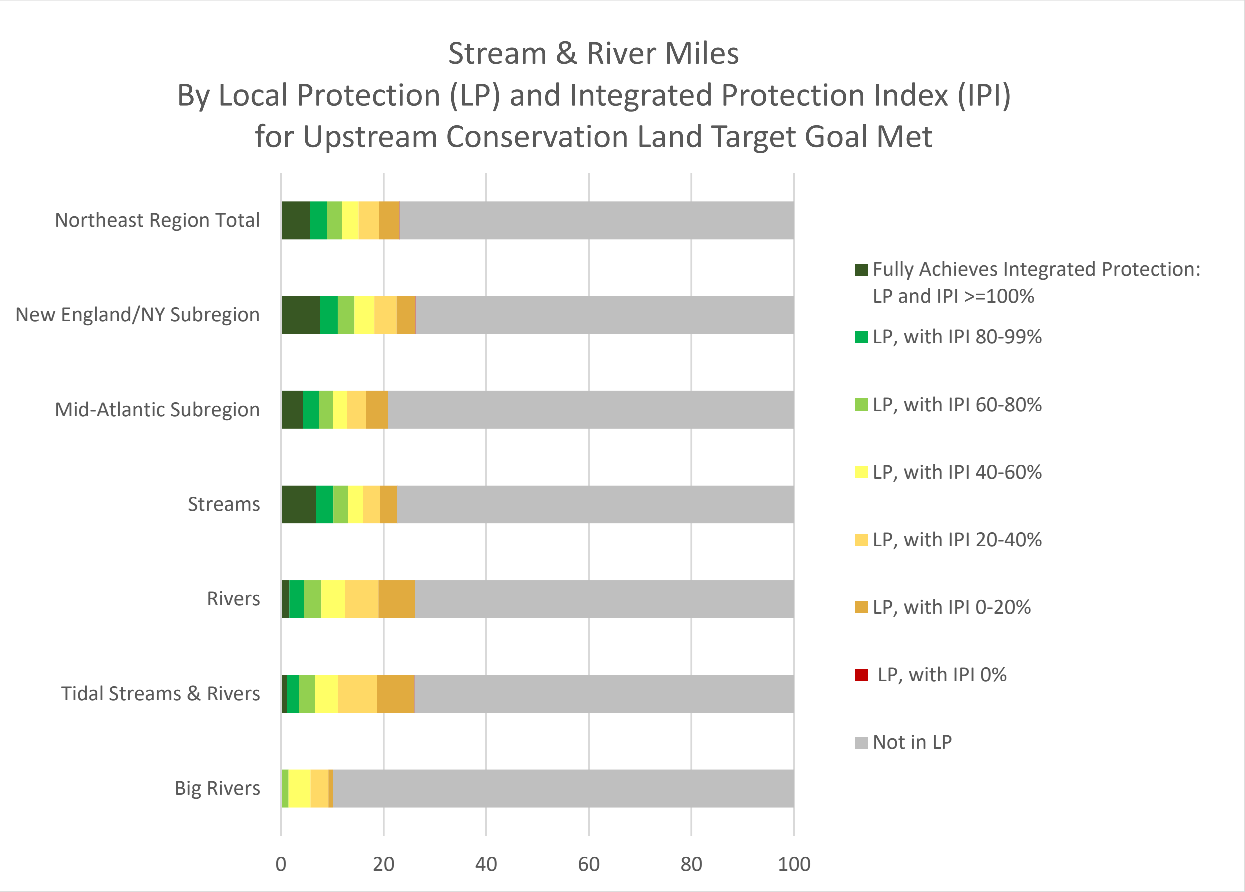
New England and New York (8%) has more miles achieving integrated protection than the Mid Atlantic (4%). Streams (7%) achieved more integrated protection than rivers (2%) or tidal streams and rivers (1%) and no big rivers meet integrated protection targets (Table 6.6)

Table 6.6. Streams and Rivers by Integrated Protection Index Class.

Percent of all streams and rivers	Total Miles	Not in Local Protection	Locally Protected (LP): In GAP 1-3 land	FULLY ACHIEVING INTEGRATED PROTECTION: Locally Protected (LP) & Integrated Protection Index (IPI) Meets >= 100% of Upstream Conservation Land Target	LP, with IPI Upstream Target Met 80-99%	LP, with IPI Upstream Target Met 60 - 80%	LP, with IPI Upstream Target Met 40 - 60%	LP, with IPI Upstream Target Met 20 - 40%	LP, with IPI Upstream Target Met 1 - 20%	LP, with IPI Upstream Target Met 0%	% of Population that Increased to Local Protection 2012-2022	% of Population that Increased to Fully Achieving Integrated Protection 2012-2022
Big Rivers	2,638	90	10	**0**	0	1	4	3	1	0	0.3	0.0
Tidal Streams & Rivers	8,420	74	26	**1**	2	3	4	8	7	0	2.3	0.0
Rivers	29,319	74	26	**2**	3	3	5	7	7	0	2.3	0.1
Streams	161,619	77	23	**7**	3	3	3	3	3	0	1.9	0.5
Northeast Region Total	201,996	77	23	**6**	3	3	3	4	4	0	1.9	0.4
New England/NY Subregion	86,460	74	26	**8**	3	3	4	4	4	0	2.0	0.8
Mid-Atlantic Subregion	115,536	79	21	**4**	3	3	3	4	4	0	1.9	0.2
Miles of all streams and rivers:	**Total Miles**	**Not in Local Protection**	**Locally Protected (LP): In GAP 1-3 land**	**FULLY ACHIEVING INTEGRATED PROTECTION: Locally Protected (LP) & Integrated Protection Index (IPI) Meets >= 100% of Upstream Conservation Land Target**	**LP, with IPI Upstream Target Met 80-99%**	**LP, with IPI Upstream Target Met 60 - 80%**	**LP, with IPI Upstream Target Met 40 - 60%**	**LP, with IPI Upstream Target Met 20 - 40%**	**LP, with IPI Upstream Target Met 1 - 20%**	**LP, with IPI Upstream Target Met 0%**	**Miles that Increased to Local Protection 2012-2022**	**Miles that Increased to Fully Achieving Integrated Protection 2012-2022**
Big Rivers	2,638	2,372	266	**0**	2	37	113	92	22	0	8	0
Tidal Streams & Rivers	8,420	6,231	2,189	**100**	192	265	375	642	614	2	192	1
Rivers	29,319	21,657	7,662	**474**	831	992	1,339	1,935	2,090	1	681	35
Streams	161,619	125,032	36,587	**10,959**	5,517	4,616	4,707	5,391	5,371	26	3049	845
Northeast Region Total	201,996	155,292	46,704	**11,533**	6,542	5,910	6,533	8,060	8,097	30	3930	881
New England/NY Subregion	86,460	63,791	22,669	**6,569**	2,977	2,815	3,359	3,733	3,194	23	1727	660
Mid-Atlantic Subregion	115,536	91,501	24,035	**4,965**	3,565	3,095	3,174	4,327	4,902	7	2203	222

Local protection did not vary much between stream types (23%-26%) except big rivers which remained the type with both the lowest local protection (10%) the least integrated protection, and as we found previously the most conservation risk in their riparian zone.

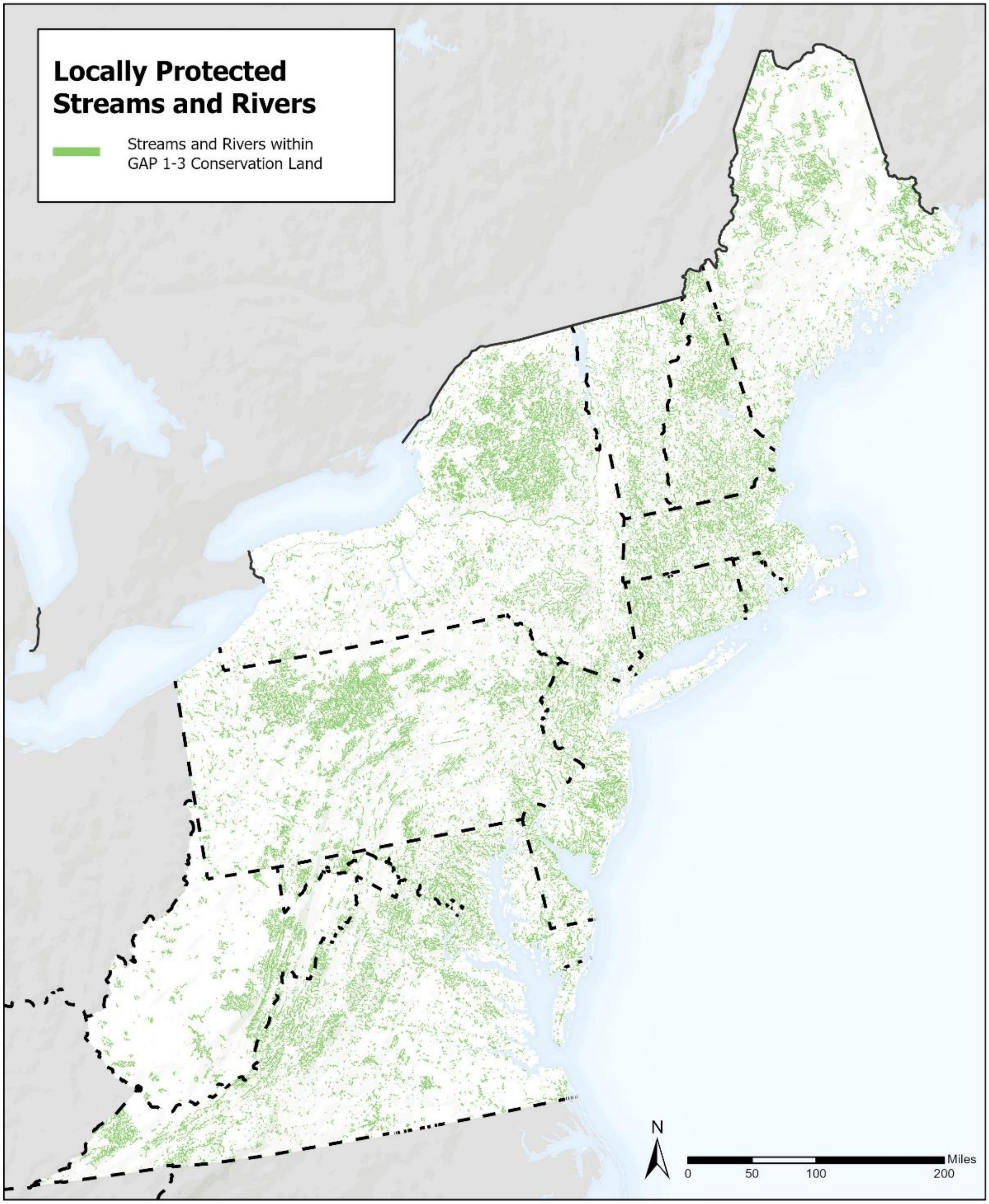
Figure 6.6. Streams and Rivers by Integrated Protection Class. The distribution of scores among the locally conserved streams (colors) and the proportion of streams that do not have local protection (grey)



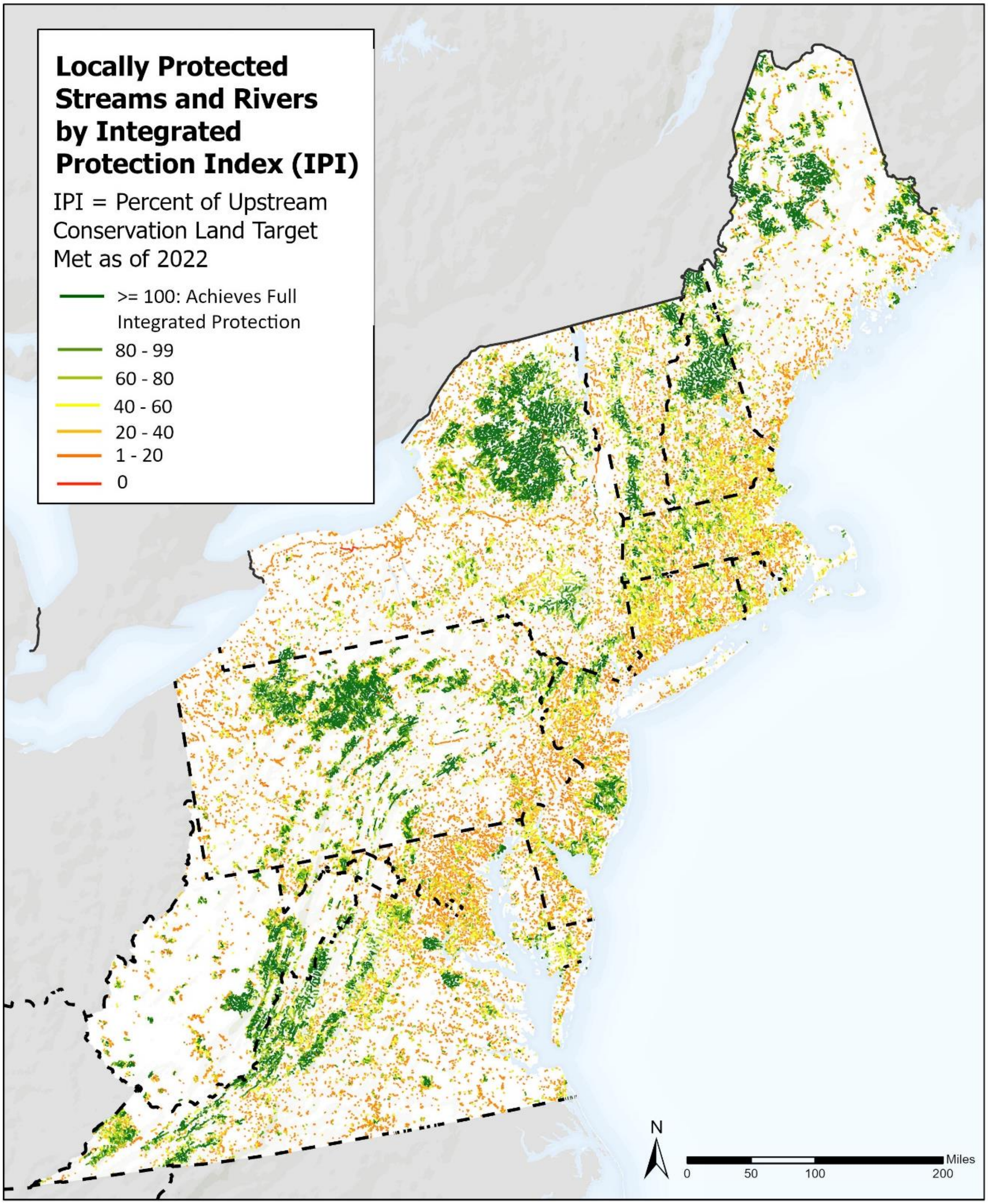
The following map series displays patterns in local protection (LP) and integrated protection (IPI).

- Map 6.5 Identifies the streams and rivers that occur on conservation land
- Map 6.6 Calculates the watershed level conservation for each reach and compares it to the target
- Map 6.7 Identifies streams and rivers systems that fully meet both local and watershed conservation goals.

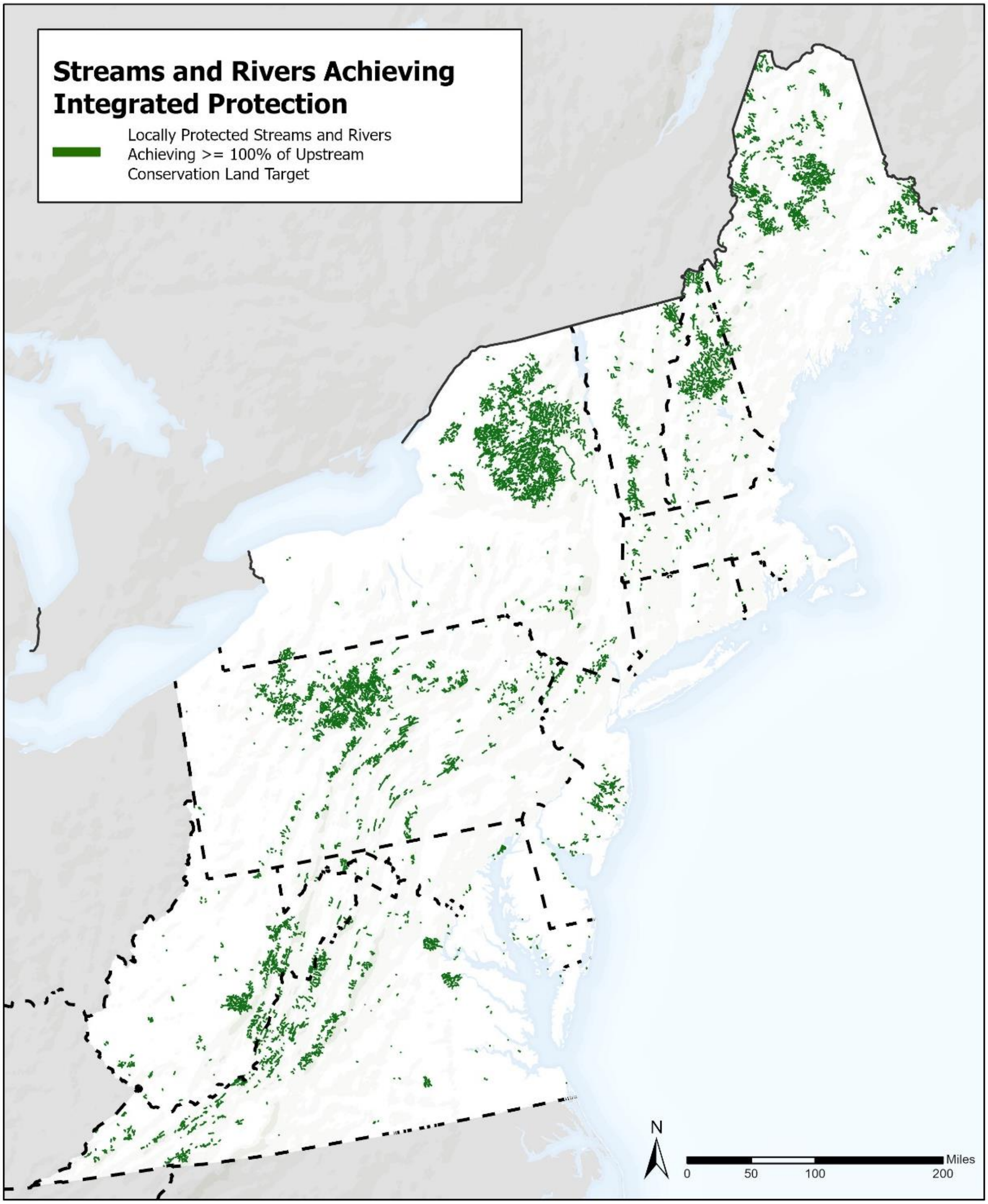
Map 6.4. Locally Conserved Streams and Rivers. This shows the portion of every stream and river that occurs on conservation land.



Map 6.5. Locally Conserved Streams and Rivers by their Integrated Protection Index. The IPI shows what percentage of the upstream watershed conservation targets are met for each locally conserved reach.



Map 6.6. Rivers Achieving Full Integrated Protection. These streams and rivers are both locally protected and meet their upstream watershed integrated protection conservation targets.



Water Quality Protection

Clean Water Act Protection: Outstanding National Resource Waters

The Clean Water Act regulations section 40 CFR 131.12(a)(3) reads: “Where high quality waters constitute an outstanding National resource, such as waters of National and State parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected.” According to the US Environmental Protection Agency’s Water Quality Standards Handbook (US EPA 2012), Outstanding National Resource Waters (ONRWs) provide the highest level of protection under the Clean Water Acts antidegradation policy by prohibiting any new or increased discharge to ONRWs or their tributaries that would lower the water quality. This designation is determined by each state for high quality waters and those of exceptional ecological significance.

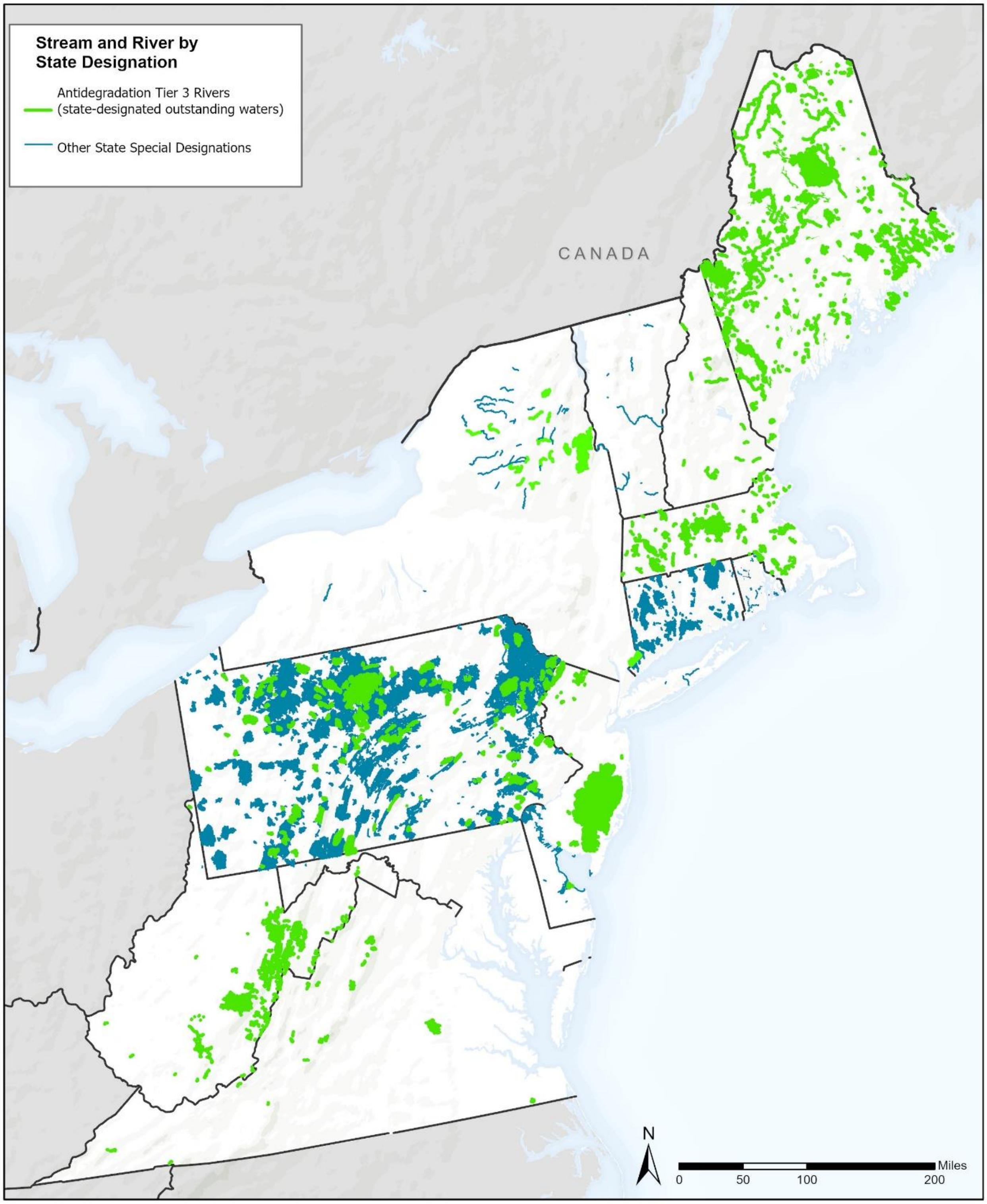
While all states are required to have antidegradation rules consistent with the federal regulations in their state water quality standards, they have discretion to designate ONRWs. Table 6.7 summarizes the status of these designations. ONRWs are often referred to as Tier 3 in state designations and in guidance from EPA. Some states also have designated high quality waters that cannot be degraded without review of practicable alternatives and preventing adverse social and/or economic impacts if the water quality change is not allowed. We have said that those other state designations provide a medium level of protection for water quality.

We compiled and reviewed the spatial distribution of these policies (Table 6.7, Map 6.7, Map 6.8) and found that eight states have designated Tier 3 ONRWs where antidegradation policies in the Clean Water Acts prohibit any new or increased discharge to the river or their tributaries that would lower the water quality. Two more states have designated other waters with a medium level of water quality protection.

Table 6.7. Tier 3 (high) and other state designations (medium) protections for water quality.

State	Tier 3 waters identified	Other state designation?	Other state designation type	Other state designation protection category	Other state designation: reason for protection
Connecticut	No	yes	AA water quality	medium	water quality
Delaware	yes	yes	ERES	medium	water quality
Maine	yes	no			
Maryland	no	yes	Tier II - high quality	low	water quality
Massachusetts	yes	no	Has category Special Resource Waters in its regs but no stream so	medium	water quality
New Hampshire	yes	no			
New Jersey	yes				
New York	yes	yes	State Scenic rivers	medium	water quality, habitat protection
Pennsylvania	yes	yes	HQ waters	medium	water quality
Rhode Island	no	yes	Rhode Island Special Protection Resource	medium	
Vermont	no	yes	Outstanding Resource Waters - have to maintain their qualities	medium	water quality
Virginia	yes	no			
West Virginia	yes	no			

Map 6.7. Tier 3 (high) and other State Designations (medium) Protections for Water Quality.



Connectivity Protection

Wild and Scenic River Designations

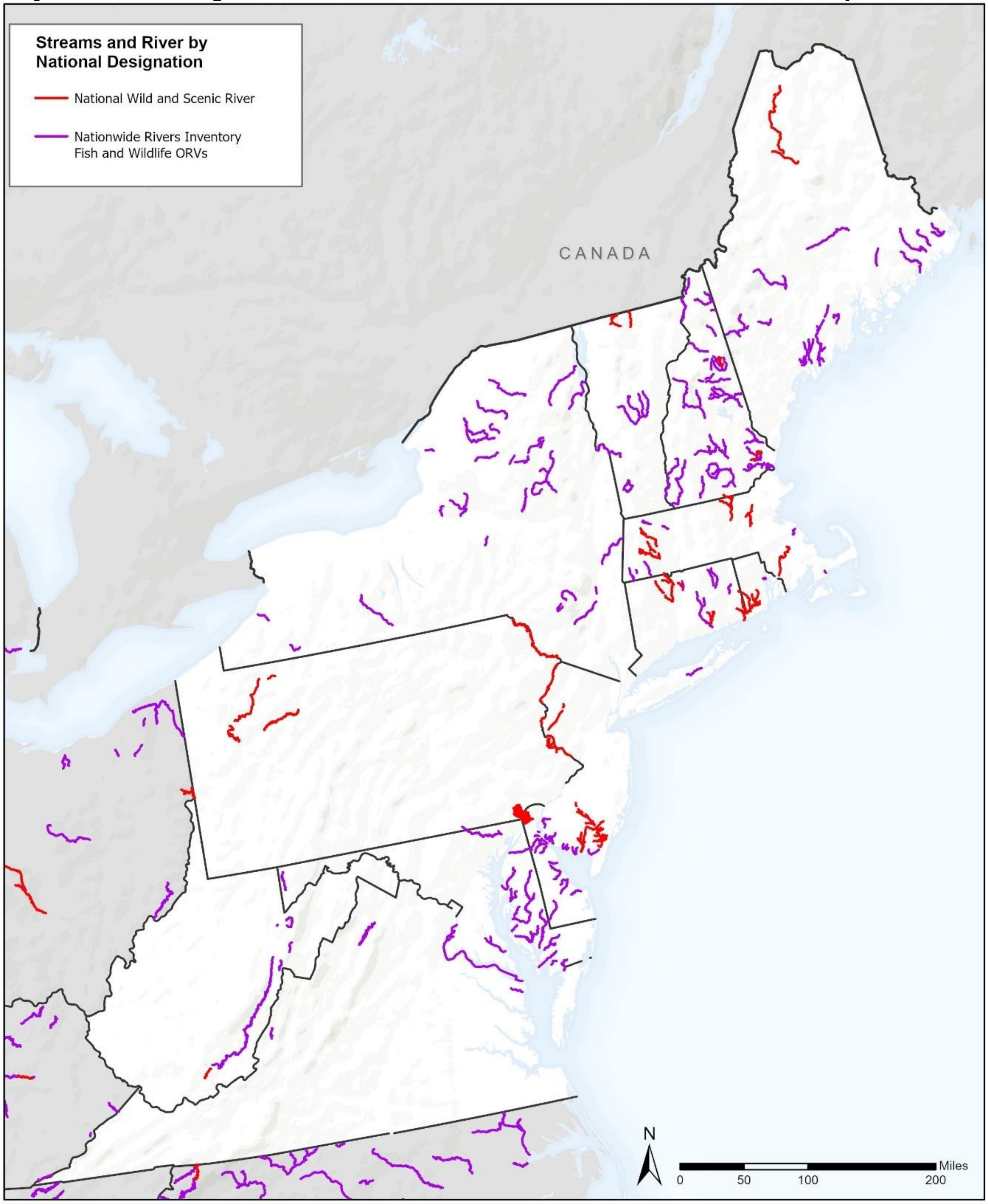
Wild and Scenic Rivers are federally protected for habitat, connectivity and water quality. Congress created the National Wild and Scenic Rivers System in 1968 (Public Law 90-542; 16 U.S.C. 1271 et seq.) with the purpose to preserve rivers with outstanding natural, cultural and recreational values. The Act calls for these rivers to "be preserved in free-flowing condition" and that their immediate environments (approximately .25 - .5 miles along the corridor) to be protected. While providing a high level of protection to the designated reach, the Act only governs federal actions, specifically, it prohibits federal support for actions such as the construction of dams or other instream activities that would harm the river's free-flowing condition, water quality, or outstanding resource values.

We compiled and mapped the Wild and Scenic Rivers for the Northeast and found that 1,528 miles of rivers have been designated in the region (Map 6.8, Table 6.8). Because these rivers must be designated by an act of Congress, less than one half of one percent of the rivers of the United States have this protection (NPS 2022). The National Park Service maintains a database of rivers called the National River Inventory that list rivers with Outstandingly Remarkable Values (ORV). These rivers could be eligible for Wild and Scenic designation but have not been acted on. Federal actions that could adversely impact these ORVs require consultation with the NPS before approval. In the Northeast 4,630 miles have been identified by the National River Inventory (Map 6.8).

Table 6.8. Northeast Wild and Scenic Rivers

Wild and Scenic River Name	STATE	Miles
Allagash Wild and Scenic River	Maine	105
Allegheny Wild and Scenic River	Pennsylvania	92
Bluestone Wild and Scenic River	West Virginia	14
Clarion Wild and Scenic River	Pennsylvania	53
Delaware (Lower) Wild and Scenic River	Pennsylvania	70
Delaware (Middle) Wild and Scenic River	Pennsylvania, New Jersey	41
Delaware (Upper) Wild and Scenic River	New York, Pennsylvania	74
Eightmile Wild and Scenic River	Connecticut	25
Great Egg Harbor Wild and Scenic River	New Jersey	148
Lamprey Wild and Scenic River	New Hampshire	23
Little Beaver Creek Wild and Scenic River	Ohio	32
Lower Farmington River and Salmon Brook Wild and Scenic River	Connecticut	63
Maurice Wild and Scenic River	New Jersey	48
Missisquoi & Trout Wild and Scenic River	Vermont	46
Musconetcong Wild and Scenic River	New Jersey	25
Nashua,Squannacook,and Nissitissit Wild and Scenic Rivers	Massachusetts and New Hampshire	52
Sudbury, Assabet and Concord Wild and Scenic River	Massachusetts	31
Taunton Wild and Scenic River	Massachusetts	38
West Branch Farmington Wild and Scenic River	Connecticut	14
Westfield Wild and Scenic River	Massachusetts	86
White Clay Wild and Scenic River	Delaware, Pennsylvania	210
Wildcate Wild and Scenic River	New Hampshire	16
Wood-Pawcatuck Watershed Wild and Scenic River	Rhode Island and Connecticut	221

Map 6.8. Federal Designations: Wild and Scenic Rivers and the National River Inventory



Flow Protection

A natural flow regime is integral to the health of every freshwater ecosystem (Poff et al. 1997). We reviewed state water policy documents to determine if water withdrawals require consideration of instream flow for ecological values.

We found that three states have specific instream flow statues and another eight have some instream flow requirements such as water permits. Two states have no flow laws, statues, or permits required for water allocation (Table 6.9).

Table 6.9. Levels of flow protection for northeast states.

No flow laws or statutes, no permit required for water allocation	Some instream flow requirements, i.e., water permits	Specific instream flow statutes
Rhode Island	Delaware	Connecticut (2019)
West Virginia	Maine	Massachusetts (2014)
	Maryland	*New Hampshire (2108)
	New Jersey	
	New York	
	Pennsylvania	
	Vermont	
	Virginia	

*Partially implemented – 2 of 19 eligible rivers have specific flows.

CONDITION: Fragmentation: Dam Distribution, Size, and Purpose

Isolation and habitat alterations due to damming has been linked to the significant decline over the last 50 year in many North American fish and mussels (Fausch et al. 2002, Pringel et al 2000, Busch et al. 1998). In addition to blocking the movement of stream biota, dams significantly alter the biological, chemical and physical properties of rivers. Water control and release can significantly alter the timing, velocity, and volume of flows. In the artificial slack-water reservoir habitat behind dams, changes in the water temperature, chemical composition, dissolved oxygen levels, and physical habitat creates conditions unsuitable to riverine biota. Reduction in sediment transport as particles are trapped behind dams also negatively affect downstream channel beds, floodplains, deltas, and coastal wetlands (Allan 1995).

The size, purpose, and operation of dams affects their relative impact on river systems. For example, larger dams can hold more water volume and are greater impediments to riverine species movement. Lower "run-of-the-river" dams are thought to have smaller adverse effects because they create a smaller slack water upstream area and release water at the rate it enters the reservoir. Impacts associated with major types of dams are summarized below (from Richter and Thomas 2007).

Dam Type and Impacts

Hydropower dams: Hydroelectric dams store water and replace a stream's natural hydrology with artificial flow regimes designed to meet daily and seasonal energy demands. Although many small hydropower dams are operated as "run-of-the-river" facilities, larger hydropower dams can store large volumes of water and are associated with significant negative riverine impacts. Episodes of power generation and high flow releases are generally followed by periods in which dam water releases may be largely or completely curtailed to allow the reservoir to refill. The rapid fluctuations in water levels associated with hydropower daily and seasonal operations can cause considerable ecological damage, as it can leave slow-moving aquatic animals such as mussels stranded when levels drop,or sweep them away when levels rise too quickly. In addition to the elimination of small floods and creating an altered flow regime, the hydroelectric generators turbine blades directly kill fish that get swept into them as they move downstream.

Water supply dams: Water supply dams are designed to capture a significant proportion of high flow events and release water according to water demands. These dams can completely rearrange seasonal patterns of water flow, such as when wet-season flows are stored for release in the dry season to support irrigated agriculture. In addition to reduced downstream flows during periods of storage, depending on diversion and release methods, river flows may become unnaturally high during periods when stored water is being released for downstream uses. These high flows can cause channel scouring, downcutting, erosion, and severe disruption to life cycles of aquatic and riparian organisms.

Flood control dams: Flood control dams collect and store water during floods and gradually release it at a later date at a lower discharge level. The general effect of a flood control dam is to reduce the peak flow, eliminate small floods and eliminate all but the most extreme large floods. This regulation of flow has severe negative impacts on floodplain and riparian ecosystems which require both small and large flood inundation for their maintenance. Riverine ecosystems are also negatively impacted by loss of peak flood flows and artificially long moderate-high flow pulses as flood control dams gradually discharge water stored during flood peaks.

Recreation dams: Recreational dams create impoundments within a river or maintain a constant high water level within an existing natural lake. These reservoirs serve as swimming, boating, and fishing places for people. In New England and New York, many of these dams are located on existing natural lakes, while in the mid-Atlantic most create new reservoirs which replace riverine habitat. Many recreation dams also have a secondary purpose such as flood control or water supply.

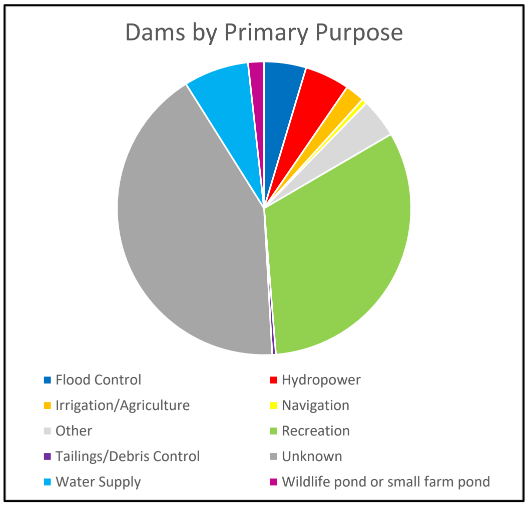
Northeast Dam Dataset:
Dams in the region were assessed using an updated regional dam dataset revised in 2022 by The Nature Conservancy. This dataset was based on the Northeast Connectivity Project's compilation of dams (Martin and Levine 2017, Martin 2019) which compiled dam locations in the 14 northeast states from multiple state and federal data sources and spatially linked the dams to the correct flowline in the USGS NHD-Plus 1:100,000 hydrography dataset. The data development method is fully described in Martin and Levine (2017). Primary steps included 1) snapping each state's dams to the NHD flowlines, 2) coding the dams for prioritization for manual review, 3) manual error checking of the prioritized dams, 4) returning the data to the states for expert review, and 5) re-incorporated the state edits into the final spatially rectified dataset. The northeast dam data was revised during 2022 by TNC to integrate additions from updated inventories, deletions of incorrect data, and deletions of dam removals. This review included quality control for correct integration of the National Anthropogenic Barrier Database beta 2.0, integration of Southeast Aquatic Resource Partnership dam data in the Southern Appalachian ecoregion, deletions of dams noted in the American Rivers dam removal database through end of 2021, and review by TNC state scientists.

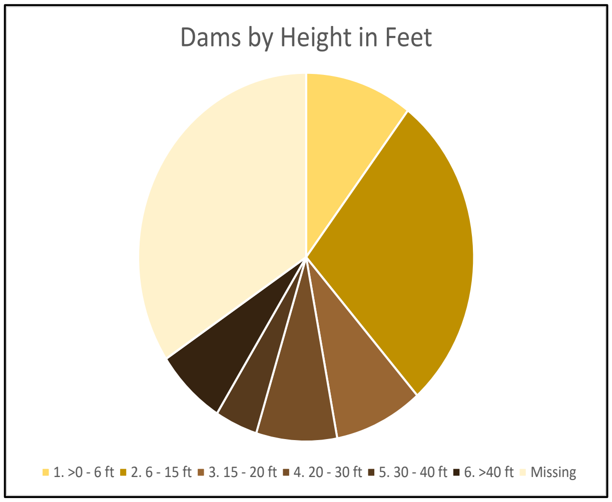
Dataset attributes were updated when possible, with a focus on key fields such as dam type, height, and passability. Not all dams are a complete barrier to aquatic organism passage and key effort was made to update and improve the coding of partially passable dams. Dams with fish passage structures, navigation locks, and very small dams that are submerged at high flows are all examples of dams that can allow for the movement of some species under certain conditions. Partially passable dams were specifically defined as those where there was presence of locks, presence of a fish passage facility, those with a height greater than zero feet and less than two feet, and those that were identified as partially passable by state and TNC program scientists. Information on locks came from the U.S. Army Corps' National Inventory of Dams (NID, https://nid.sec.usace.army.mil/). Dam height was taken from the source data attributes (NID or other source data). Data on fish passage facilities came primarily from the USGS Fishways Database compiled dataset 2022 version (https://doi.org/10.5066/P9IB1GWS) or local knowledge.

The TNC compiled 2022 regional dam dataset shows 29,583 dams for the northeast states, and the true number of dams is likely even higher given dams on the smallest headwater streams are still inconsistently inventoried and mapped from state to state. For consistency in analysis and to match the consistent hydrography used for this and previous reports (Anderson and Olivero, 2013, Martin and Levine 2017), only the 13,898 dams located on streams greater than 1 sq.mi. in drainage area were included in the following statistics and analysis.

Dam Type and Size: The dams in the northeast had a variety of primary purposes; the most common was recreation followed by water supply, hydroelectric, and flood control dams (Figure 6. 7, Map 6.9). The New England and New York subregion had more hydroelectric dams than the Mid-Atlantic which had a higher percentage of irrigation and tailings dams, along with flood control and water supply dams. Hydroelectric dams had the highest normal and maximum storage capacity and recreational dams the lowest, while flood control dams had a large difference between normal and maximum storage, with their maximum storage being almost three times their normal storage. The highest dams in the region were flood control dams, followed by water supply, hydroelectric, and recreational. There were 946 very high dams over 40 feet (Map 6.9) while 38% were less than 15ft tall.

Figure 6. 7. Northeast Dams by Primary Purpose and Height



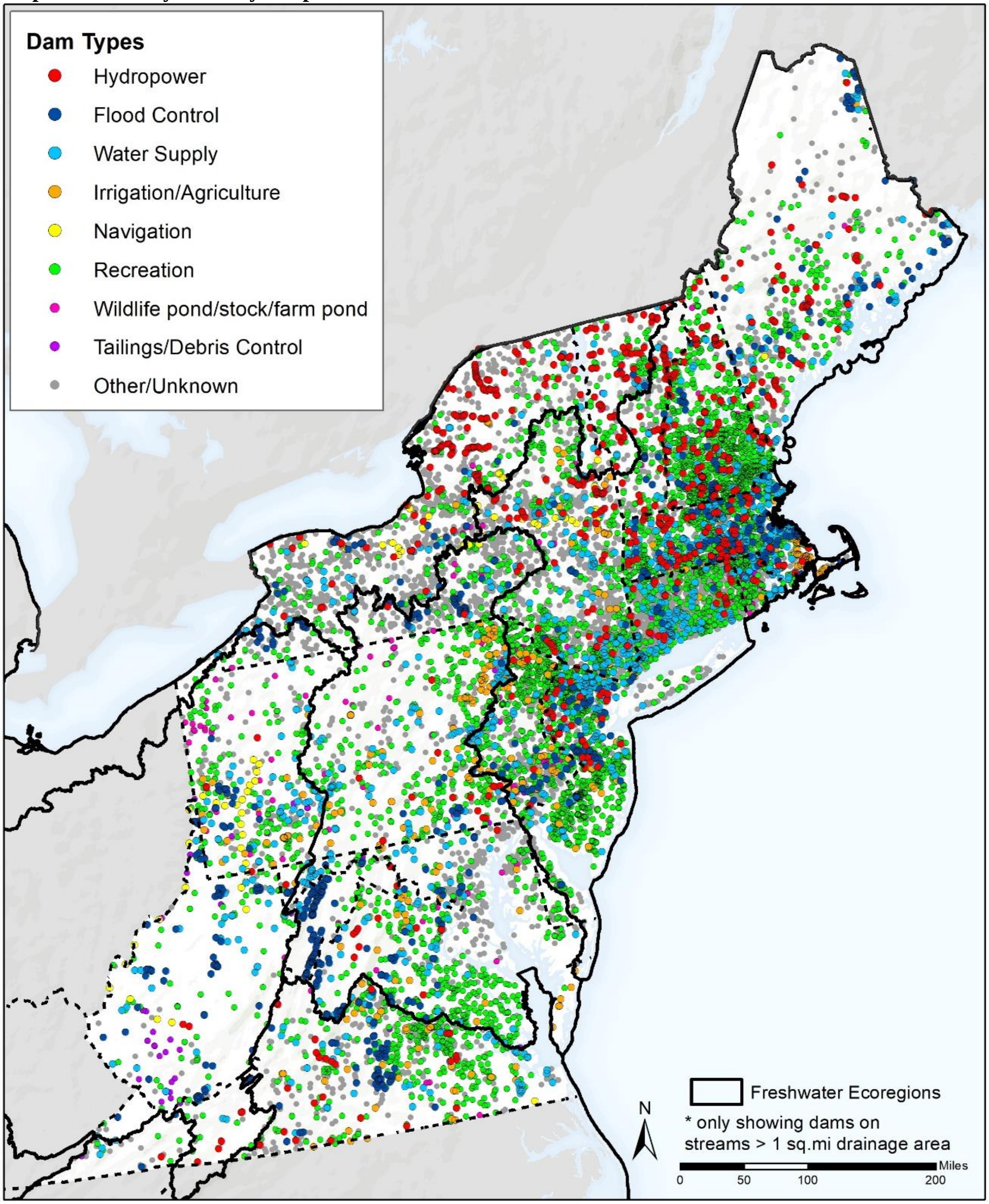


Across all dams, 80% were located on streams, 16% on rivers, 4% on tidal streams and rivers and 1% on big rivers (Table 6.10). Dam density across all streams and rivers was on average 7 dams for every 100 miles. The density of dams in New England and New York was 2.5 times the density in the Mid-Atlantic. Hydroelectric and navigation dams had their highest density on rivers while the density of recreational and irrigation dams was highest on the streams (Table 6.X.).

Table 6.10. Number, primary purpose, and density dams. This table summarizes the types and number of dams by stream type and region.

Number of Dams	Flood Control	Hydropower	Irrigation	Navigation	Other	Recreation	Tailings	Unknown	Water Supply	Wildlife or farm pond	Total
Big Rivers	2	28		33	1	4	1	8	3		80
Rivers	94	524	12	30	143	331	6	900	128	39	2207
Streams	531	130	272	11	425	3898	46	4716	828	197	11054
Tidal Streams & Rivers	16	4	13	4	32	233	2	209	37	7	557
NORTHEAST	643	686	297	78	601	4466	55	5833	996	243	13898
Mid-Atlantic	351	104	218	31	96	2040	51	1462	390	110	4853
New England/NY	292	582	79	47	505	2426	4	4371	606	133	9045
Density/100 miles	Flood Control	Hydropower	Irrigation	Navigation	Other	Recreation	Tailings	Unknown	Water Supply	Wildlife or farm pond	Total/100 miles
Big Rivers	0.1	1.1	0.0	1.3	0.0	0.2	0.0	0.3	0.1	0.0	3.0
Rivers	0.3	1.8	0.0	0.1	0.5	1.1	0.0	3.1	0.4	0.1	7.5
Streams	0.3	0.1	0.2	0.0	0.3	2.4	0.0	2.9	0.5	0.1	6.8
Tidal Streams & Rivers	0.2	0.0	0.2	0.0	0.4	2.8	0.0	2.5	0.4	0.1	6.6
NORTHEAST	0.3	0.3	0.1	0.0	0.3	2.2	0.0	2.9	0.5	0.1	6.9
Mid-Atlantic	0.3	0.1	0.2	0.0	0.1	1.8	0.0	1.3	0.3	0.1	4.2
New England/NY	0.3	0.7	0.1	0.1	0.6	2.8	0.0	5.1	0.7	0.2	10.5

Map 6.9. Dams by Primary Purpose



Passability:

We identified 693 dams (5%) as partially passable (Map 6.10, Table 6.11). These were found across a variety of primary purposes including 15% of hydropower dams, 7% of flood control dams, and over 70% of navigation dams in the region. The density of partially passable dams is highest on big rivers and tidal systems which may reflect efforts to provide passability for anadromous fish.

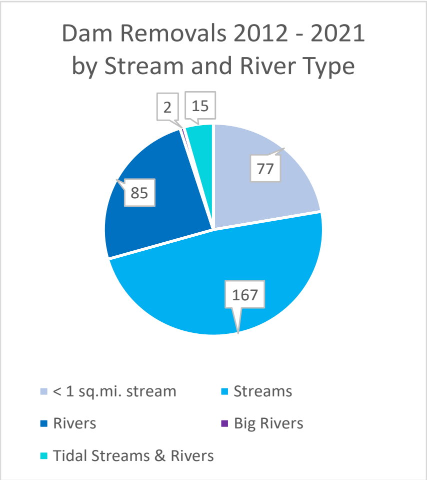
Table 6.11. Partially Passable Dams: Number, primary purpose, and density. Summarizes patterns of dams identified as partially passable on streams

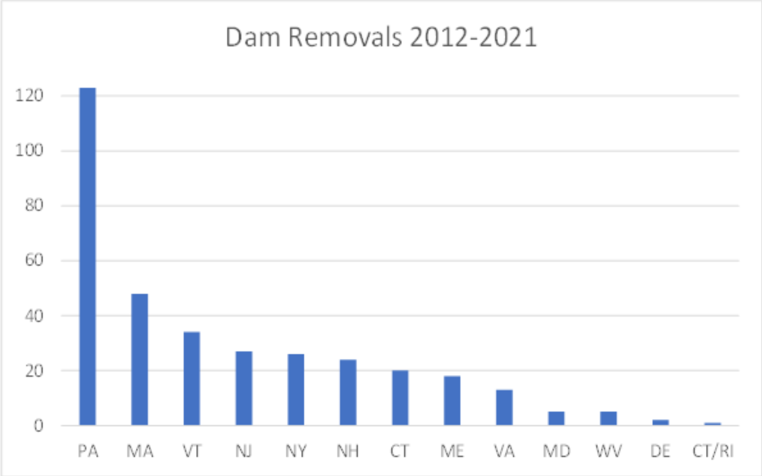
Partially Passable Dams	Flood Con	Hydropow	Irrigation	Navigatio	Other	Recreatio	Unknown	Water Sup	Wildlife o	Total	# Passable/100 miles
Big Rivers		11		33			3	1		48	1.8
Rivers	13	89		20	18	31	60	15	1	247	0.8
Streams	25	4	11	2	34	91	124	22	5	318	0.2
Tidal Streams and Rivers	4	2	2	2	9	32	21	7	1	80	1.0
Grand Total	42	106	13	57	61	154	208	45	7	693	0.3

Dam Removals:

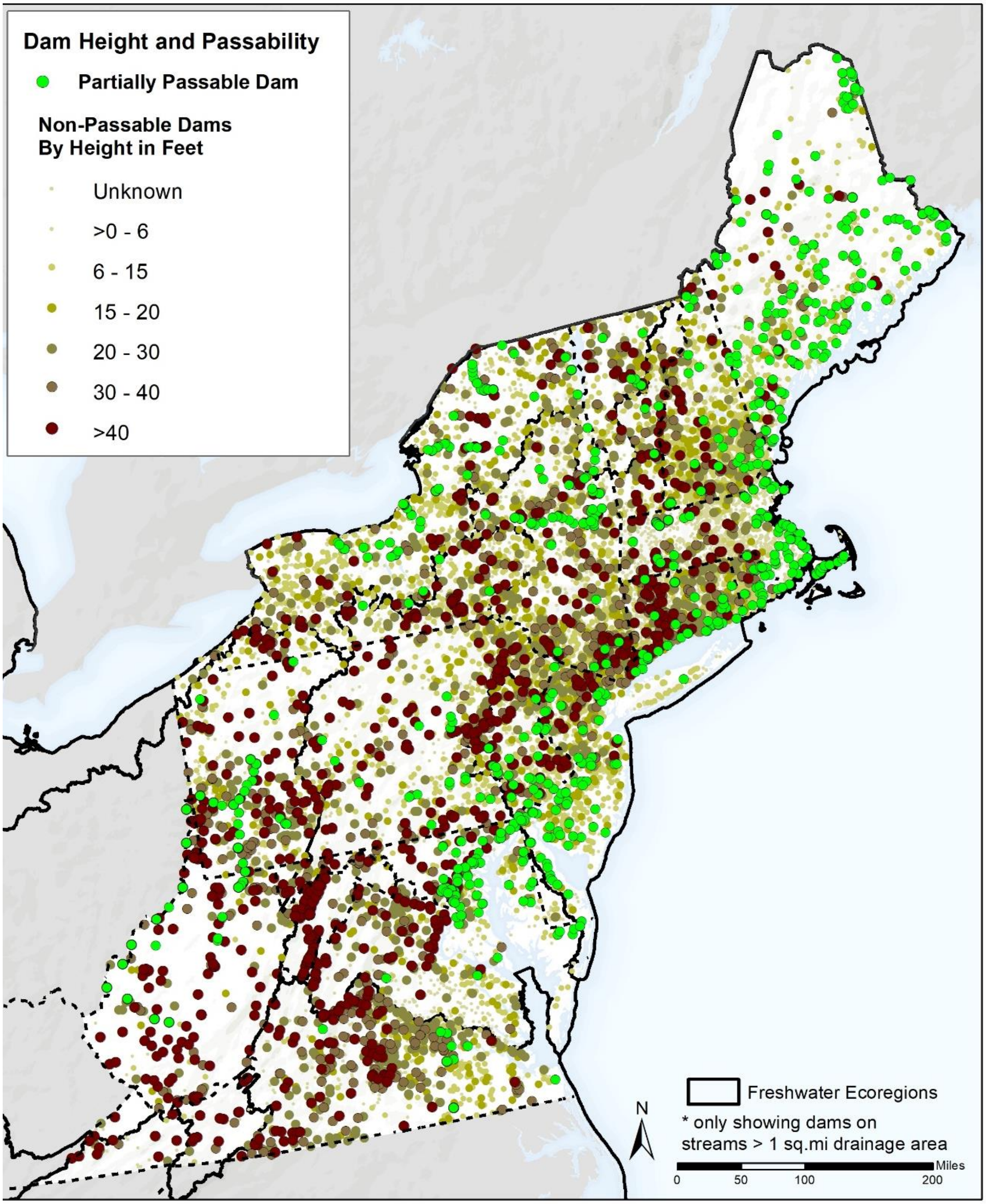
The American Rivers Dams Removal database (American Rivers, 2022) documented the removal over the last decade 2012-2021 of 346 dams in the region (Map 6.11). Pennsylvania, Massachusetts, and Vermont all removed more than 30 dams, with Pennsylvania removing 123 structures (Figure 6. 8). Of the dams removed, 70% were located on streams, 25% on rivers, 5% on tidal streams and rivers, and only 2 were located on big rivers; these were the Great Works and Veazie Dam on the Penobscot River.

Figure 6.8. Number of Dam Removals by State 2012-2021

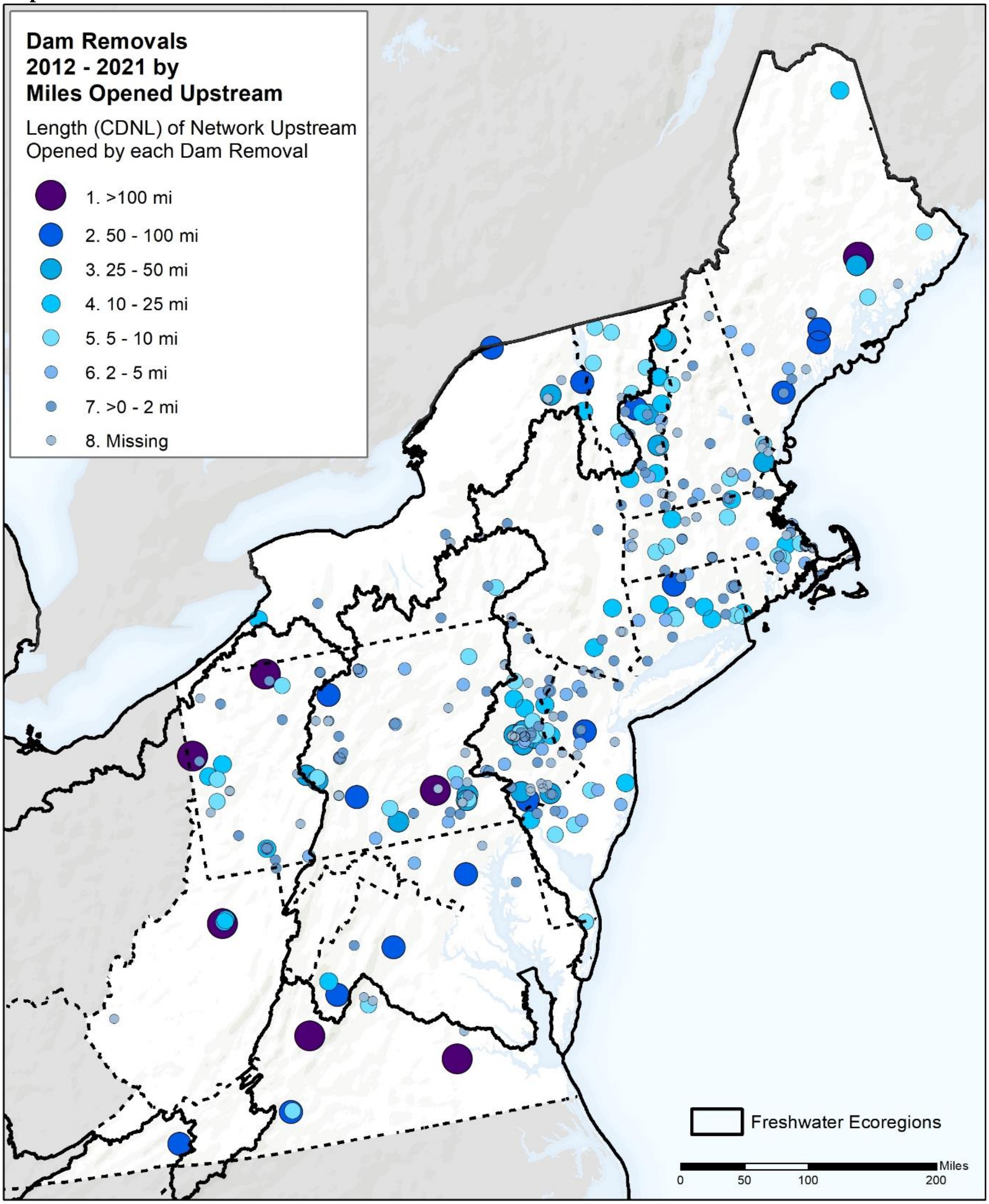




Map 6.10. Dams by Height and Passability



Map 6.11. Dams Removals 2012-2021



Miles Reopened

Removed dams that had been located on streams (> 1 sq.mi. drainage area) and rivers were run through a network analysis to quantify the length of upstream habitat opened by these dam removals. Summarizing the miles of the network directly upstream of these 269 dams, shows removing these dams collectively made accessible a minimum of 3,657 miles. Partially passable dams in the newly accessible upstream network expanded that accessibility to 4,965 miles (cumulative discounted network length, CDNL). (Map 6.11, Table 6.12). This is an incredible gain for freshwater species. The miles opened is also certainly even larger because 77 dams were located on very small headwater streams not included in our analysis.

Table 6.12. Dam Removal and Miles of Reopened Stream Network by State and Year. Summarizes patterns of dams identified as partially passable on streams (source data American Rivers)

State	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total # Dams	Sum of Upstream Network Length (CDNL) Opened
CT	2		1	5	4	2	1	2	1	2	20	178
CT/RI				1							1	19
DE			1					1			2	15
MA	9	3	5	2	5	9	5	1	6	3	48	145
MD	1		1	1			1	1			5	91
ME	2	4	1		1	2	3	3	1	1	18	1,227
NH	3	1	2	2	5	1	1	6	2	1	24	54
NJ	2	4	4	1	2	3	3	1	1	6	27	163
NY	5	1	1	3	4		3	1	6	2	26	243
PA	10	17	17	21	9	16	7	15	4	7	123	1,551
VA	1	1	1	2	2	3		1	2		13	741
VT	2	3	2	1	1	6	4	6	3	6	34	323
WV					3			2			5	216
Grand Total	37	34	36	39	36	42	28	40	26	28	346	4,966

The ten dams that opened up the most miles in the last decade are listed in Table 6.13 along with links to more information about these particular projects. Ninety percent of the top ten were located on large mainstem or big rivers and eighty percent were in the Mid-Atlantic. Only one dam on the list was on a small river, reinforcing the idea that dam removals on larger rivers usually open up more total miles given network connectivity.

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Table 6.13. Top 10 Dam Removals in the last Decade by Miles Opened Upstream

	State	Dam Name	Year Removed	River	City	Upstream Network CDNL Length in Miles: Newly Accessible Habitat Made Available	Link to Project Information
1	ME	Great Works Dam	2012	Penobscot River	Old Town	940	https://www.nature.org/en-us/about-us/where-we-work/united-states/maine/stories-in-maine/restoring-the-penobscot-river/
2	PA	SunRay (Hospital) Dam	2014	Conewango Creek	North Warren	479	https://www.timesobserver.com/news/local-news/2014/08/conewango-creek-dam-removed/
3	VA	Jordan's Point Dam	2019	Maury	City of Lexington/Rockbridge County	324	https://roanoke.com/news/virginia/jordans-point-dam-removed-from-maury-river-in-lexington/article_64b04958-f16a-50d7-a4e0-533ad71fbd0f.html
4	WV	West Milford Dam	2016	West Fork River	West Milford, Harrison Cty	180	https://wvmetronews.com/2016/03/21/dam-removal-begins-along-west-fork-river-in-harrison-county/
5	PA	Orr's Bridge Dam	2019	Conodoguinet Creek	Hampden Township	155	https://cumberlink.com/news/local/hampden-township-residents-ask-for-authorities-to-re-engage-after-bureaucratic-conflict-over-rock-dam/article_bd2471b6-d7f0-5a16-afa4-8de1211c5345.html
6	VA	Harvell Dam	2014	Appomattox River	Petersburg	140	https://www.fws.gov/project/harvell-dam-removal-appomattox-river-virginia
7	PA	Pulaski Mills Dam	2015	Shenango River	Pulaski/Lawrence	108	https://www.ncnewsonline.com/news/dam-removed-from-shenango-river-in-pulaski/article_42a6cc1e-840c-11e5-9cfb-0f74e3bd7443.html
8	NY	Saw Mill Dam	2015	Bouquet River	Willsboro	82	https://www.adirondackdailyenterprise.com/opinion/columns/adirondack-gadabout-outdoors-by-joe-hackett/2015/10/dam-removal-clears-the-way-for-migrating-fish/
9	MD	Bloede Dam	2018	Patapsco River	Elkridge	77	https://dnr.maryland.gov/fisheries/pages/fishpassage/bloede.aspx
10	PA	Trough Creek Dam	2013	Great Trough Creek	Todd Twp, Huntingdon County	76	https://s3.amazonaws.com/american-rivers-website/wp-content/uploads/2019/07/03135819/DamsRemoved_1999-2018.pdf

Connected River Networks

Connectivity within a network of streams and rivers is essential to healthy freshwater ecosystems. Key benefits include:

- Permits freshwater species to move throughout the network to find the best feeding and spawning conditions
- Enables individuals to colonize, recolonize, and migrate to locations where conditions are more suitable for survival during times of stress
- Facilitates maintenance of metapopulations and accompanying genetic diversity
- Enables water flow, sediment and large woody debris transport, and nutrient regimes to function naturally

Key freshwater biota benefiting from more connected stream networks include the following:

Diadromous Fish: Diadromous fish exploit both freshwater and saltwater habitats. The distance traveled to do this varies widely among the species. Rainbow smelt live their entire life within about a mile of the coast while Atlantic salmon spawn in headwater streams hundreds of miles inland. Diadromous fish species of the northeast include alewife, American eel, American shad, Atlantic salmon, Atlantic sturgeon, Atlantic tomcod, blueback herring, hickory shad, rainbow smelt, searun trout, and shortnose sturgeon. Dams have caused the loss of access to 91% of stream habitat within the historic unrestricted range of diadromous fishes in New England from Maine to Connecticut (Busch et al. 1998).

Resident Freshwater Fish: Many resident freshwater fish species exhibit freshwater migrations and move significant distances within the stream network for feeding, seasonal refuge, and life stage segregation. This includes native eastern freshwater fish species such as: suckers, redhorses, brook trout, fallfish, yellow perch, bullhead, and pickerel (Nedeau 2006).

Freshwater Mussels: Many freshwater mussels are dependent upon migratory fishes as hosts for their parasitic larvae (Neves et al. 1997, Vaughn and Taylor 1999). Dams and the loss of migratory fish have been linked to mussel population declines and local mussel population extirpations (Watters 1996). By blocking fish movements, dams have eliminated host fish availability in reaches otherwise supportive to mussel populations.

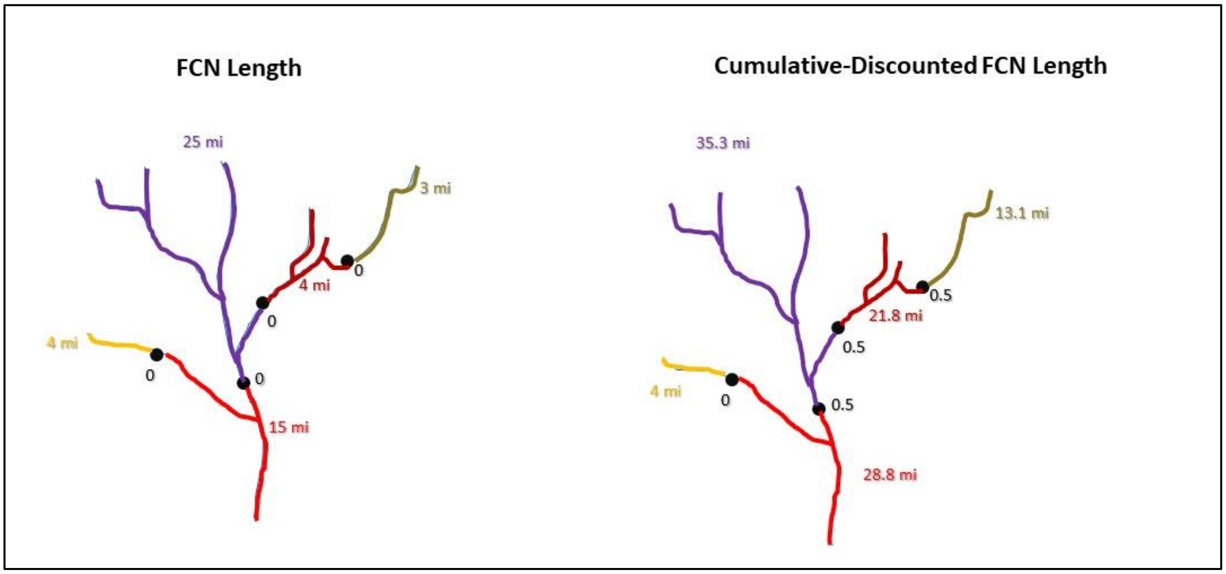
Northern Riffleshell from French Creek, PA (D. Crabtree, TNC PAFO

Plants and Floodplain Ecosystems: Floodplain ecosystems depend on stream connectivity for natural flows to remove vegetative encroachment on floodplains, maintain sediment and nutrient regimes, and disperse seeds. Dams disrupt the dispersal of emergent and submerged floras whose spores or seeds are waterborne (Jansson et al. 2000).

Climate Change: Climate change is creating shifts in the temperature, water quantity and flow regimes of our river systems creating suitable habitat in new places and reducing suitability of others. In response, freshwater species need to explore, disperse, and establish in new region of their network.

Methods: We defined a ***functionally connected network (FCN)*** as the set of connected stream-river-lake-pond segments bounded by dams and/or the topmost extent of headwater streams. Dams were from the updated 2022 dataset described earlier and streams were from the previously described NHDPlus V21. We included all reaches with at least 1 sq.mi. drainage area to focus our results on a consistent set of perennial connected features. Centerlines through connected lakes were also included in this analysis to preserve network connectivity through waterbodies. Road-stream crossings and waterfalls were not used as barriers due to uncertainty as to whether these features were barriers to movement for most species, at all times of the year, and because of inconsistencies in mapping these features across the region. The original FCN network length before dams was also generated using the coasts and the topmost extent of headwater streams as bounding features.

Figure 6. 9: Functionally Connected Network (FCN) Length. The network on the left is comprised of five FCN each bounded by a dam, upper headwaters or river mouth. Each network has a total length that reflects all the available tributaries and connected freshwater habitat. When a dam is removed, two FCN can fuse to create one longer FCN. If the network is bounded by passable dams the length gets a weighted and proportional increase (cumulative-discounted network length) that is less than if the dam was actually removed, but reflects the partial passability of the dams



Creating the FCNs and measuring their length revealed that the region's network of 214,000 miles of streams, rivers and interconnected lakes are fragmented into almost 30,000 FCNs with 20% of them less than 25 miles in length (Table 6.14A). Current network are longer networks in the Mid-Atlantic region and shorter throughout much of New England, New York, and New Jersey (Map 6.12), perhaps reflecting dam building activity in colonial and pre-industrial settlement time periods. Similar patterns are seen by freshwater ecoregion with FCNs in the Northeast US Atlantic Drainages and Great Lakes/St. Lawrence being mostly less than 25 miles long. The Appalachian Piedmont, Chesapeake Bay, and Ohio/Tennessee have a much larger percentage of FCNs (over 40%) over 500 miles long. The Ohio/Tennessee has the highest proportion of FCNs over 1000 miles long and is the only ecoregion with any networks over 5,000 miles long.

Table 6.14. Distribution of (A) Current Network Lengths and (B) Original Network Lengths

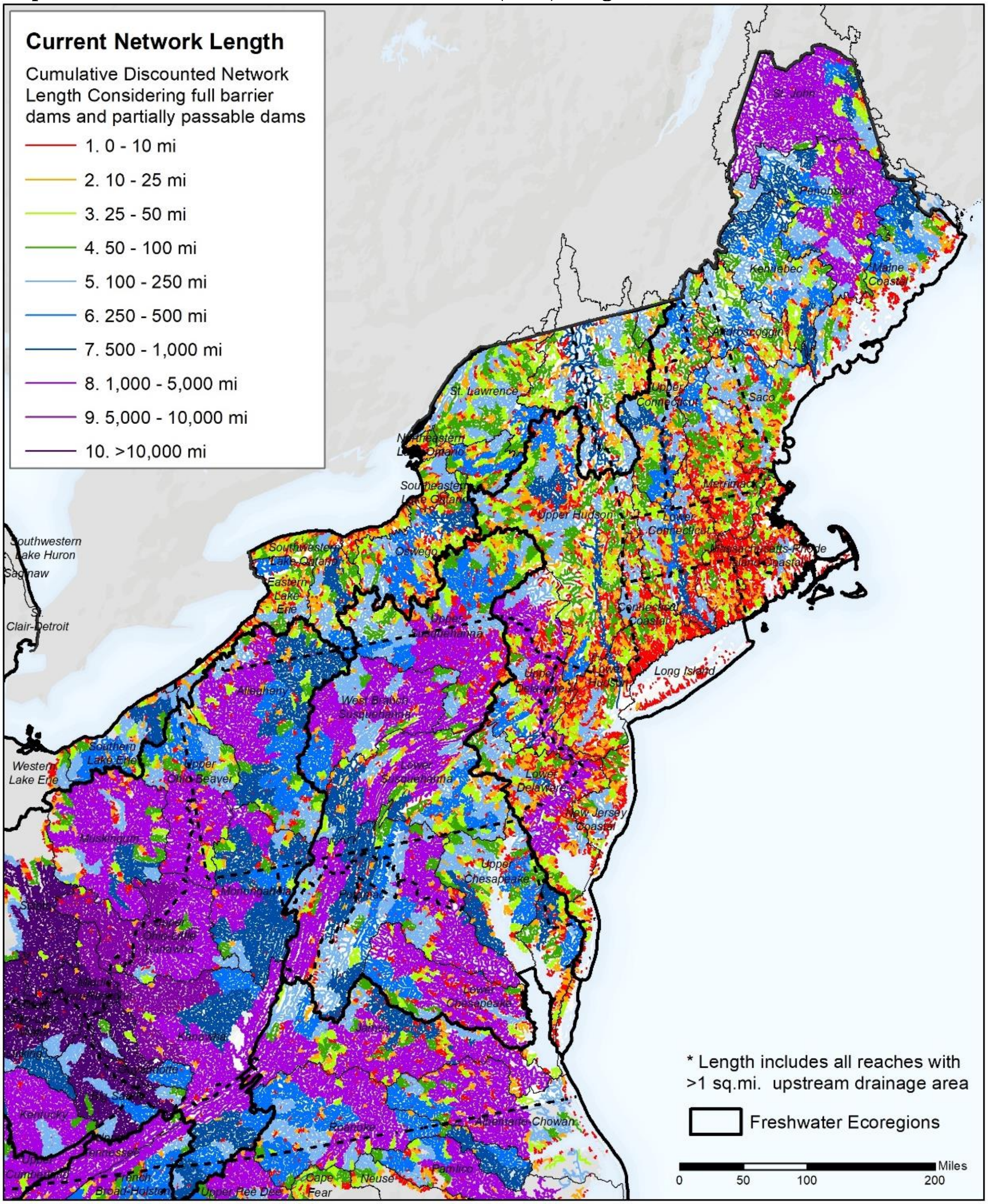
(A) Current Network Length Distribution

Current Network Length (CDNL)	Miles in Class										
	1. 0 - 10 mi	2. 10 - 25 mi	3. 25 - 50 mi	4. 50 - 100 mi	5. 100 - 250 mi	6. 250 - 500 mi	7. 500 - 1,000 mi	8. 1,000 - 5,000 mi	9. 5,000 - 10,000 mi	10. >10,000 mi	Total Miles
Appalachian Piedmont	1,182	1,052	719	889	2,129	3,125	894	8,851			18,840
Chesapeake Bay	3,728	2,818	3,174	3,639	8,387	6,371	4,906	17,300			50,323
Great Lakes/St. Lawrence	3,269	4,218	4,306	3,930	5,378	2,949	2,105				26,155
Northeast Atlantic Drainages	15,657	9,785	8,076	8,200	11,718	6,434	4,651	11,351			75,872
Ohio/Tennessee	1,319	1,056	1,082	1,555	2,880	5,132	8,990	14,288	3,873	2,587	42,764
NORTHEAST REGION	25,155	18,930	17,358	18,213	30,492	24,010	21,545	51,790	3,873	2,587	213,954
MID-ATLANTIC SUBREGION	9,224	6,857	5,905	6,004	14,024	13,958	14,451	41,931	3,873	2,587	118,815
NEW ENGLAND/NY SUBREGION	15,932	12,072	11,453	12,209	16,467	10,052	7,095	9,859			95,139
	Percent in Class										
	1. 0 - 10 mi	2. 10 - 25 mi	3. 25 - 50 mi	4. 50 - 100 mi	5. 100 - 250 mi	6. 250 - 500 mi	7. 500 - 1,000 mi	8. 1,000 - 5,000 mi	9. 5,000 - 10,000 mi	10. >10,000 mi	
Appalachian Piedmont	6.3	5.6	3.8	4.7	11.3	16.6	4.7	47.0	0.0	0.0	
Chesapeake Bay	7.4	5.6	6.3	7.2	16.7	12.7	9.7	34.4	0.0	0.0	
Great Lakes/St. Lawrence	12.5	16.1	16.5	15.0	20.6	11.3	8.0	0.0	0.0	0.0	
Northeast Atlantic Drainages	20.6	12.9	10.6	10.8	15.4	8.5	6.1	15.0	0.0	0.0	
Ohio/Tennessee	3.1	2.5	2.5	3.6	6.7	12.0	21.0	33.4	9.1	6.1	
NORTHEAST REGION	11.8	8.8	8.1	8.5	14.3	11.2	10.1	24.2	1.8	1.2	
MID-ATLANTIC SUBREGION	7.8	5.8	5.0	5.1	11.8	11.7	12.2	35.3	3.3	2.2	
NEW ENGLAND/NY SUBREGION	16.7	12.7	12.0	12.8	17.3	10.6	7.5	10.4	0.0	0.0	

(B) Original Network Length before Dams Distribution

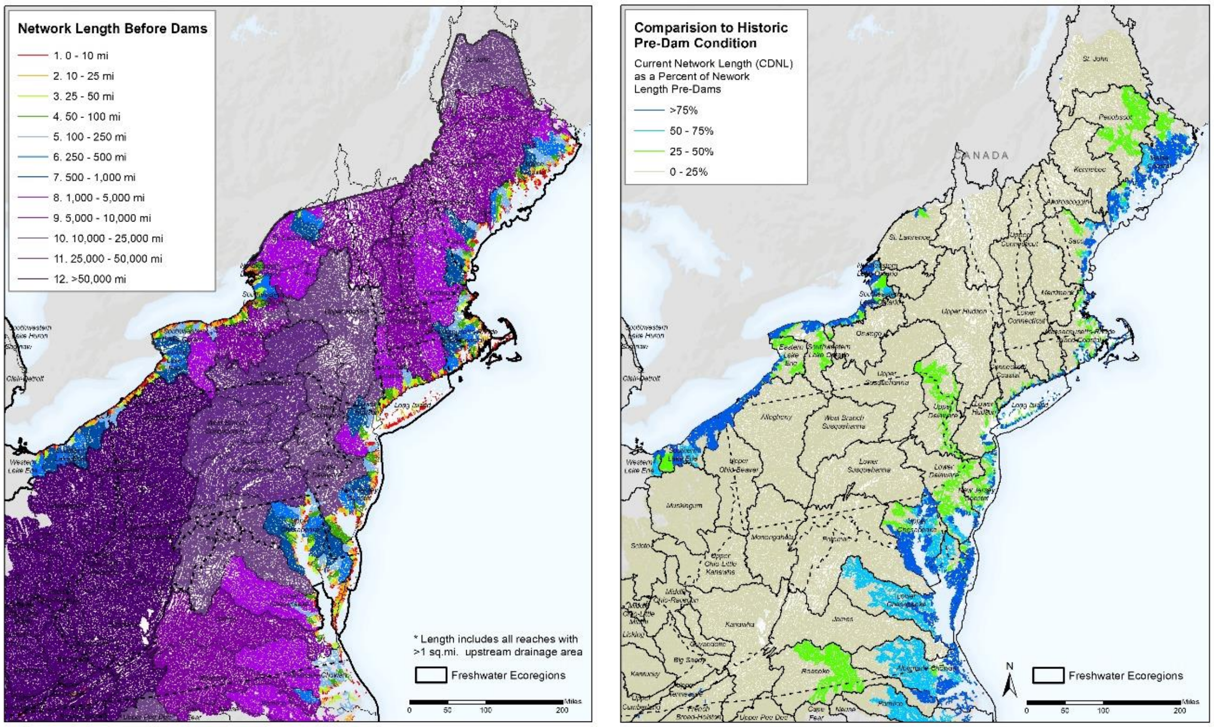
Original Network Length Before Dams	Miles in Class												
	1. 0 - 10 mi	2. 10 - 25 mi	3. 25 - 50 mi	4. 50 - 100 mi	5. 100 - 250 mi	6. 250 - 500 mi	7. 500 - 1,000 mi	8. 1,000 - 5,000 mi	9. 5,000 - 10,000 mi	10. 10,000 - 25,000 mi	11. 25,000 - 50,000 mi	12. >50,000 mi	Grand Total
Appalachian Piedmont	16	17		1	204			3,478	15,014	110			18,840
Chesapeake Bay	284	518	395	668	787	1,281	3,032	4,811	1	13,137	25,408		50,323
Great Lakes/St. Lawrence	485	588	723	626	1,164	1,592	2,136	8,336	10,505	0			26,155
Northeast Atlantic Drainages	1,573	1,223	1,214	2,009	2,177	2,247	4,212	10,914	23,055	27,249			75,872
Ohio/Tennessee	13	13										42,738	42,764
NORTHEAST REGION	2,370	2,359	2,331	3,304	4,332	5,119	9,380	27,540	48,576	40,495	25,408	42,738	213,954
MID-ATLANTIC SUBREGION	752	1,071	694	1,438	1,854	1,849	4,299	9,393	15,016	21,726	19,595	41,127	118,815
NEW ENGLAND/NY SUBREGION	1,618	1,288	1,638	1,866	2,478	3,270	5,082	18,146	33,560	18,769	5,813	1,611	95,139
	Percent in Class												
	1. 0 - 10 mi	2. 10 - 25 mi	3. 25 - 50 mi	4. 50 - 100 mi	5. 100 - 250 mi	6. 250 - 500 mi	7. 500 - 1,000 mi	8. 1,000 - 5,000 mi	9. 5,000 - 10,000 mi	10. 10,000 - 25,000 mi	11. 25,000 - 50,000 mi	12. >50,000 mi	
Appalachian Piedmont	0.1	0.1	0.0	0.0	1.1	0.0	0.0	18.5	79.7	0.6	0.0	0.0	
Chesapeake Bay	0.6	1.0	0.8	1.3	1.6	2.5	6.0	9.6	0.0	26.1	50.5	0.0	
Great Lakes/St. Lawrence	1.9	2.2	2.8	2.4	4.4	6.1	8.2	31.9	40.2	0.0	0.0	0.0	
Northeast Atlantic Drainages	2.1	1.6	1.6	2.6	2.9	3.0	5.6	14.4	30.4	35.9	0.0	0.0	
Ohio/Tennessee	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.9	
NORTHEAST REGION	1.1	1.1	1.1	1.5	2.0	2.4	4.4	12.9	22.7	18.9	11.9	20.0	
MID-ATLANTIC SUBREGION	0.6	0.9	0.6	1.2	1.6	1.6	3.6	7.9	12.6	18.3	16.5	34.6	
NEW ENGLAND/NY SUBREGION	1.7	1.4	1.7	2.0	2.6	3.4	5.3	19.1	35.3	19.7	6.1	1.7	

Map 6.12. Current Functional Connected Network (FCN) Length 2022.



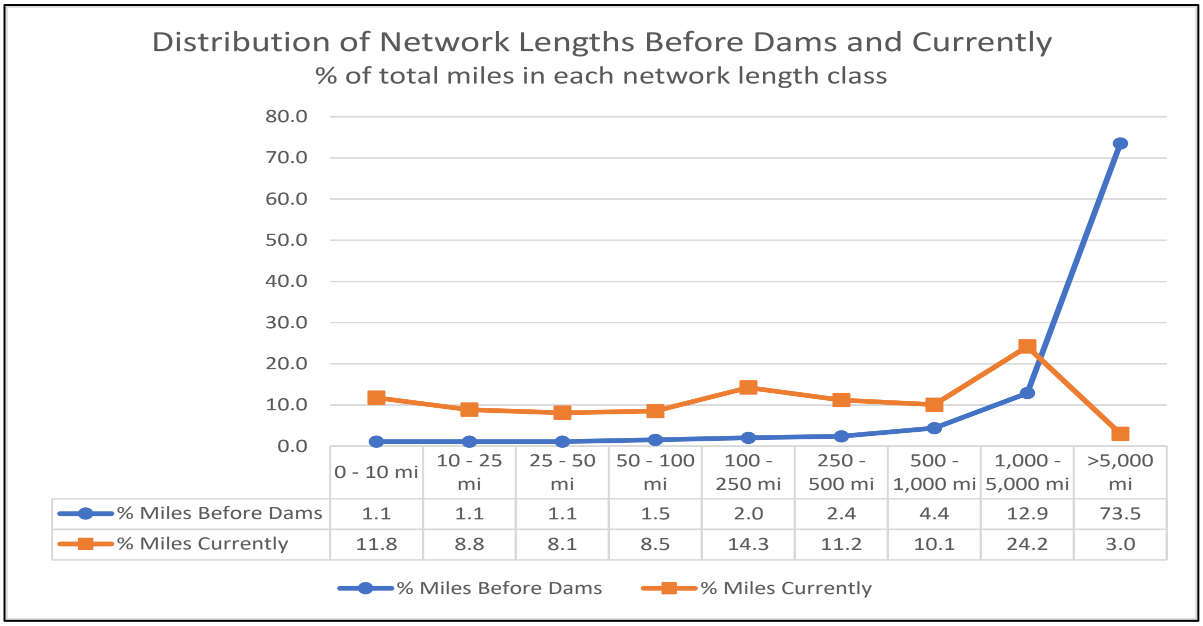
For context, we created a map and table showing the sizes of the original FCN if there were no dams creating barriers to movement (Table 6.14B, Map 6.13). Although relatively long networks can still be found in the Ohio/Tennessee Ecoregion, Chesapeake Bay Ecoregion, Appalachian Piedmont Ecoregion, the Delaware River mainstem, and northern Maine, in general networks have decreased dramatically in size from their historic pre-dam conditions. Even given the dam removals and improvements in partial passability in the last decade, graphing the distribution of stream and river miles historically and currently by network size class shows a striking loss of large networks and a corresponding shift in the distribution to much smaller networks (Figure 6. 10).

Map 6.13. Comparing Current Network Length to Network Length Before Dams



Historically, 74% of all stream miles in the region were embedded in very large networks over 5,000 miles long and today only 3% of miles are in these very large length networks. Conversely, only 2% of miles historically were in networks less than 25 miles long, while today 21% of miles are in these small networks (Table 6.13). In New England and New York, 91% of all miles were originally found in networks over 500 miles long and currently only 37% of the subregion’s miles are found in these sized networks.

Figure 6. 10. Distribution of Current and Historic Network Lengths



Compared to historic conditions, 86% of miles in the region are in networks less than a quarter of their pre-dam size (Table 6.15). This includes 100% of networks in the Ohio/Tennessee basin which were once part of the gigantic Mississippi drainage basin. Even ecoregions with naturally smaller networks, or networks connected to the ocean and great lakes coasts have a similar pattern with 77-84% of miles now in networks less than a quarter of their pre-dam size. Today only 4% of miles are found in networks that are at least 75% of their original size (Table 6.14). Many of these are clustered along the Atlantic or Great Lakes coasts in low gradient, naturally small river systems where often the physical settings was less ideal for dam building given the hydraulic head.

Overall, these results highlight the pervasive impact dams have had on reducing connectivity in Northeast freshwater systems. We have lost not only our largest networks, but there has been a massive reduction in the size of nearly all networks, and a large increase of very small networks. Again we applaud the last decades' 346 dam removals and the newly opened 4,965 miles of river and stream habitat.

Table 6.15. Current Network Length as a Percentage of its Original Pre-Dam Length

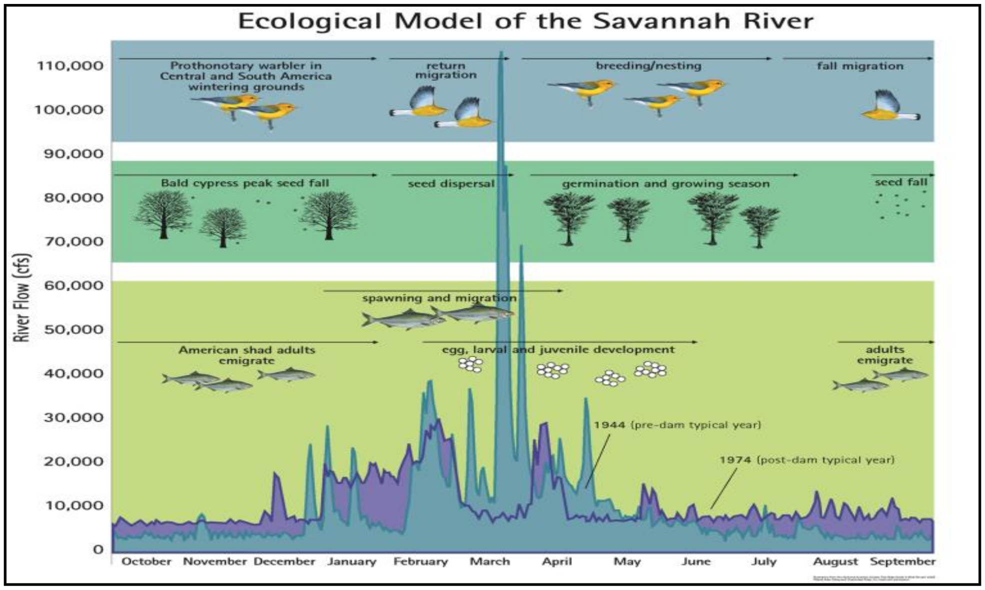
Current Network Length (CDNL) as a Percent of Original Length of Nework Before Dams	Miles in Class					Percentage in Class			
	1. >75%	2. 50 - 75%	3. 25 - 50%	4. 0 - 25%	Grand Total	1. >75%	2. 50 - 75%	3. 25 - 50%	4. 0 - 25%
Appalachian Piedmont	177	1,868	2,360	14,435	18,840	1	10	13	77
Chesapeake Bay	3,020	4,518	736	42,049	50,323	6	9	1	84
Great Lakes/St. Lawrence	1,860	502	2,089	21,703	26,155	7	2	8	83
Northeast Atlantic Drainages	3,593	1,780	8,055	62,443	75,872	5	2	11	82
Ohio/Tennessee	25			42,739	42,764	0	0	0	100
NORTHEAST REGION	8,674	8,668	13,241	183,370	213,954	4	4	6	86
MID-ATLANTIC SUBREGION	4,399	6,916	6,409	101,090	118,815	4	6	5	85
NEW ENGLAND/NY SUBREGION	4,275	1,752	6,832	82,280	95,139	4	2	7	86

Hydrologic Alteration

Flow is the essence of a stream or river, the “master variable” that structures the physical habitat both in the channel and on the adjacent floodplain (Poff et al. 1997). The natural timing, magnitude, and frequency of stream flow influences the evolutionary adaptations of river biota and controls many physical and chemical processes. High flows shape the stream channel, move sediment, and deposit silt-laden floodwaters on adjacent floodplains, replenishing the soil, and creating feeding and nursery grounds for fish. Low flows define the smallest habitat area available to stream biota during the year. Riparian species have evolved to complete their life histories when water is available and are adapted to the natural flow fluctuations (Allan 1995, Figure 6. 11).

Lotic ecosystems have been highly impacted by the human manipulation and alteration of natural stream flows. Roughly 50% of rivers and streams across the world are hydrologically altered from their natural state, including 80% of streams and rivers in the conterminous US (McManamay et al, 2022). Alterations in the northeast are often due to dams which alter the storage and release of water. Their hydrological impacts may be described based on their designated purposes. Hydropower dams hold and release water in response to or following the demand for energy. Water supply dams are characterized by extended low flows as reservoirs capture upstream inflows. Large recreational reservoirs often function similarly, as they capture all upstream inflows until the reservoir is full, at which point outflows equal inflows. Flood control dam management results in increased flow stability and decreased high flow events. (Richter and Thomas 2007).

Figure 6. 11. Ecological functions and hydrograph before (blue) and after (purple) damming. Kelly Applegate, TNC GAFO used with permission.



Hydrologic flows are also altered by impervious surface runoff which increases flashiness, water withdrawals for agriculture leading to low flows in summer growing season, and municipal water withdrawals and returns which can both decrease and increase baseflows depending on the pattern of extraction and return (Eng et al. 2019). Several northeast rivers such as the Connecticut (Kennedy et al. 2018) and Delaware (DePhilip, M. and T. Moberg. 2013) have been studied to document the extent of their high flow alteration, identify causes, and possible remediation.

Until recently, it has been challenging to comprehensively map and model the extent of flow alterations across large geographies. In 2022, McManamay and colleagues published an innovative method to comprehensively map a Hydrologic Alteration Index (HAI) for the coterminous U.S. (McManamay et al. 2022). The HAI index reports the degree of separation between the current flow regime of streams and rivers and that of reference streams within the same hydrologic class. It used reference and non-reference gages, over 110 hydrologic metrics, multidimensional measures of hydrologic regime, a principal components analysis, and a Random Forest Models to predict flows at ungaged locations for all NHD Medium Resolution flowlines using natural and human landscape characteristics. The resultant HAI ranges from 0−1, with 0 being unaltered reference condition. Anthropogenic variables with highest relative importance in predicting flow alteration included dam related variables followed by urban land use, agriculture, a disturbance index, discharge points, and energy sector withdrawals (power plants) in that order.

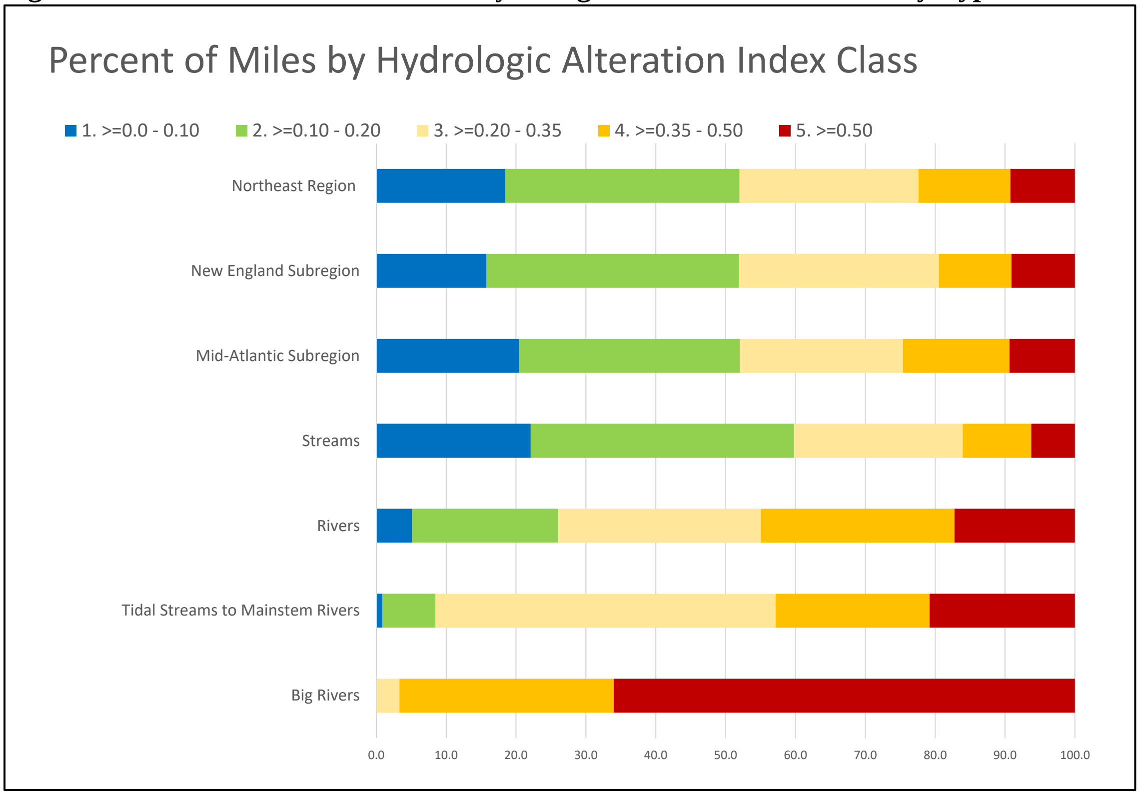
Mapping the HAI for the northeast (Map 6.14, Table 6.16, Figure 6. 12) reveals that the majority of stream and river miles are expected to show signs of hydrologic alteration, with larger rivers showing higher levels of alteration. Thresholds for reporting hydrologic alteration vary, with McManamay et al 2020 using a 20% threshold of change in hydrologic indices from reference conditions to report significant hydrologic alteration (HAI values >= 0.2) , while some other studies report finding impacts at a 10% alteration from reference condition threshold (Carlisle et al, 2011). Using the HAI index and the most conservative threshold of 10% alteration, 82% of stream and river miles in the northeast are altered, and 48% meet the higher threshold of being altered at 20% compared to reference conditions.

For Big Rivers the alteration threshold makes no difference as 100% are altered at either the 10% or 20% reference condition (Table 6.15). Tidal streams and rivers also show very high levels of alteration with 99 and 92% respectively altered using the 10% or 20% threshold. For rivers (small to mainstem), the HAI data shows 95% altered 10% from reference and 74% altered 20% from reference. Headwater and creek streams come in as least altered, with 78% showing some alteration at 10% and only 40% showing alteration 20% or more from reference condition. Applying only the most severely altered class (>50% HIA), 66% of Big River miles fall in this class, 21% of tidal streams and rivers, 17% rivers, and 6% of streams. Across all types 9% of stream and river miles fall in the most severely impacted class.

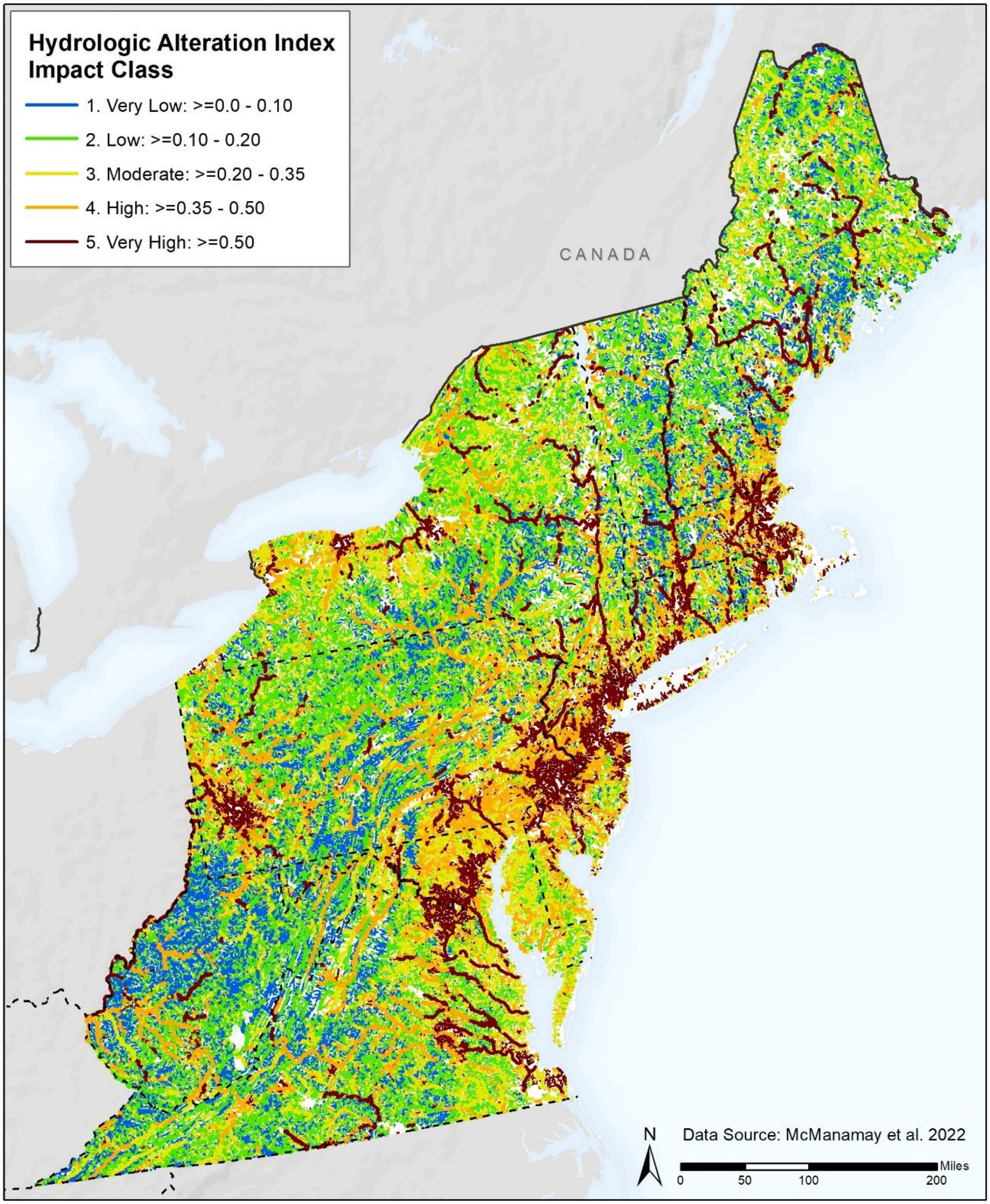
Table 6.16. Percent of miles in each hydrologic alteration index class by stream and river type

	% HAI Class 1. >=0.0 - 0.10	% HAI Class 2. >=0.10 - 0.20	% HAI Class 3. >=0.20 - 0.35	% HAI Class 4. >=0.35 - 0.50	% HAI Class 5. >=0.50
Streams	22	38	24	10	6
Rivers	5	21	29	28	17
Tidal Streams & Rivers	1	8	49	22	21
Big Rivers	0	0	3	31	66
New England-NY Region	16	36	29	10	9
Mid-Atlantic Region	20	32	23	15	9
Northeast Region	18	34	26	13	9

Figure 6. 12. Percent of Miles in each Hydrologic Alteration Index class by Type and Subregion.



Map 6.14. Index of Hydrologic Alteration Impacts (HAI. McManamay et al. 2022)



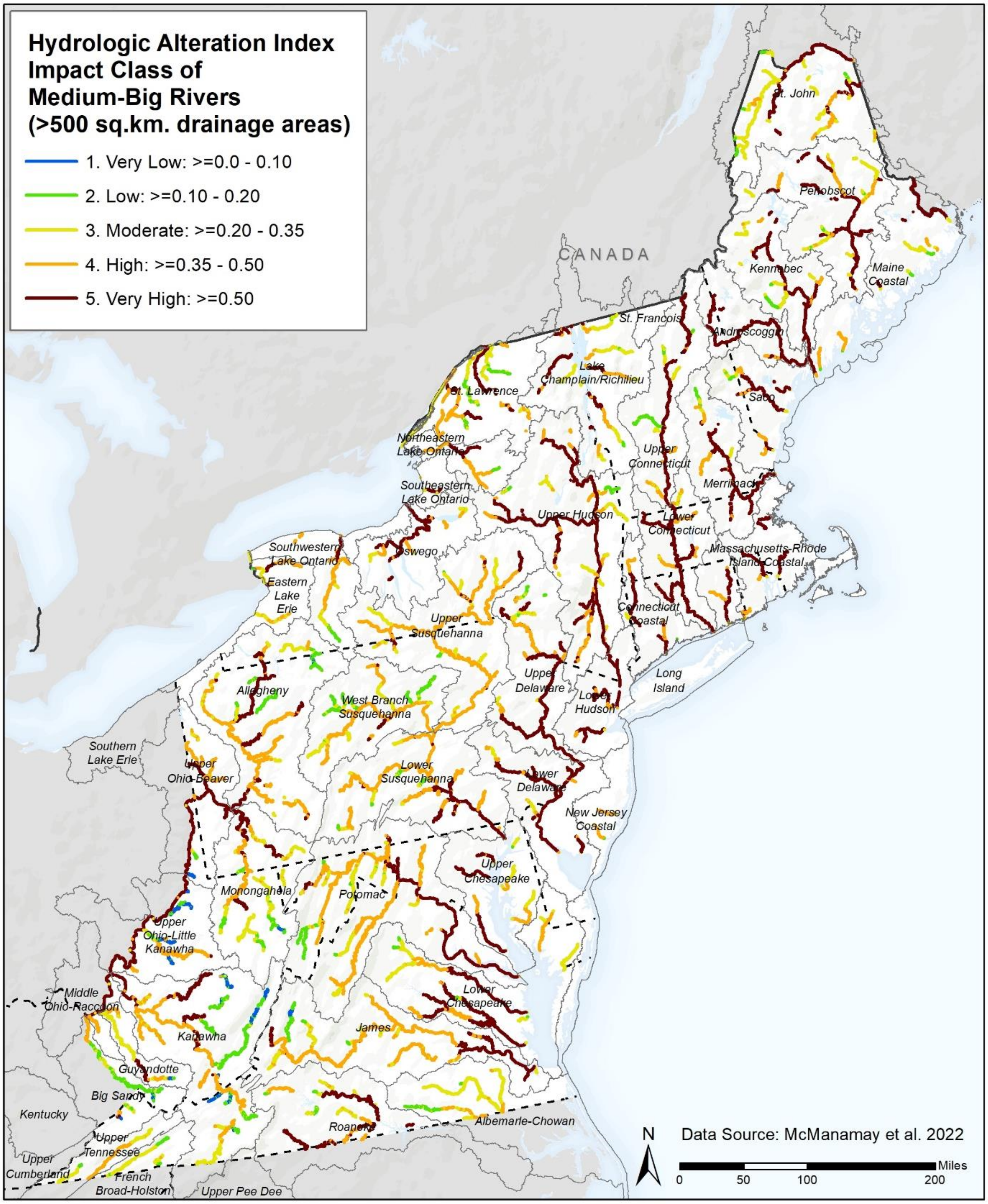
Considering only our familiar Medium-Big rivers with over 500 sq.km. drainage area (Map 6.15) almost every lower mainstems river entering the Atlantic Ocean scores as severely altered as does the Ohio River mainstem. Medium-big rivers of the Mid-Atlantic have fewer miles (28%) in the most impacted class (HAI 50%), while New England-NY has a higher percentage (48%) in the most impacted class.

Summarizing the above rivers by name within HUC6 watersheds (See Appendix for full list) shows that only 28 out of 460 have over 75% of their total length in the relatively unaltered class (HAI <20%). This includes the following short list of most hydrologically intact larger rivers that are particularly rare and outstanding among larger rivers in our region (Table 6.17). Most of these are found in the Mid-Atlantic region, including many in the Teays-Old Ohio freshwater ecoregion and a few in the Appalachian Piedmont, Chesapeake Bay, and Tennessee ecoregions. The longest is the Greenbrier River in the Kanawa river basin with 136 miles of hydrologically intact river. Second is the Cow Pasture River in the James river basin. Only one river in the North Atlantic Freshwater Ecoregion met the 75% criteria – the White River of the Upper Connecticut. No rivers in the Great Lakes ecoregion met the 75% criteria.

Table 6.17. List of Most Hydrologically Intact Medium-Big Rivers by HUC6 Watershed. These named rivers (>500 sq.km upstream drainage area and at least 2 miles long) have more than 75% of their total length in the least altered class (HAI <0.2).

Freshwater Ecoregion	HUC6 Watershed	River Name	Total Miles	% in Least Impacted Top 2 Classes (<0.2 HAI)
Appalachian Piedmont	Albemarle-Chowan	Stony Creek	4	100
Appalachian Piedmont	James	Calfpasture River	3	100
Appalachian Piedmont	James	Cowpasture River	63	95
Chesapeake Bay	Lower Susquehanna	Dunning Creek	3	98
Chesapeake Bay	Lower Susquehanna	Tuscarora Creek	13	93
Chesapeake Bay	Potomac	North Fork South Branch Potomac River	20	99
Northeast US Atlantic Drainages	Upper Connecticut	White River	36	97
Teays - Old Ohio	Allegheny	Oswayo Creek	7	95
Teays - Old Ohio	Allegheny	Potato Creek	5	100
Teays - Old Ohio	Allegheny	Tionesta Creek	33	95
Teays - Old Ohio	Big Sandy	Dry Fork	11	99
Teays - Old Ohio	Kanawha	Big Reed Island Creek	16	97
Teays - Old Ohio	Kanawha	Greenbrier River	136	98
Teays - Old Ohio	Kanawha	Indian Creek	3	100
Teays - Old Ohio	Kanawha	Meadow River	31	95
Teays - Old Ohio	Kanawha	Walker Creek	24	99
Teays - Old Ohio	Kanawha	Wolf Creek	16	98
Teays - Old Ohio	Monongahela	Black Fork	4	100
Teays - Old Ohio	Monongahela	Dry Fork	14	100
Teays - Old Ohio	Monongahela	Dunkard Creek	15	86
Teays - Old Ohio	Monongahela	Shavers Fork	7	99
Teays - Old Ohio	Upper Ohio-Beaver	Fish Creek	14	100
Teays - Old Ohio	Upper Ohio-Little Kanawha	Fishing Creek	6	91
Teays - Old Ohio	Upper Ohio-Little Kanawha	Hughes River	14	100
Teays - Old Ohio	Upper Ohio-Little Kanawha	Middle Island Creek	50	100
Teays - Old Ohio	Upper Ohio-Little Kanawha	South Fork Hughes River	15	100
Teays - Old Ohio	Upper Ohio-Little Kanawha	West Fork Little Kanawha River	14	98
Tennessee	French Broad-Holston	South Fork Holston River	4	100

Map 6.15. Hydrologic Alteration Index Impacts for Medium-Big Rivers



Impervious Surfaces

Impervious surfaces are substrates, like asphalt or concrete, incapable of being penetrated by water. Impervious surfaces prevent the natural pattern of rainwater soaking into the ground and slowly seeping into streams. Instead, the rainwater accumulates and flows rapidly overland. This harms streams in important ways:

- **Water Quantity:** Storm drains deliver large volumes of water to streams much faster than would occur naturally, resulting in flooding and bank erosion. Flows peak more rapidly during storms, and peak flows are higher and more frequent. Lack of groundwater recharge during rain events leads to lower daily base flows.
- **Channel Habitat:** Stream channels become wider, less stable, and less complex. Stream inhabitants are stressed, displaced, or killed by fast moving water and the debris, sediment, and disturbed channel habitat it brings.
- **Water Quality:** Pollutants (gasoline, oil, fertilizers, etc.) accumulate on impervious surfaces and are washed into the streams.
- **Water Temperature:** During warm weather, rain that falls on impervious surfaces becomes superheated and can stress or kill stream inhabitants.

All indicators of stream quality relative to biotic condition, hydrologic integrity, and water quality, decline with increasing watershed imperviousness. Research suggests that aquatic systems become seriously impacted when watershed impervious cover exceeds 10% (CWP 2003) and show significant declines in many stream taxa at levels of impervious surface as low as 0.5 to 2% of the watershed. Serious 40-45% declines in regional steam biodiversity (invertebrates, fish, amphibians) have been found at watershed imperviousness greater than 3% (King and Baker 2010) based on the National Land Cover Impervious Dataset (NLCD 2001-2019).

To examine impervious surface impacts in the region, we used data available from the US EPA StreamCat database (https://www.epa.gov/national-aquatic-resource-surveys/streamcat-dataset) which provides the upstream watershed percent imperviousness for each NHD Plus reach based on the reprocessed and consistently calibrated NLCD impervious dataset (Hill et al. 2016, StreamCat 2022). We grouped all stream and river reaches into one of four impact reporting categories using thresholds published by King and Baker (2010) and used in our previous report (Anderson and Olivero Sheldon 2011).

- Class 1: Undisturbed-Very low impacts: 0 < 0.5% impervious.
- Class 2: Low impacts: >=0.5-2% impervious.
- Class 3: Moderately impacted: >=2-10% impervious.
- Class 4: Highly impacted: >=10% impervious.

Applying the categories to the northeast region revealed that 34% of total stream and river miles were undisturbed, 42% had low impacts, 18% were moderately impacted and 7% were highly impacted (Map 6.16, Figure 6. 13, Table 6.18). The percent of miles falling in the undisturbed class decreased with increasing stream size from a high of 38% in streams to a low of 6% for big rivers (Table 6.18). The percent of highly impacted miles was 23% for tidal streams, 6% for streams, 3% for rivers, and 0% for big rivers. The latter is likely due to the fact that big river watersheds were so huge that the effects of impervious surfaces in one area may be offset by the presence of natural cover in another. The highly impacted tidal streams and rivers makes sense because coastal areas tend to be densely populated with development in the small upstream drainages of these tidal systems.

Map 6.16. Streams and rivers by upstream impervious surfaces impact class (NLCD 2019)

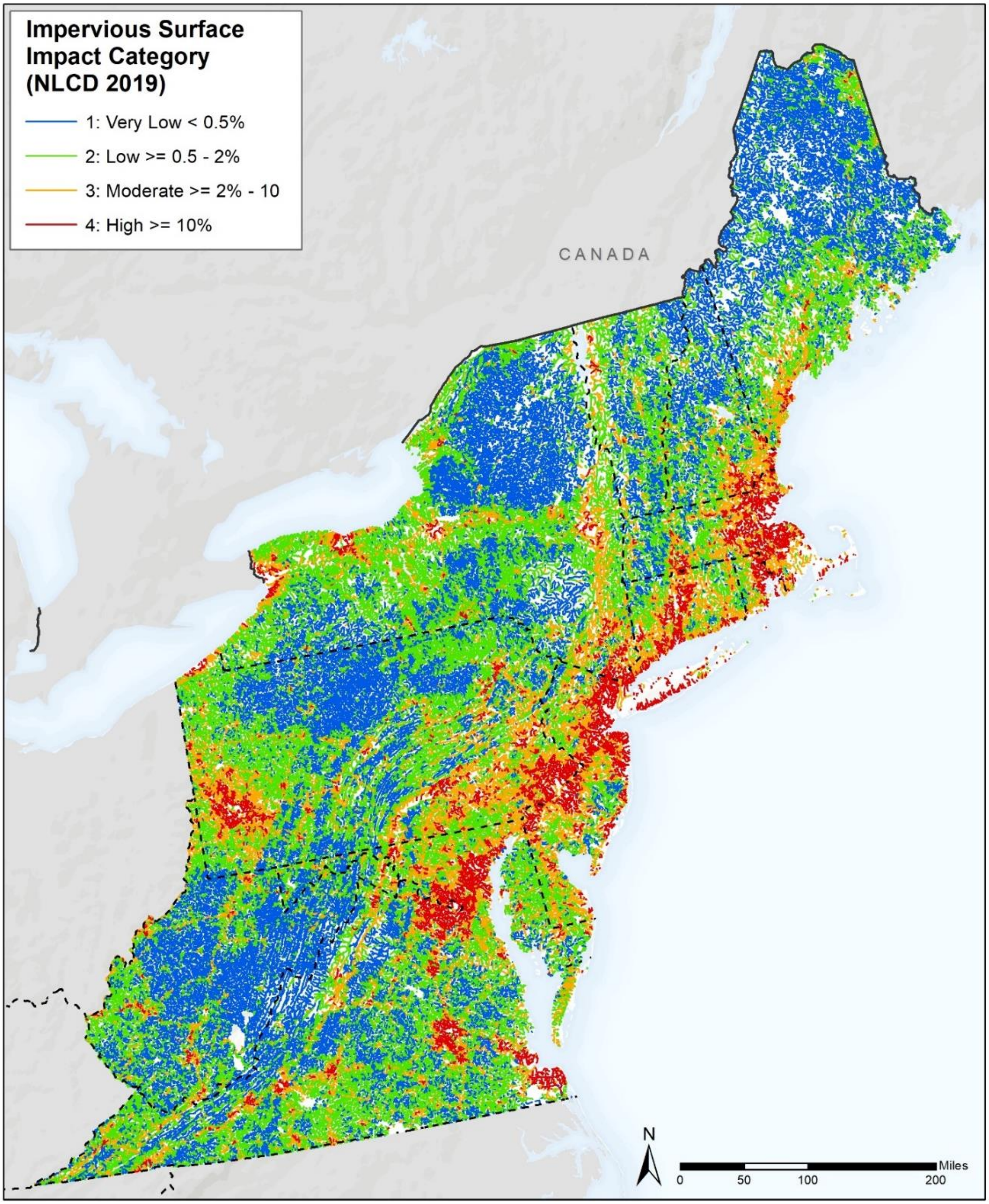


Figure 6. 13. Percent of Stream Miles by Upstream Impervious Surface Class. In this chart, each bar represents the total miles of the habitat type or subregion. Different colors represent the percent of stream miles in the impact class: 1) Undisturbed, 2) Low Impacts, 3) Moderately Impacted, 4) Highly Impacted.

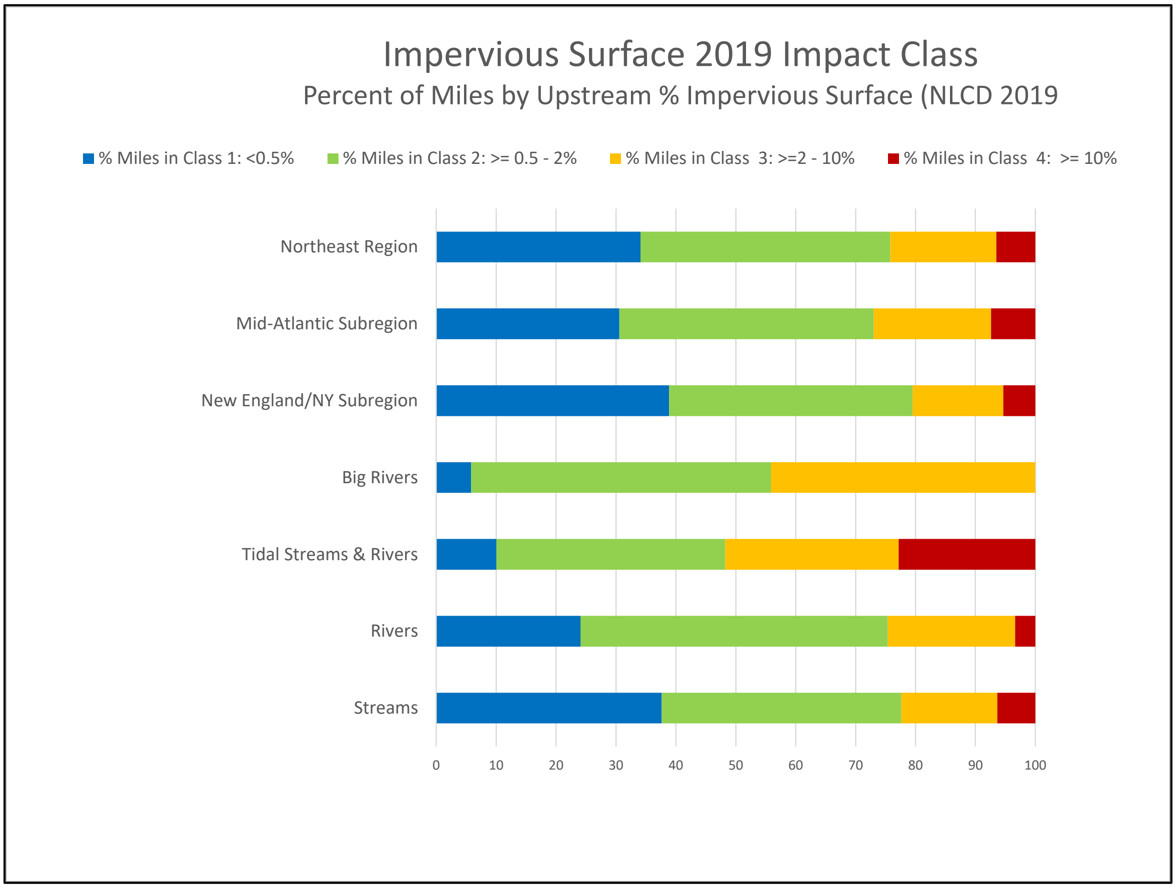


Table 6.18. Percent of Total Mile in each Impervious Surface Class. The classes are 1) Undisturbed, 2) Low Impacts, 3) Moderately Impacted, 4) Highly Impacted.

Upstream Percent Impervious Surfaces 2019 Impact Classes	% Miles in Class 1: <0.5%	% Miles in Class 2: >= 0.5 - 2%	% Miles in Class 3: >=2 - 10%	% Miles in Class 4: >= 10%
Streams	38	40	16	6
Rivers	24	51	21	3
Tidal Streams & Rivers	10	38	29	23
Big Rivers	6	50	44	0
New England/NY Subregion	39	41	15	5
Mid-Atlantic Subregion	31	42	20	7
Northeast Region	34	42	18	7

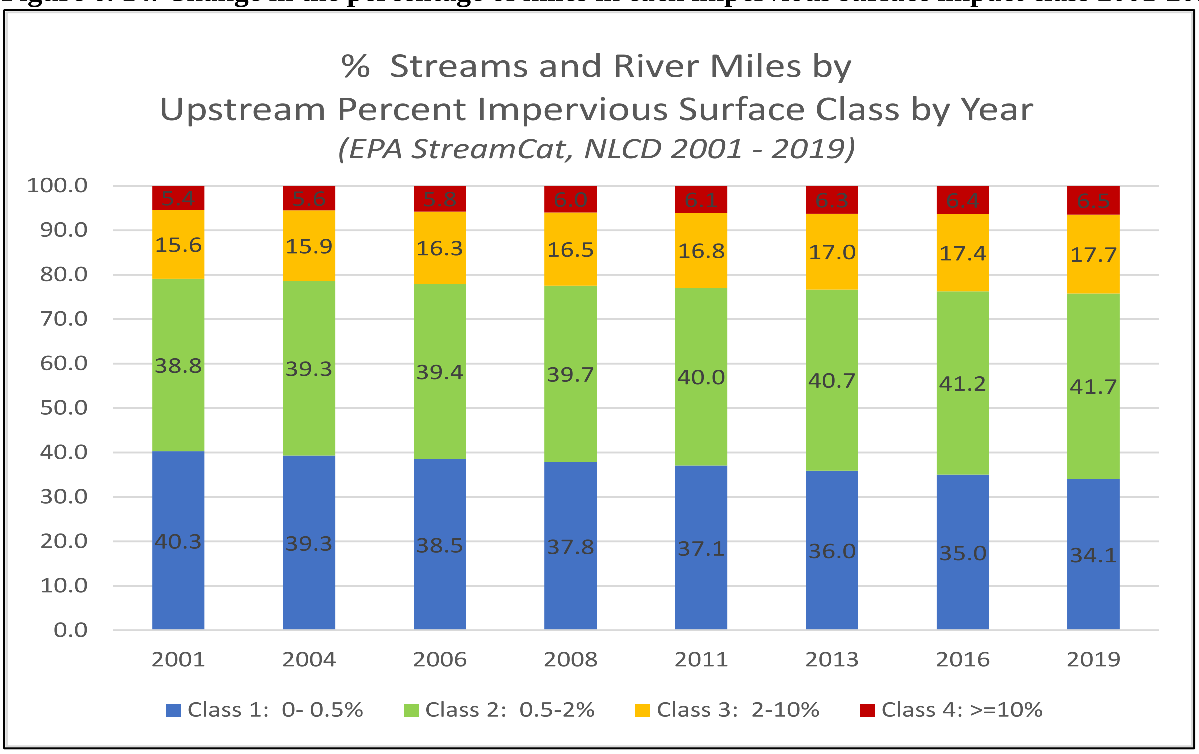
New-England and New York had 39% of its miles in the undisturbed class and the Mid-Atlantic had 31%, however the Mid-Atlantic also had the most impacted miles (7%, Figure 6. 13). Impacts largely track development with CT, DC, RI, NJ and MA all having more than 20% of their miles in the high impact class, while more rural states like ME, WV, NH, VT had over 25% in the undisturbed class.

Recent Trends in Impervious Surfaces.

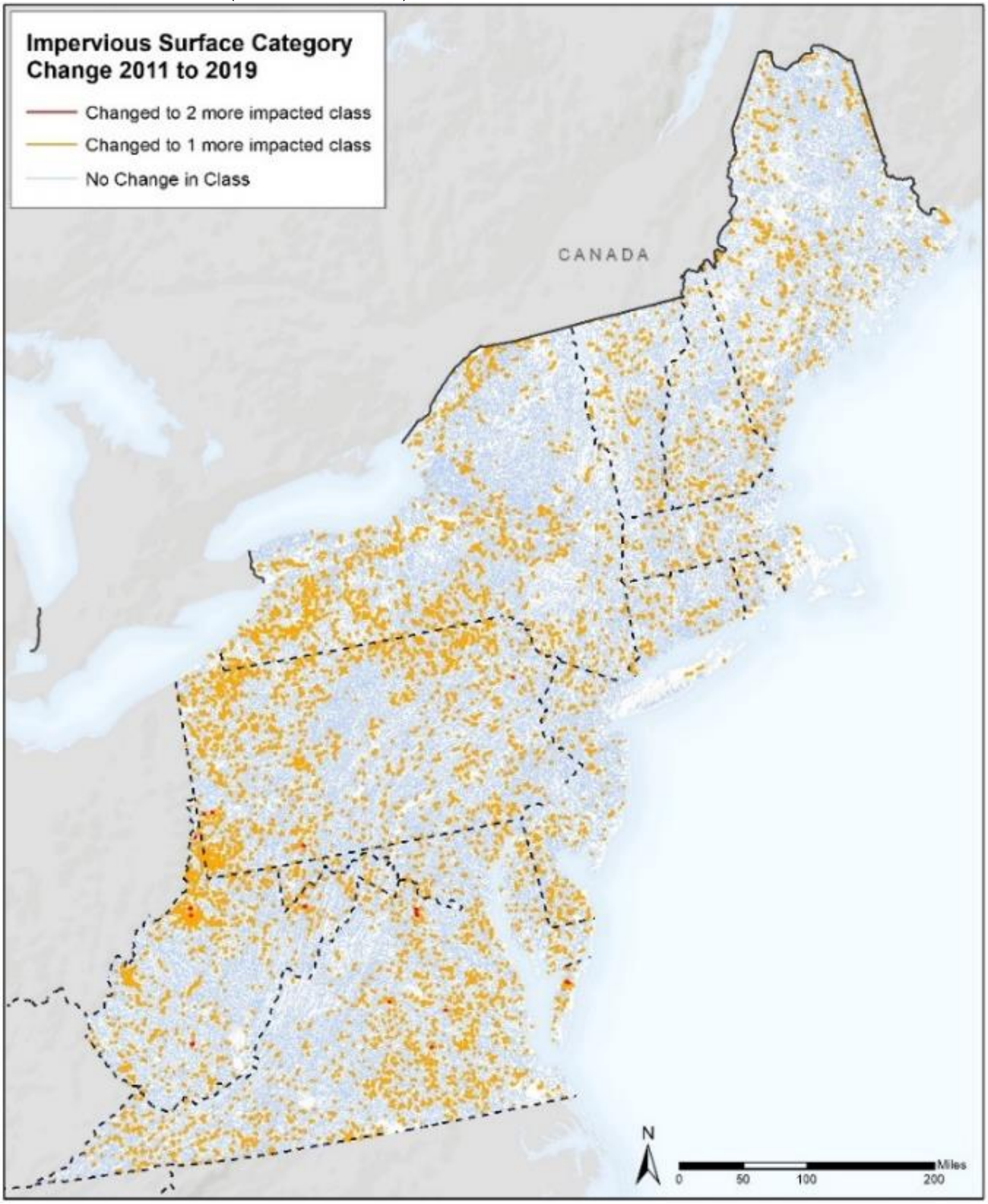
Over the last two decades (2001-2019) impervious surfaces have continued to increase consistent with the expansion of development and suburban sprawl in the northeast (Figure 6. 14). The undisturbed class was no longer the majority after 2004 and the two most highly impacted classes collectively grew from 21% to 24% of all miles between 2001 and 2019. Overall, 11% of the total miles changed to a more impacted class in 2019 compared to their class in 2001.

Within the last decade (2011-2019), 5% of all stream and river miles moved to a more impacted class; 4% of river miles, 5% of stream miles, 4% of tidal systems, and 2% of big river miles. The reaches that changed to a more impacted class in the last decade were widely dispersed across the region with only lands under conservation or very remote and mountainous areas seeing no change (Map 6.17). The Mid-Atlantic states were slightly more impacted by increasing imperviousness with 4-8% of miles changing to a more impacted class compared to 2-4% in New England and New York. Given that once areas are developed into impervious surface it is very hard to return them to a natural state, effort should be made to reduce further loss of land to impervious surfaces to prevent the further degradation and loss of intact stream and river ecosystems.

Figure 6. 14. Change in the percentage of miles in each impervious surface impact class 2001-2019.



Map 6.17. Stream reaches with change to a more impacted upstream impervious surfaces class between 2011 and 2019 (NLCD 2011, 2019)



Nutrient Enrichment

Recent studies suggest most U.S. streams and rivers have higher levels of nitrogen and phosphorus than is recommended (Manning et al. 2020). Although nutrients are a natural part of aquatic ecosystems, human activity has increased nitrogen and phosphorus levels in streams and rivers. At high levels, nutrients can lead to excessive algal growth which can harm water quality, alter food webs and resources, decrease the oxygen that fish and other aquatic life need to survive, and contribute to hypoxia in coastal waters.

Nitrogen is most likely to come from high rates of atmospheric deposition from the burning of fossil fuels or from agriculture and fertilizer application. Agriculture is noted as a substantial source of nitrogen to streams in the Northeast, particularly in the mid-Atlantic region (Ator, 2019). Urban and atmospheric sources also contribute substantial nitrogen to streams throughout the Northeast and most of the nitrogen to streams in New England. Increased phosphorus is more commonly the result of sewage waste, increased soil erosion, and urban runoff. More than one-half of the phosphorus reaching streams in the northeast is contributed by wastewater point sources or urban nonpoint sources (Ator 2019). Northeastern streams also receive phosphorus from agriculture and natural mineral sources.

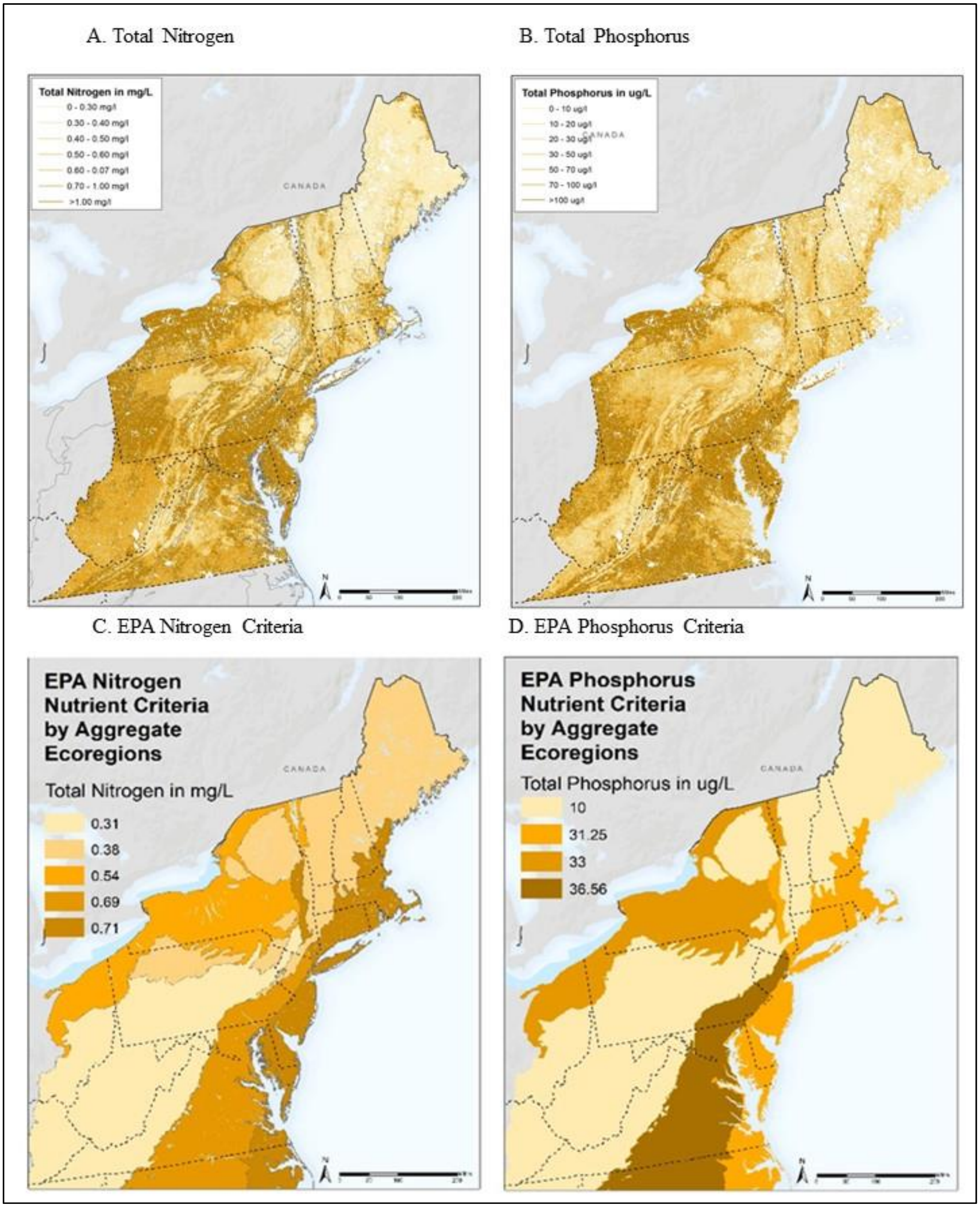
Nutrient enrichment has been listed as the cause of impairment of hundreds of miles of streams, rivers, and waterbodies in the northeast as reported to the EPA under the Integrated Report (IR) and Clean Water Act Sections 303(d) and 305(b). Based on the most recent EPA ATTAINS Water Quality Assessment dataset (https://www.epa.gov/waterdata/get-data-access-public-attains-data; Aug 9, 2022), every northeast state has reported impaired waters due to nutrients and/or closely related impairment causes such as agal blooms and low dissolved oxygen. These include:

- Many rivers draining into the Chesapeake Bay or Delaware Bay,
- Areas of northern VA such as the South Fork Shenandoah River,
- Areas of western PA in the Western Allegheny Plateau,
- Areas of NY such as tributaries of Lake Ontario and NYC’s East River and Bronx River,
- CT’s Housatonic River, Quinnipiac River, Thames River,
- MA’s Merrimack River, Nashua River, Assabet, Blackstone, Charles, and Taunton River,
- RI’s Providence River,
- NH’s tributaries of Great Bay,
- VT’s lower tributaries of Lake Champlain,
- ME’s Mousam, Lower Androscoggin, Sabattus River, and Prestile Stream.

Although not all waters in the northeast states have been sampled for water quality impairment as part of state and EPA water quality monitoring, the USGS SPARROW Models provide an additional assessment of nutrient loads in streams and allow fully comprehensive mapping of nutrient impacts. The SPARROW models use spatially comprehensive geospatial data in a calibrated model to predict water-quality conditions at unmonitored stream locations. The most recent SPARROW model provides an estimated nutrient load for each NHD Medium Resolution reach, as of circa 2012 (USGS, 2019).

We combined the SPARROW Northeast (Ator 2019), Mid-West (Hoos and Roland 2019), and Southeast (Robertson and Saad 2019) outputs to cover the entire NEAFWA geography and summarized patterns in total upstream accumulated nitrogen and phosphorous for streams and rivers. In SPARROW, concentration (*Accumulated load/Accumulated flow*) should be interpreted as concentration weighted by mean-annual flow. Results highlight higher nutrient loads around agriculture and urban areas (Map 6.18).

Map 6.18. Stream and River Reaches by Total Nitrogen and Phosphorus. This shows total nitrogen (A) and phosphorus (B) by stream reach and EPA nitrogen (C) and phosphorus (D) criteria by ecoregion.



We compared the SPARROW nutrient loads to the EPA Nutrient Criteria by Aggregate Ecoregions to evaluate where nutrients are potentially elevated beyond reference condition thresholds. Although most states to not have formal nutrient criteria in their water quality standards, EPA provides recommended nutrient criteria for rivers and streams by ecoregion across the country (Map 6.19). The recommended criteria are not laws or regulations but provide specific guidance that states and tribes may use as a starting point for the criteria for their water quality standards. (https://www.epa.gov/nutrient-policy-data/ecoregional-nutrient-criteria-rivers-and-streams**)**.

Results show 75% of stream and river miles in the northeast exceeded EPA Nitrogen recommended criteria for their aggregate nutrient ecoregion. Much fewer streams and rivers meet the EPA Phosphorus baseline criteria, with 94% of miles exceeding the phosphorus criteria including 98% in the Mid-Atlantic and 90% in New England and New York. Patterns are slightly better for nitrogen with 92% exceeding in the Mid-Atlantic and 54% in New England and New York. Levels of exceedance again follow dominant patterns in agriculture and urban land use.

At the most extreme levels, the top two reporting classes in Map 6.19, the spatial pattens begin to highlight many of the same surface waters reported as highly impaired by nutrients via 303d and 305b reporting. Overall, in the northeast 21% of all streams and rivers fall in these highest two impact categories for nitrogen (exceedance > 1mg/l) and phosphorus (exceedance > 100 ug/l). In the Mid-Atlantic it is 27% for nitrogen and 29% for phosphorus, while in New England and New York it is 13% for nitrogen and 10% for phosphorus. The highest proportion of miles in the highest impact classes for nitrogen include tidal streams and rivers at 36%, followed by streams at 21%, rivers at 19% and big rivers at 12%. For phosphorus it is tidal streams and rivers at 33%, streams at 21%, big rivers at 19% and rivers at 17% (Map 6.19).

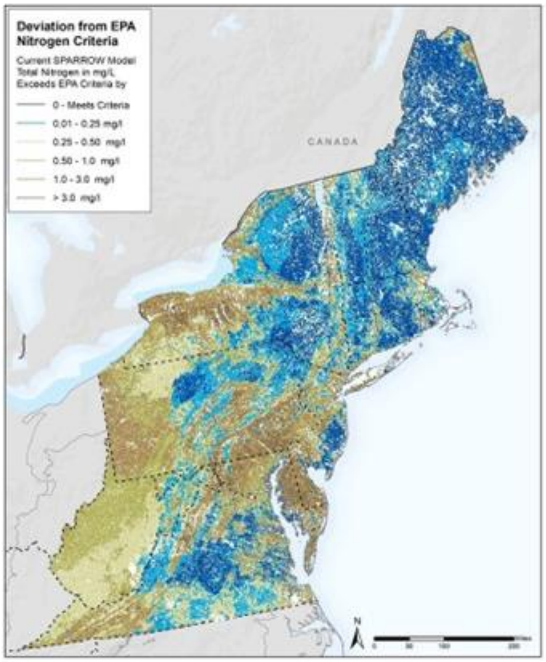
Table 6.19. Nitrogen and Phosphorus Exceedance by Percent Steam Miles: How much the current nutrient load exceeds the EPA suggested criteria by percent of total stream miles.

Nitrogen	%Miles in N Class 1: 0 mg/l: Meets Criteria %	%Miles in N Exceedance Class 2. >0 - 0.25 mg/l	%Miles in N Exceedance Class 3. >0.25 - 0.50 mg/l	%Miles in N Exceedance Class 4. >0.50 - 1 mg/l	%Miles in N Exceedance Class 5. >1 - 3 mg/l	%Miles in N Exceedance Class 6. > 3 mg/l
Big Rivers	21	15	13	39	12	0
Rivers	24	18	18	20	17	3
Streams	25	19	17	19	16	5
Tidal Streams & Rivers	25	14	10	15	26	10
New England/NY Subregion	46	22	9	10	10	3
Mid-Atlantic Subregion	8	16	23	26	21	6
Northeast Region	25	19	17	19	16	5

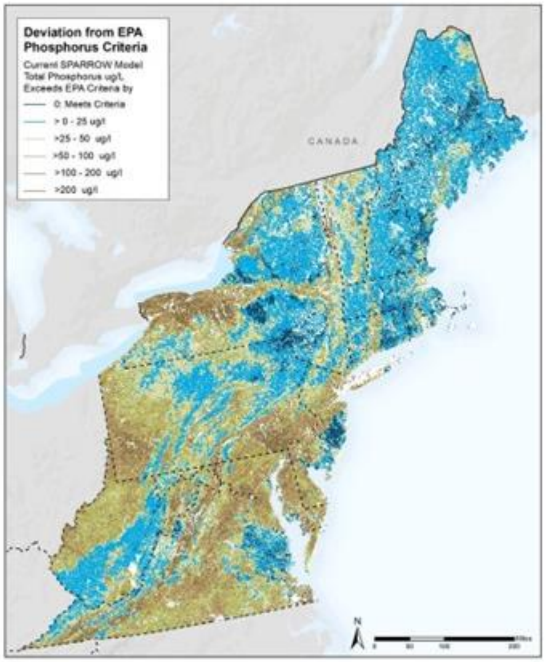
Phosphorus	%Miles in P Class % 1: 0 ug/l: Meets Criteria %	%Miles in P Exceedance Class 2. >0 - 25 ug/l	%Miles in P Exceedance Class 3. >25 - 50 ug/l	%Miles in P Exceedance Class 4. >50 - 100 ug/l	%Miles in P Exceedance Class 5. >100 - 200 ug/l	%Miles in P Exceedance Class 6. > 200 ug/l
Big Rivers	4	21	22	34	19	0
Rivers	7	31	20	24	13	4
Streams	5	35	18	21	15	6
Tidal Streams & Rivers	11	22	14	21	24	9
New England/NY Subregion	10	51	18	10	6	4
Mid-Atlantic Subregion	2	21	17	31	22	6
Northeast Region	6	34	18	22	15	5

Map 6.19. Stream and River Reaches by deviation from EPA Criteria. Map shows the SPARROW model results minus EPA Criteria. Deviations in nitrogen (A) and phosphorus (B) are mapped them summed by stream type and subregon (C & D).

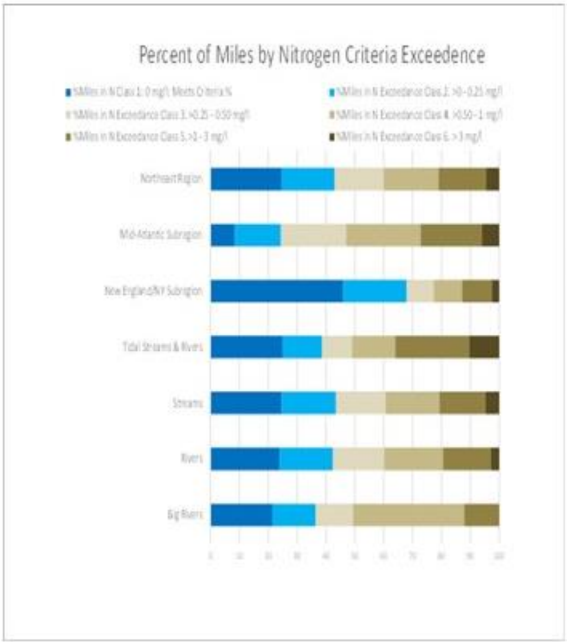
A. Nitrogen: Deviations from EPA



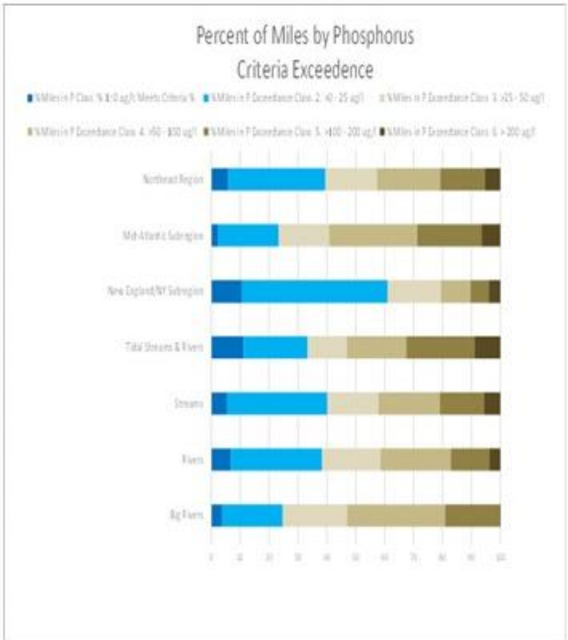
B. Phosphorus: Deviations from EPA



C. Nitrogen Deviations by Type & Subregion



D. Phosphorus Deviations by Type and Subregion



BIOTIC CONDITION: Benthic Macroinvertebrate Index

Although we don't know exactly how landscape variables affect instream biota, the biological condition of streams and rivers can be assessed directly by analyzing the characteristics of the benthic organism communities. These characteristics include the composition and relative abundance of key macro-invertebrates that reflect the quality of their environment and respond to human disturbance in predictable ways. The EPA's NSR Benthic Invertebrate Multimetric Index (BMMI) is a multi-metric measure that integrates across many indices describing the benthic community including: taxonomic richness, composition, and diversity, habits and feeding groups, and pollution tolerance. The index is widely used by state and federal agencies to assess the ecological quality of streams, and it has been incorporated into the water quality criteria regulations of some state agencies.

Although only a small number of sites are regularly monitored and assessed for BMMI, the EPA released a new model (Hill et al., 2017) that predicts for every NHD Plus reach the probability that the reach is in good BBMI biological condition. These probabilities were generated using a random forest model developed from BMMI data for known sample locations and a variety of local and landscape GIS predictor variables which were used to estimate the probability at unsampled locations.

Mapping the predicted BBMI (Hill et al. 2017) for the Northeast shows that only 5% of it streams and rivers have an 80% probability of having a good benthic index, distributed as 13% in New England and New York and 1% in the Mid-Atlantic (Table 6.20, Map 6.20, Figure 6. 14) . Streams (6%) and rivers (5%) have a larger proportion in the more intact probabilities than big rivers (1%) or tidal systems (1%). Lowering the threshold for the region does not alter the results much: 8% have a 70% probability of having good BBMI.

Table 6.20. Distribution of each Benthic Invertebrate Multimetric Index (BMMI) Probability Class. In this table the rows are the percent of stream miles in the probability class. For example, row 1 and column 1 show that 0% of tidal streams and rivers are predicted to be in the BMMI 90% class.

	1. >90%	2. >=80 - 90 %	3. >=70 - 80 %	4. >=60 - 70 %	5. >=50 - 60 %	6. >=40 - 50 %	7. >=30 - 40 %	8. >=20 - 30 %	9. >=10 - 20 %	10. >=0 - 10 %
Tidal Streams & Rivers	0	0	0	5	11	15	28	21	3	17
Big Rivers	0	0	2	8	19	17	18	18	9	9
Rivers	0	5	12	19	20	17	11	9	6	1
Streams	0	6	8	11	16	17	15	9	5	13
New England/NY Subregion	1	12	14	14	15	12	10	9	6	7
Mid-Atlantic Subregion	0	0	4	11	17	20	19	10	4	15
Northeast Region	0	5	8	12	16	17	15	9	5	11

Map 6.20. Probability of Good BMMI Biotic Condition. (Hill et al., 2017)

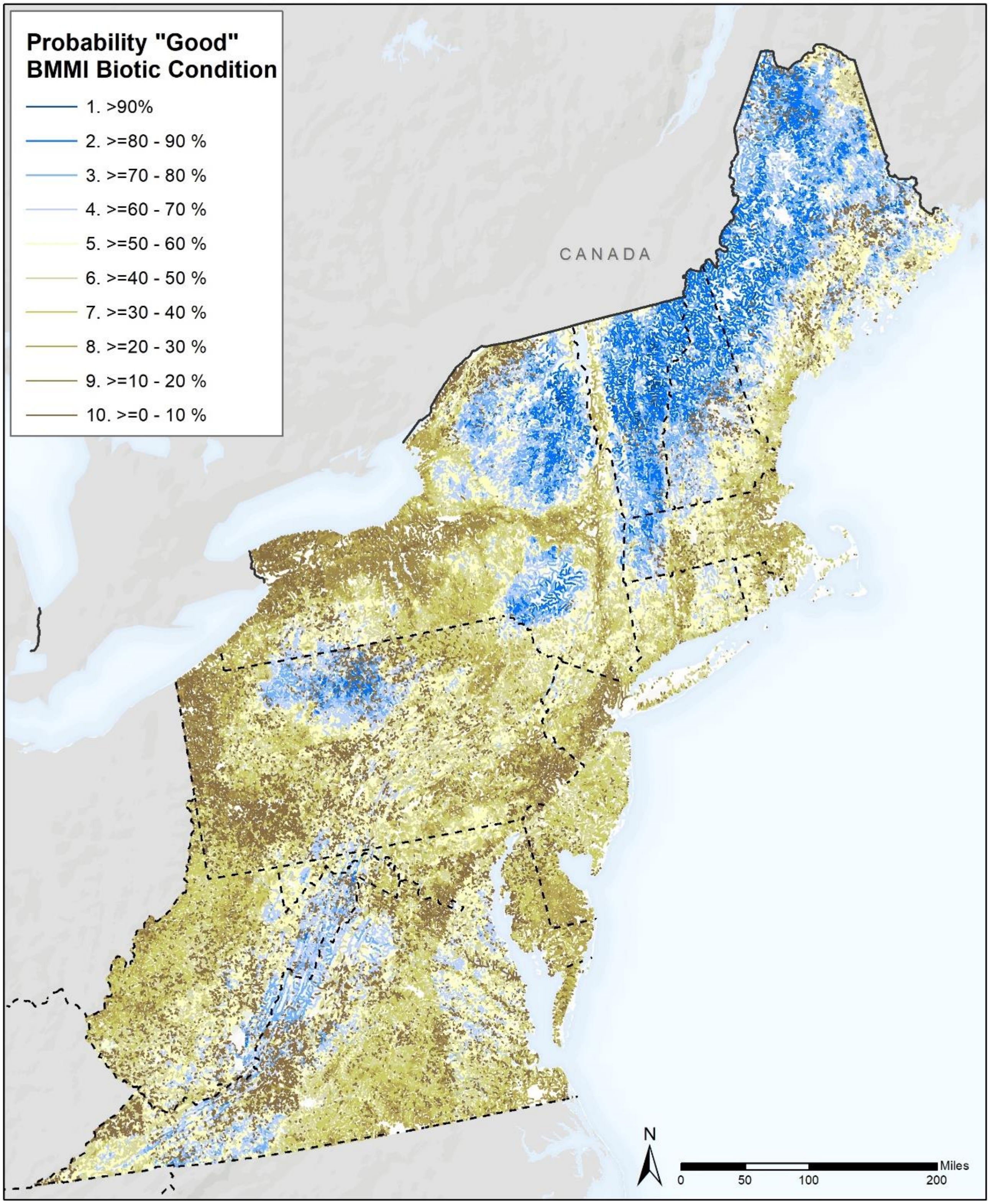


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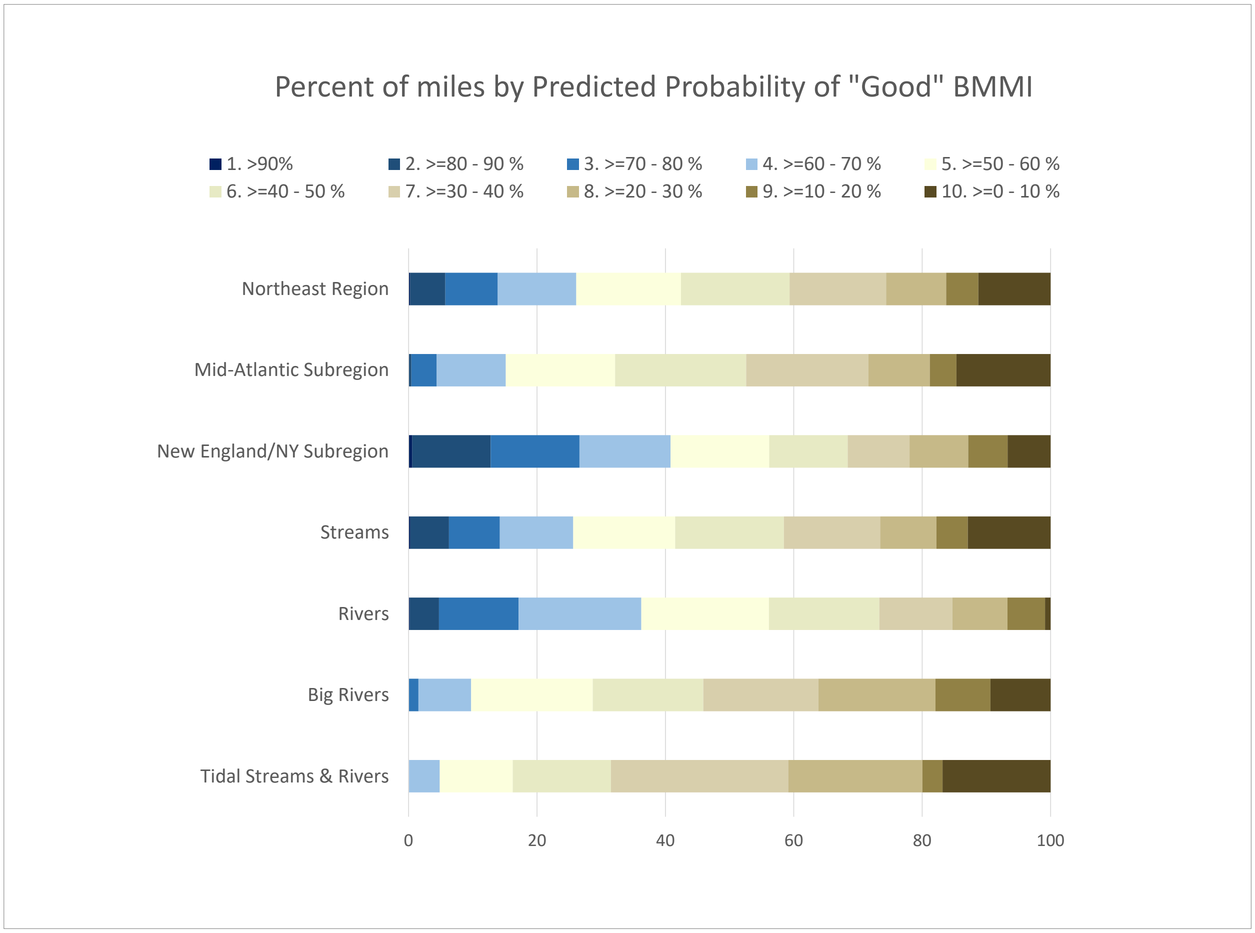
Figure 6. 14. Percent of miles by Predicted Probability of Good BMMI



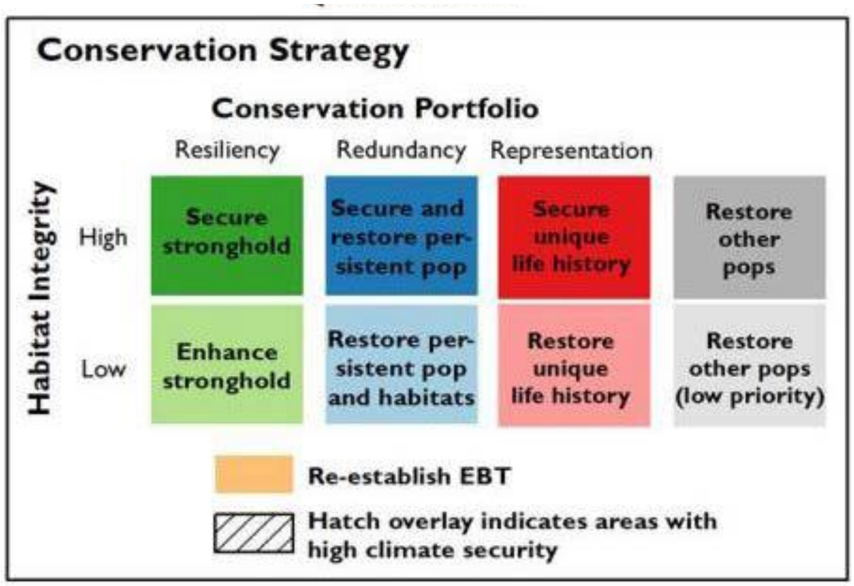
Brook Trout

Within their eastern range in the United States, brook trout (*Salvelinus fontinalis* or EBT) are a primary species of conservation concern. Trout Unlimited developed a widely recognized Conservation Strategy area map for Brook Trout Conservation in the eastern U.S. (Fesenmyer et al. 2017) based on data related eastern brook trout populations, their habitats, and threats to those habitats.

The mapped Conservation Strategies (Figure 6. 15, Map 6.21, Table 6.21) are based on combining a Brook Trout Conservation Portfolio Score with a Habitat Condition Score. The Portfolio Score characterized each contiguous brook trout population "patch" for its resiliency to disturbances, likelihood of demographic persistence, and representation of genetic, life history, and geographic diversity. The Habitat Integrity Score provides a measure of habitat quality and the magnitude of habitat restoration need for each population. The categories are further described, per Fesenmyer et al. 2017 in Table 6.21.

To assess progress towards this strategy, we overlaid the Brook Trout Conservation Strategy areas (Map 6.21) with the 2022 Conservation Lands and National Land Cover 2019 and 2011 datasets. This allowed us to generate the Conservation Risk Index (CRI) and Nature Risk Index (NRI) described previously in the section on conservation status for each brook trout category. The CRI and NRI measure if conservation is outpacing the conversion to agricultural or developed land. It is defined as the amount of permanent conversion (agriculture and developed land) divided by the amount of permanent conservation (CRI = GAP 1-3, NRI = GAP 1-2) which yields a ratio that when >1 indicates more loss than conservation and when < 0 indicates more conservation than loss of natural habitat.

Figure 6.15: Eastern Brook Trout Conservation Strategies. (Fesenmyer et al. 2017)



Map 6.21. Eastern Brook Trout Conservation Strategy Result (Fesenmyer et al 2017). Legend in Table 6.21 describes each strategy.

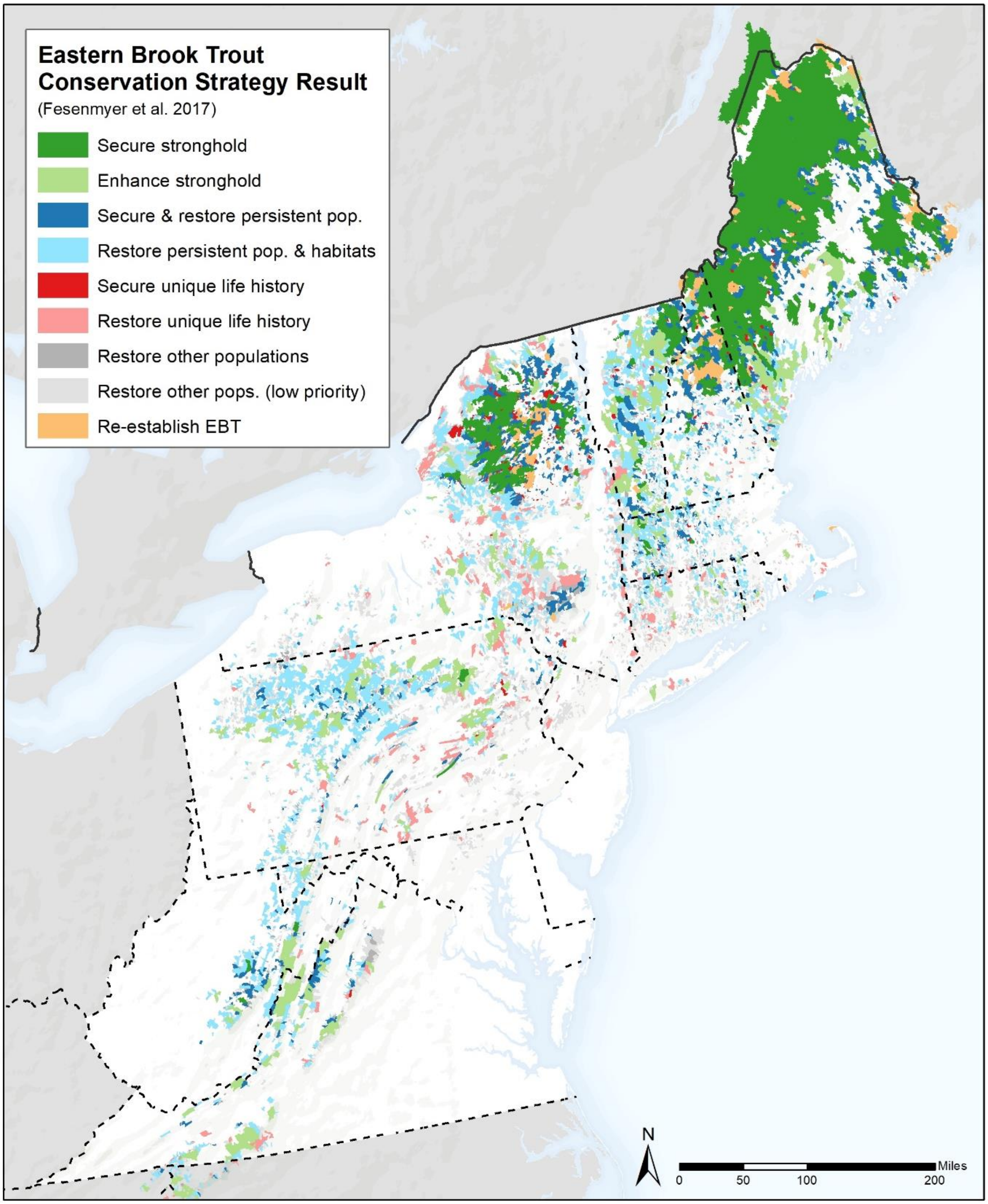


Table 6.21. Legend to Map 6.20 and Description of Eastern Brook Trout Conservation Strategy.
(From Fesenmyer et al. 2017)

• *Secure strongholds* strategy is assigned to resilient patches with high habitat integrity. These patches meet our criteria as strongholds and have relatively few stressors present. Due of overlap in the portfolio categories, these patches also meet redundancy criteria and contain migratory river populations. This category represents an objective – ideally all patches would be in this category, with large interconnected habitats with few acute stressors. Limited restoration action is likely required to secure these populations.
• *Enhance stronghold* is assigned to resilient patches with lower habitat integrity. These patches meet our criteria as strongholds, but have single significant or multiple smaller stressors present – restoration focused on addressing existing stressors within these patches can enhance the strongholds.
• *Secure and restore persistent population* strategy is assigned to redundant patches with high habitat integrity scores. These patches meet our criteria as persistent and have relatively few stressors present – restoration of populations through non-native trout eradication or connectivity enhancements to provide more available habitat for allopatric populations, combined with limited habitat restoration effort could shift these populations to the resilient, stronghold category.
• *Restore persistent populations and habitats* strategy is assigned to redundant patches with low habitat integrity scores. These patches meet our criteria as persistent but have single significant or multiple smaller stressors present – restoration of populations through non-native trout eradication or connectivity enhancements could shift these populations to the resilient, stronghold category, but may require concurrent habitat restoration work.
• *Secure unique life history* strategy is assigned to patches which do not meet portfolio redundancy and resiliency criteria, but which may contain unique life histories (all life histories except resident less productive are considered unique) and have high composite habitat condition scores. Multiple conservation strategies may be necessary within these patches depending on EBT population status or habitat disturbance. River and lake migratory populations offer the best opportunity to shift populations into the redundant category due to their large size and productivity. Anadromous, resident lake/pond, and resident more productive populations may be small, but represent rare and unique life histories.
• *Restore unique life history* strategy is assigned to patches not meeting resiliency or redundancy criteria in the portfolio analysis, but with low habitat integrity scores. These patches may provide some opportunity for population and habitat restoration work to shift to the redundant category.
• *Restore other populations* strategy is assigned to populations that do not meet the resiliency, redundancy, or representation criteria . These populations are largely small allopatric or small to moderately sized sympatric resident EBT populations. Adjacent populations may provide some opportunity for reconnection activities to create additional redundant patches. As new information regarding EBT genetic status or other population attributes, such as population densities, conservation opportunities and needs for these populations may be revealed to be higher priority.
• *Re-establish EBT* is assigned to surrounding or adjacent subwatersheds – those habitats currently unoccupied by EBT – with average composite habitat integrity scores greater than 0.7 and subwatershed-average maximum 30-day average stream temperatures less than 17°C. These subwatersheds may provide an opportunity for reintroducing EBT in locations with minimal habitat restoration need and with lasting value in the face of climate change.

Results of conservation lands and NLCD overlay show that the entire eastern brook trout range was 32% conserved and 12% converted to agriculture or development, equivalent to 0.38 acres of conversion for every acre conserved (CRI=0.38) (Table 6.22 and 6.23, Figure 6.16). Sites for all three securement strategies (strongholds, populations, unique life history) had CRI and NRI scores well below 0 and below the regional mean, indicating good progress already made on conserving these areas and preventing conversion (Table 6.21, Figure 6.16). The lowest CRI (0.09) was for the Secure Strongholds category which covers 13 million acres and has 37% in GAP 1-3 land and 3% developed reflecting 10 times more conservation land than conversion. Although this "secure stronghold" area includes 4.7 million acres of conservation land, there is still much opportunity for further conservation in its nearly 8 million acres of relatively intact unconserved natural lands (Table 6.22 and 6.23). Sites for two restoration strategies - restore brook trout and restore other populations - were also below the mean and seem promising as good restoration areas. Strategies related to "Restore and Enhance" had CRI values above the regional mean.

Over the last decade, conservation has surpassed conversion in every brook trout strategy area. Strongholds targeted for securement had 179 times more conservation than conversion! and securement to restore persistent populations had 54 times more conservation than conversion (Table 6.24).

Table 6.22. Acres of Eastern Brook Trout Conservation Strategies by Land Cover Type and Conservation Status

Conservation Strategy	Agriculture	Developement	GAP 1 and 2	GAP 3	Unconserved Natural	Total Acres
Secure stronghold	-179,453	-236,901	1,557,403	3,197,724	7,840,645	13,012,126
Enhance stronghold	-669,575	-386,553	358,284	1,131,634	3,406,294	5,952,339
Secure & restore persistent pop.	-60,335	-93,248	1,171,546	1,173,842	2,380,118	4,879,089
Restore persistent pop. & habitats	-848,679	-519,372	452,991	2,120,647	5,325,202	9,266,891
Secure unique life history	-1,351	-7,985	121,222	105,208	175,650	411,416
Restore unique life history	-422,697	-233,712	95,120	306,794	1,192,364	2,250,687
Restore other populations	-8,660	-15,895	287,488	368,449	390,743	1,071,235
Restore other pops. (low priority)	-1,047,948	-789,889	386,032	1,181,186	3,906,675	7,311,730
Re-establish EBT	-28,315	-38,337	417,856	286,410	656,242	1,427,161
Northeast Region Total	-3,267,014	-2,321,892	4,847,941	9,871,895	25,273,933	45,582,675

Table 6.23. Eastern Brook Trou Conservation Strategies by Conservation Risk Index (CR) and% of Land Cover and Conservation Land

Conservation Strategy	Percent Converted (Dev & Ag)	Percent Protected (GAP 1 & 2)	Percent Conserved (GAP 1-3)	CRI	NRI
Secure stronghold	3.20	11.97	36.54	0.09	0.27
Enhance stronghold	17.74	6.02	25.03	0.71	2.95
Secure & restore persistent pop.	3.15	24.01	48.07	0.07	0.13
Restore persistent pop. & habitats	14.76	4.89	27.77	0.53	3.02
Secure unique life history	2.27	29.46	55.04	0.04	0.08
Restore unique life history	29.16	4.23	17.86	1.63	6.90
Restore other populations	2.29	26.84	61.23	0.04	0.09
Restore other pops. (low priority)	25.14	5.28	21.43	1.17	4.76
Re-establish EBT	4.67	29.28	49.35	0.09	0.16
Northeast Region Total	12.26	10.64	32.29	0.38	1.15

Figure 6.16. Conversion and Conservation within Eastern Brook Trout Conservation Strategy Areas

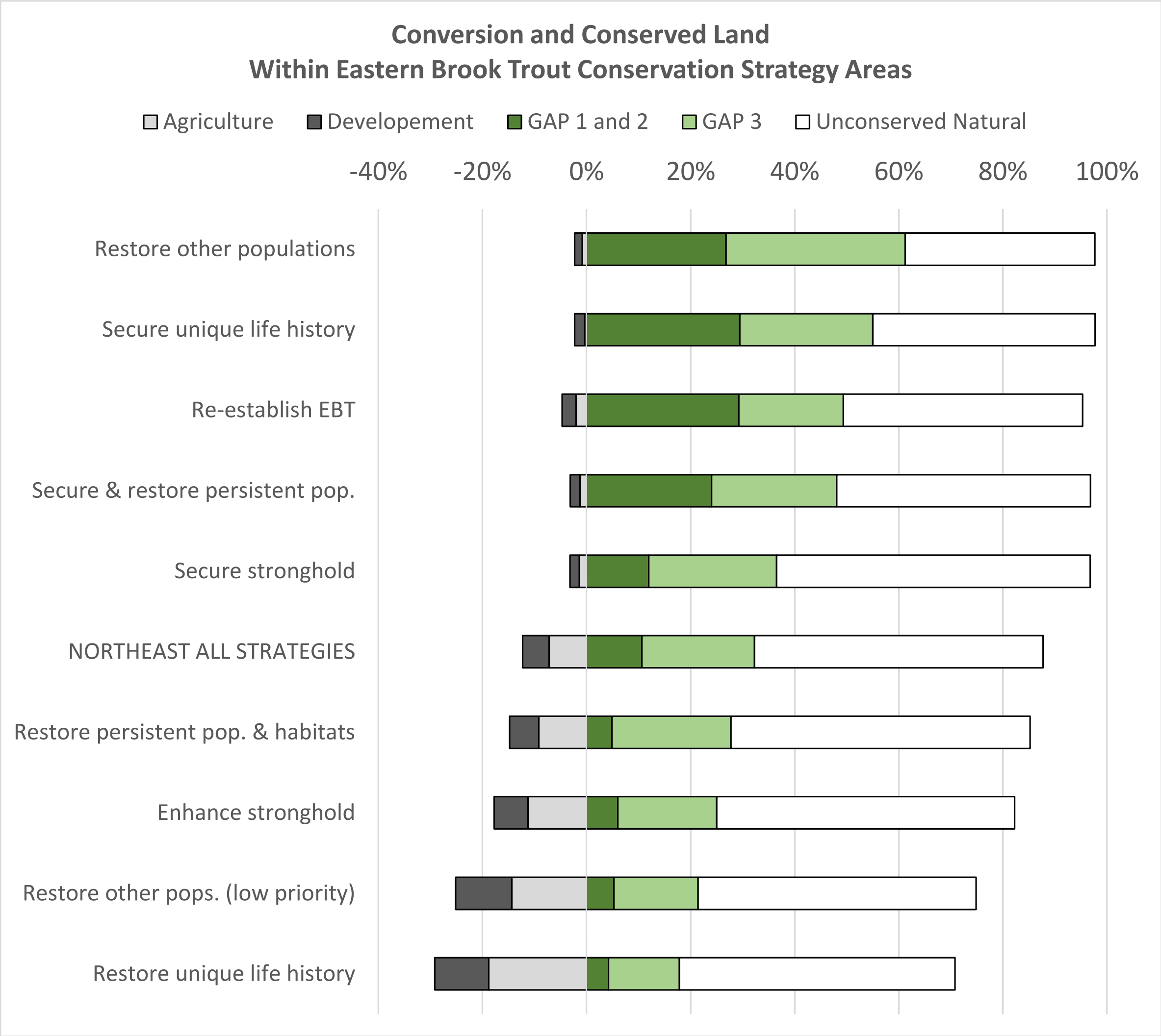


Table 6.24. Eastern Brook Trou Conservation Strategies by Last Decade: Conservation Land and Conservation Risk Index, 2012-2022

Conservation Strategy	2012-2022 Loss Acres	2012-2022 Conserved Acres	% of Total Area Lost 2012-2022	% of Total Area Conserved 2012-2022	2012-2022 CRI
Secure stronghold	3,237	575,896	0.02	4.43	0.01
Enhance stronghold	13,197	57,176	0.22	0.96	0.23
Secure & restore persistent pop.	1,871	101,755	0.04	2.09	0.02
Restore persistent pop. & habitats	21,147	91,173	0.23	0.98	0.23
Secure unique life history	106	2,296	0.03	0.56	0.05
Restore unique life history	10,021	13,108	0.45	0.58	0.76
Restore other populations	325	17,712	0.03	1.65	0.02
Restore other pops. (low priority)	30,038	46,166	0.41	0.63	0.65
Re-establish EBT	680	38,737	0.05	2.71	0.02
Northeast Region Total	80,623	944,018	0.18	2.07	0.09

Non-Indigenous Aquatic Species:

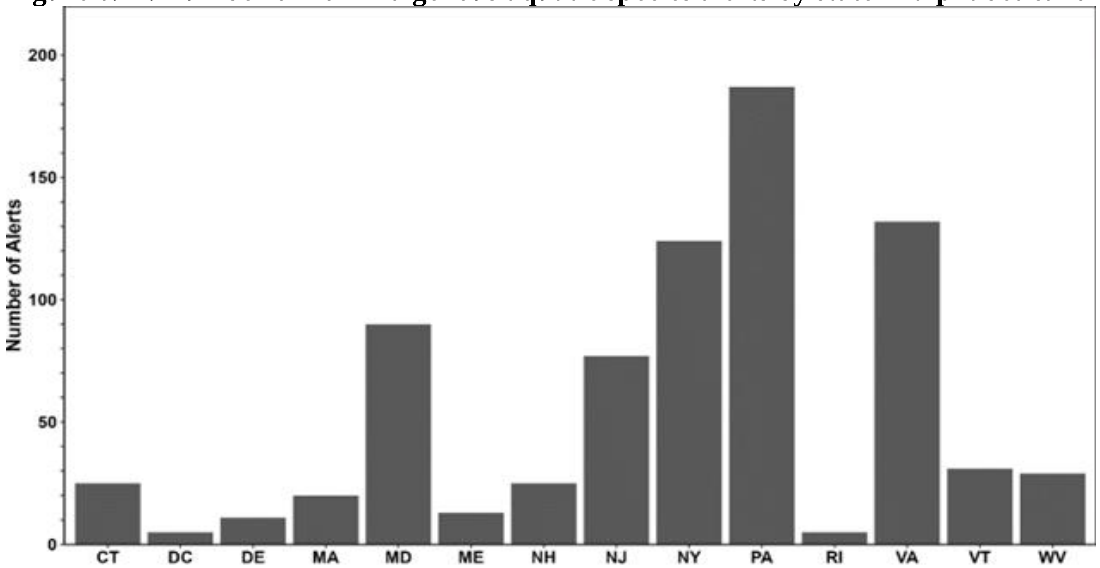
Non-indigenous aquatic species (NAS) are individuals or populations of a species that enter an aquatic ecosystem outside of its historic or native range. They may be vertebrates, invertebrates, plants, or diseases. Invasive NAS may alter ecosystems by preying on natives, competing with natives, hybridizing with natives, or spreading diseases to native species. NAS may be more likely to become established when stream and watershed conditions are degraded.

The most comprehensive survey of NAS is the USGS Non-indigenous Aquatic Species program that maintains a useful website of information (http://nas.er.usgs.gov/queries/). This site was established as a central repository for accurate and spatially referenced biogeographic accounts of NAS, obtained from a variety of sources such as researchers, field biologists, and fishermen**.** Because the reports are opportunistic, rather than based on comprehensive surveying, some states have better reporting than others. The reports are also influenced by publications, or lack thereof, and by news coverage.

Data from NAS was extracted and summarized for the region and subregions by Matthew Neilson, PhD from USGS Nonindigenous Aquatic Species Program, Gainesville, FL as of 1/2023, and we are grateful to him for the charts and summaries in the following section. Information is provided for all NAS species observed and for species established based on population shows evidence of successful reproduction and overwinter survival. The number of alerts in the NAS system regarding new species introductions between 2017-2022 are also provided to show the context of change over the last 5 years.

Results show that nearly 500 non-indigenous aquatic species have been observed in the region and just over 300 have been determined to have established populations (Figure 6.17). By taxa group, over two-thirds of them are fish with the next most common taxa group being plants, followed by crustaceans, mollusks, reptiles, amphibians, and others. The Mid-Atlantic had more NAS fish and plants while New England and New York had more crustaceans and mollusks than the Mid-Atlantic.

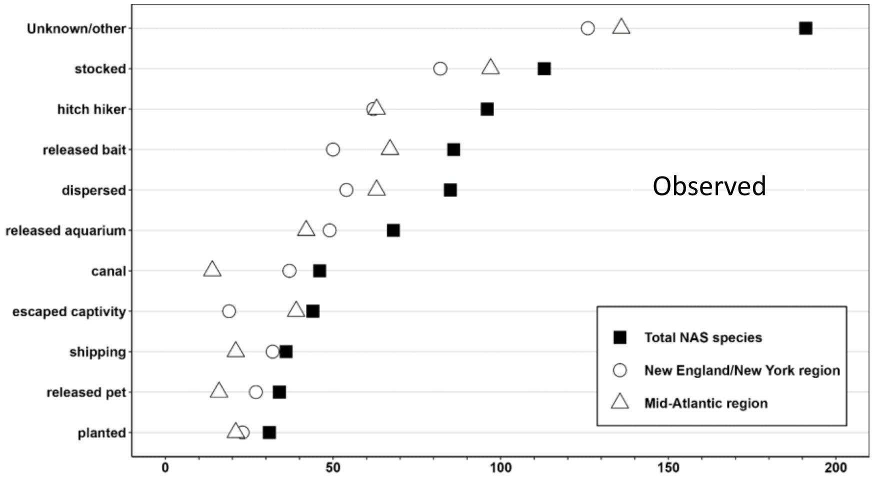
Figure 6.17. Number of non-indigenous aquatic species alerts by state in alphabetical order.

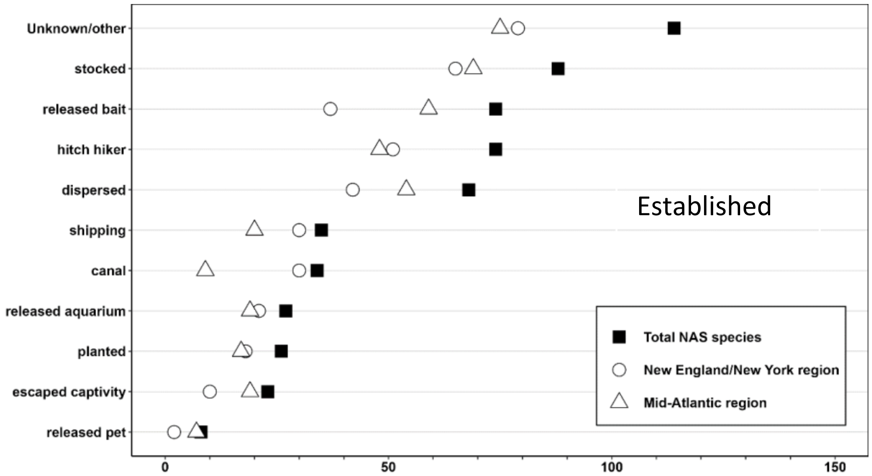


Mapping the results by watershed revealed that there were few areas of the region with less than five NAS established species or ten NAS observed species (Map 6.22). Areas with high number of NAS species include Boston harbor drainages, the middle and lower mainstem Connecticut River, Housatonic, middle to lower Hudson, New York Finger Lakes drainages, lower Delaware, lower Susquehanna, mid to lower Potomac, upper Roanoke, middle-upper New River, and Youghiogheny. Many of these same areas have high numbers of established NAS and high numbers of alerts (Map 6.22)

In addition to the presence or establishment of individual species, the NAS program tracks the method of introduction for each species and its location. Summaries of this data (Figure 6.18) show that the source of most introductions are unknown. After that, stocking and released bait are the major pathways of introduction followed by more natural methods of hitch hiker and dispersal (Figure 6.18).

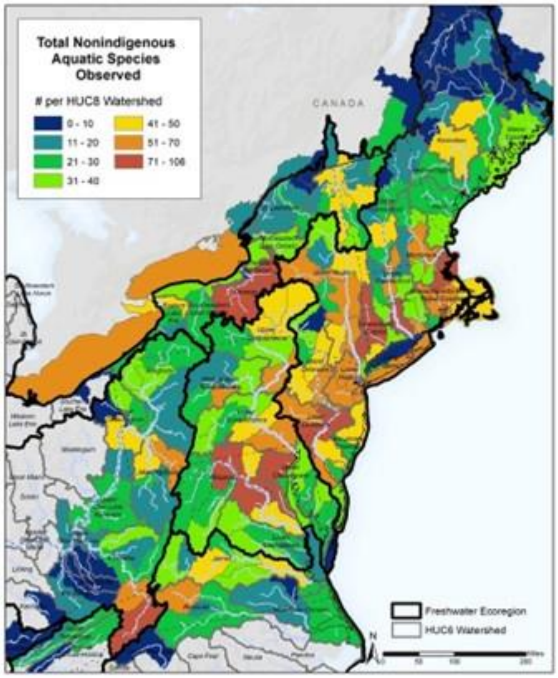
Figure 6.18: Major pathways of non-indigenous aquatic species introductions.



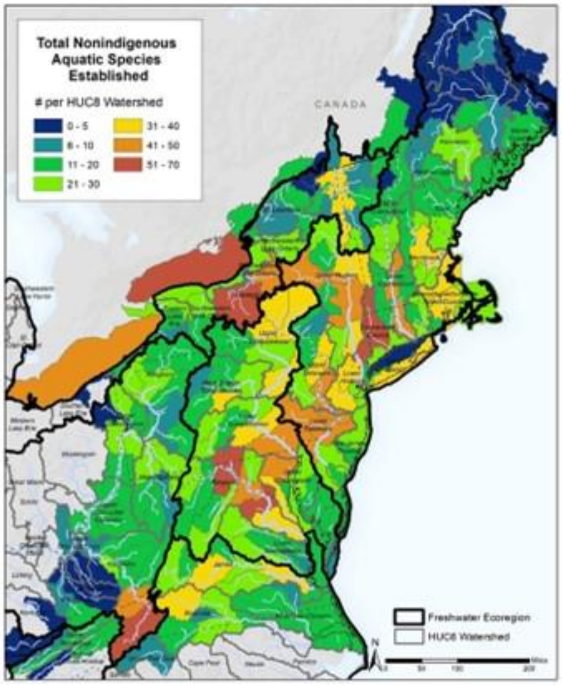


Map 6.22. Total number of non-indigenous aquatic species observed per HUC8 drainage

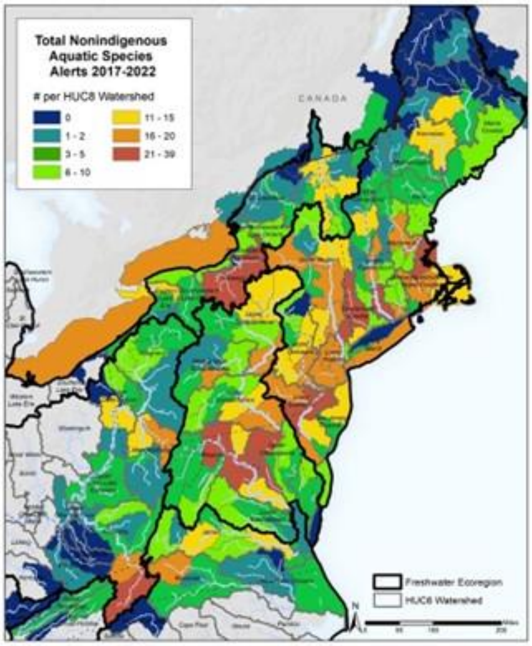
A. Total Number of NAS: Observed



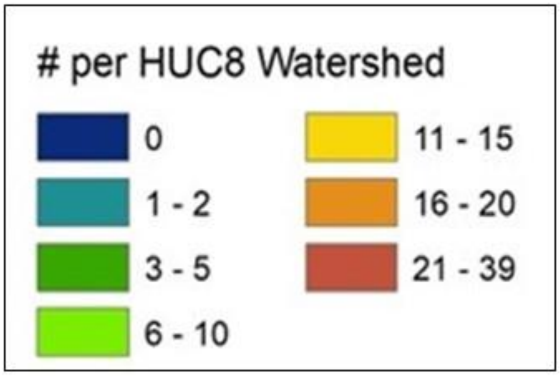
B. Total Number of NAS Established



C. Total Number of NAS Alerts



D. Legend



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CHAPTER

Lakes and Ponds 7

Condition and Conservation Status

Feb 2023

A. Olivero & M. G. Anderson

Lakes and ponds are bodies of standing water with a discernible shoreline. Collectively, the region has over 35,000 lakes and ponds which have a surface area of 2.7 million acres (over twice the area of Delaware). They range in size from small shallow ponds to huge deep lakes over 10,000 acres. Here we review the characteristics of lake and pond systems and examine their loss, degradation, and conservation. We focus on a few key measurable status metrics which are available consistently across the entire geography and allow for comparison between previous time periods and the current state.

Lake and Pond Conservation Status: Of the regions 35,000 lakes and ponds 21% have most of their shoreline conserved. Over the last decade (2012-2022), another 446 waterbodies have joined this group: 300 in New England and New York and 146 in the Mid-Atlantic. Another 800 have shown increased conservation of their shorelines.

Loss and Conservation in the Riparian Zone: Lakes and ponds cover almost three million acres of the region (excluding the three great lakes), creating 1.9 million acres of riparian shoreline habitat critical to wildlife. Of this, 79% is in natural cover and 30% is conserved, while 21% has been converted to development (15%) or agriculture (6%), a ratio of 0.7 acres converted for every one acre conserved. In the past decade (2012-2022) conservation has surpassed conversion by a ratio of 4 to 1.

Shoreline Disturbance Index: Despite the good news about shoreline conservation, 44% of the region's waterbodies have high disturbance impacts in their shoreline buffer zones, reflecting high levels of development, agriculture, and roads in this ecologically sensitive area. Balancing that, 33% are in lowest shoreline disturbance class. Over the two decades (2001-2019) impacts have increased in 36% of waterbodies while 6% have improved, reflecting a reduction in shoreline agriculture.

Impervious Surfaces: Collectively 38% of the region' waterbodies rank very low for impervious surface impacts while 14% rank so high that they are likely experiencing a loss of diversity and an increase in chemical pollutants. Over the last two decades (2001-2019), the number of waterbodies in the two most impacted classes has increased from 32% to 35%. No waterbodies have changed to a lower impact class, highlighting the difficulty in improving impervious surfaces impacts.

Biological and Chemical Indicators: The 2017 National Lake Assessment data shows New England New York and New Jersey with over 50% of their waterbodies showing good biological and nutrient conditions. The Mid-Atlantic had fewer with good biological (12-17%) or nutrient (12-13%) conditions. Over 74% of the region's waterbodies are in good condition for dissolved oxygen..

Waterbody Types and Associated Species

Lakes and ponds provide habitat to thousands of species, the types of which depend on the characteristics of the waterbody. Waterbodies differ substantially in size, depth, shape, location within a stream network and in water properties like clarity, color, pH, nutrient level. These characteristics shape the identity of their flora and fauna, while total surface area is the best predictor of overall species richness.

A wide variety of plant and animal life rely on lakes and ponds for primary habitat. Typical plants range from mosses and algae to specialized rooted plants such as spatterdock, pondweed, duckweed, stonewort, fanwort, hornwort, elodea, water milfoil, lotus and water lily. Standing water supports a wide variety of microscopic animals, worms and insects, the larval stages of midges, mosquitoes, dragonflies, and damselflies, and freshwater snails, mussels, and clams. The rich invertebrate fauna in turn supports a wide range of amphibian, reptiles, fish and birds. In addition to the lake proper, the shoreline habitat provides feeding and breeding areas for great blue heron, black-crowned night heron, green heron, kingfisher, bald eagle, osprey, cormorants, spotted sandpiper, red-winged blackbirds, and mammals such as moose and mink.

Herptiles: mudpuppy, spotted salamander, red-spotted newt, bullfrog, leopard frog, green frog, pickerel frog, eastern painted turtle, Blanding's turtle, common water snake

Fish: bluegill, pumpkinseed, black crappie, golden shiner, yellow perch, chain pickerel, largemouth bass, brown bullhead. **Coldwater fish (deep lakes):** lake trout, brook trout, rainbow smelt, burbot, landlocked Atlantic salmon

Birds: mallard, blue-winged teal, green-winged teal, wood duck, ruddy duck, pied-billed grebe, hooded merganser, bufflehead, common goldeneye, redhead, lesser scaup, and common loon.

In this report, we distinguished between Ponds, Lakes, and Great Lakes (matching the SWAP 2022 habitat lexicon). Ponds are distinct because their shallow depth has a direct influence on the physical components of their ecosystem. Specifically, they are shallow enough to have light penetration throughout, supporting rooted plant growth from shore to shore. Lakes have deep areas without enough light penetration to support plants and are more likely to become temperature stratified in the summer (dimictic). Waterbody size is a gradient within which multiple habitat types exist. Larger lakes typically contain a wide diversity of habitat types and support a broader suite of species (Minns 1989, Tonn & Magnuson 1982). The three Great Lakes in the region, Lake Erie, Ontario, and Champlain are separated from the other lakes and ponds and only a few metrics are reported for them given their extremely large size which make their ecosystems and conditions particularly different.

We map ponds and lakes according to the Northeast Lake and Pond Classification System and dataset (Olivero and Anderson, 2016). This dataset used the NHD Plus V2 Medium Resolution 1:100,000 scale waterbodies as its base and was augmented with waterbodies over 10 acres in size from the high resolution NHD+ dataset and the National Wetlands Inventory. In addition to separating ponds from lakes, we report additional patterns by size class within these two major groups (Table 7.1, Map 7.1). While there are biological differences between small and large lakes, the reporting size classes do not necessarily reflect biologically identified thresholds but is simply a practical way to summarize patterns across lakes and ponds in this region. These size classes match the lake size classes in the original Northeast Aquatic Habitat Classification System (Olivero and Anderson 2008) and those used by New Hampshire DES and Maine DEP. This chapter focuses primarily on the non-Great Lake lentic systems.

Table 7.1. Types of Ponds and Lakes used in this report

PONDS	Small Pond 2-10 acres
	Large Pond > 10 acres
LAKES	Small Lake 2- 100 acres
	Medium Lake 100-1000 acres
	Large Lake 1,000-10,000
	Very Large Lake >10,000
GREAT LAKES	Great Lakes: Erie, Ontario, Champlain

Distribution and Abundance

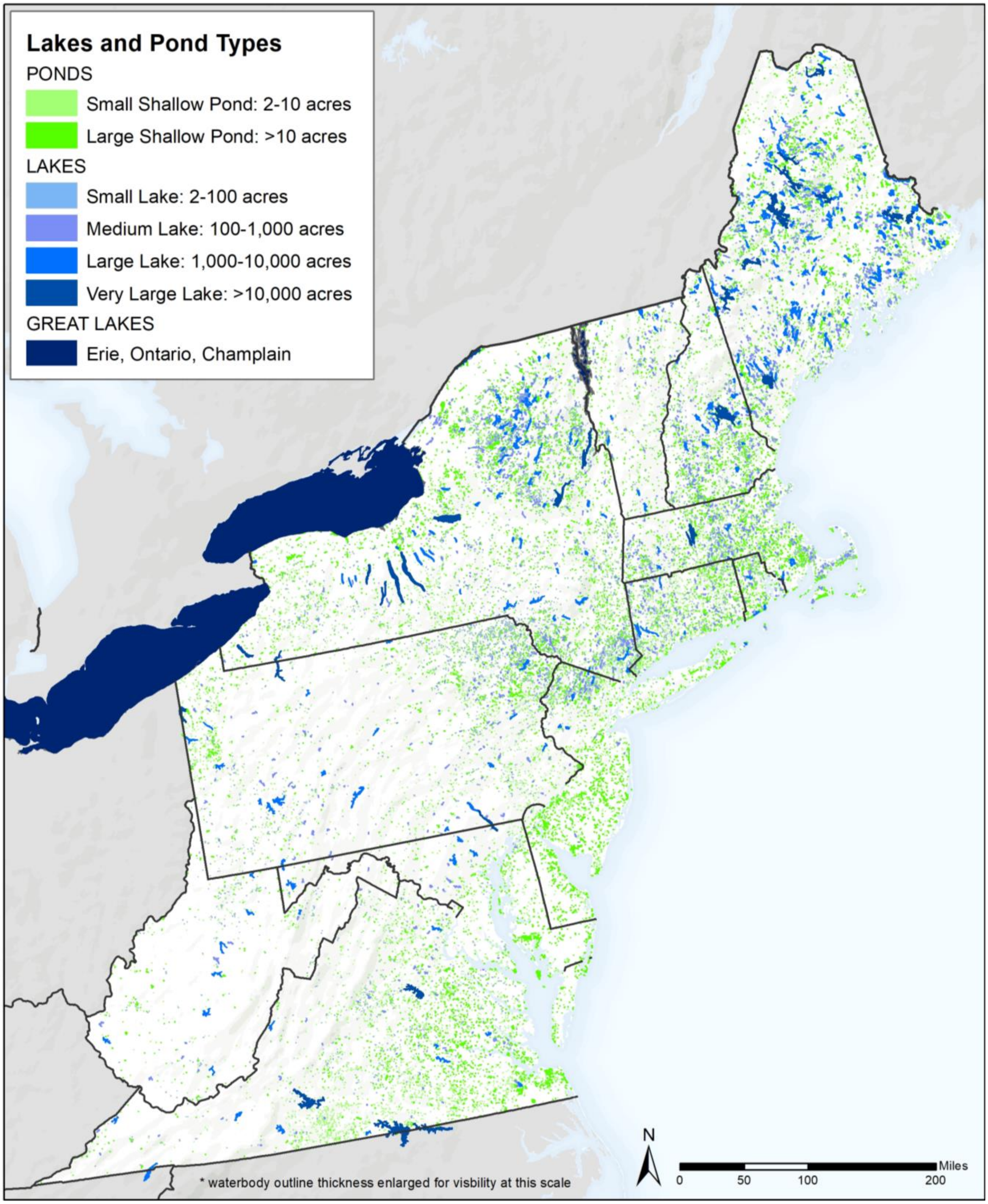
Lakes and ponds are primarily features of the glaciated northern region, with 73% of all lakes found in the New England and New York subregion. (Map 7.1). While the northern region has most of the lakes, the regions 28,000 ponds are more evenly spread among the two sub-regions. Shallow ponds make up nearly 80% of the number of waterbodies in the region, but account for only 21% of the total waterbody area, excluding great lakes.

By size class, the majority of shallow ponds are small (2-10 acres), but shallow ponds over 10 acres in size make up 85% of the total pond area. Likewise, small lakes less than 100 acres in size account for 71% of all lakes, but lakes over 100 acres account for more than half of the total lake surface area. Lakes over 1000 acres in size account for 70% of the total surface area. (Table 7.2)

Table 7.2. Number and acreage of lakes and ponds in the region (also see Map 7.1).

Lake and Pond Types	# New England/NY	# Mid-Atlantic	**Total Number**	**% of Total Number** (excluding Great Lakes)	Acres New England/NY	Acres Mid-Atlantic	**Acres**	**% of Total Area** (excluding Great Lakes)
Small Pond: 2-10 acres	8663	7612	16275	44	45463	37379	82842	3
Large Pond: > 10 acres	7781	4695	12476	34	318089	160664	478754	18
PONDS	16444	12307	28751	79	363553	198043	561596	21
Small Lake: 2- 100 acres	4039	1841	5880	16	119189	46826	166014	6
Medium Lake: 100-1000 acres	1379	250	1629	4	407610	67986	475596	18
Large Lake: 1,000-10,000 acres	254	45	299	1	683188	113421	796609	29
Very Large Lake: >10,000 acres	21	7	28	0	565241	136945	702186	26
LAKES	5693	2143	7836	21	1775227	365178	2140405	79
TOTAL LAKES AND PONDS (excluding Great Lakes)	22,137	14,450	36,587		2,138,779	563,221	2,702,000	

Map 7.1. Lakes and Ponds by Size Class. The region has over 36,000 waterbodies covering 2.7 M acres.



Habitat Conservation of the Shoreline Riparian Zone

The riparian zone is the land directly adjacent to a stream or waterbody. Lakes and ponds with intact riparian habitats are more likely to support healthy biotic populations than lakes that have been deforested by shoreline development (NLA, 2017). Intact riparian areas play a critical role in reducing erosion, filtering nutrients to maintain water quality, supplying needed organic matter and woody debris, providing shade to maintain cooler temperatures, and they provide a suite of other habitat and biodiversity values for fish, wildlife, and other aquatic communities (Palone et al. 1997).

Land Cover of the Riparian Zone

In this section, we assessed the riparian zone by creating a standard 100m (~300 ft.) buffer landward from the shorelines of the lakes and ponds. The 100 m distance was chosen to encompass a broad range of the types of riparian functions noted for eastern riparian zones as one moves landward from the water interface (Palone et al. 1997, Anderson and Olivero, 2011). We calculated the amount of agriculture and developed land within each ~100m riparian buffer zone by overlaying the 2011 and 2019 National Land Cover dataset (Dewitz and U.S. Geological Survey 2021).

Our results show that 1.9 million acres of land is within a waterbody riparian zone. Of that 79% is in natural cover, 6% in agriculture, and 15% in developed cover (Table 7.3). Lakes and pond riparian zones had the same amount of development (15%) but ponds had more agriculture (8%) than lakes (3%). The Great Lakes had the highest amounts of agriculture (15%) and development (29%) in the riparian zone. Loss of natural cover in the riparian zone was least in the large lakes. The Mid-Atlantic states had more agriculture (10%) in the riparian zone than New England and New York (3%).

The above statistics reflect impacts to the entire footprint of waterbody riparian zones. In the condition section of this chapter we report on individual waterbodies to highlight the ones with various levels of conversion to agriculture or development in the riparian zone.

Table 7.3. Acres of Lake and Pond Riparian Land by Cover Type and Conservation Status

Habitat	Agr. Acres	Dev. Acres	GAP 1 and 2 Acres	GAP 3 Acres	Unconserved Natural Acres	Total Acres
Small Pond	-42,103	-61,226	24,990	42,223	178,791	349,333
Large Pond	-37,691	-87,574	73,843	117,363	332,193	648,664
PONDS	**-79,794**	**-148,800**	**98,833**	**159,586**	**510,984**	**997,998**
Small Lake	-10,653	-37,463	31,388	44,070	130,114	253,688
Medium Lake	-4,667	-46,978	25,636	60,919	136,214	274,415
Large Lake	-3,611	-28,059	21,841	76,710	105,930	236,150
Very Large Lake	-3,166	-18,757	7,809	34,012	48,522	112,266
LAKES	**-22,096**	**-131,257**	**86,674**	**215,711**	**420,780**	**876,518**
Great Lakes: Erie, Onatario, Champlain	-4,817	-9,487	1,904	4,151	12,419	32,777
NORTHEAST REGION	**-106,708**	**-289,544**	**187,411**	**379,448**	**944,183**	**1,907,293**
MIDATLANTIC SUBREGION	-63,732	-102,895	38,454	138,050	292,081	635,213
NEW ENGLAND/NY SUBREGION	-42,975	-186,649	148,957	241,397	652,101	1,272,080

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Conservation of the Riparian Zone

To evaluate the amount of conservation land in the riparian zone, we overlaid the TNC 2022 Conservation Lands data set on the 100m (~300ft) riparian shoreline buffer zone. Results indicate that nearly 567,000 acres (30%) of lake and pond riparian land was under conservation (GAP 1-3) including 10% conserved explicitly for nature (GAP 1-2). This is almost twice as high as for streams and rivers riparian land (18%). The two subregions had a similar overall percentage of conserved land in this zone but New England and New York had more land conserved for nature (12%) than the Mid-Atlantic (6%).

Excluding the great lakes, the lake riparian zone had more conservation land (34%) than did ponds (26%). Larger pond riparian areas were more conserved (29%) than small ponds (19%) perhaps reflecting a bias towards conserving areas with larger amounts of open water for recreation and esthetic values along with biodiversity values. Lakes showed a similar pater with large lakes (42%) having more conservation in the riparian zone than smaller lakes (30%). Detailed assessment of individual waterbodies is described later in the lake securement section where we highlight waterbodies with their entire shorelines conserved.

The Conservation Risk Index (CRI) measures the ratio of habitat lost through conversion to agriculture or development to the amount conserved, where a ratio greater than 1 indicates more habitat lost than conserved and thus greater risk. For the riparian zone we measured CRI as the amount of agriculture and developed land divided by the amount of conserved land (GAP 1-3, Figure 7.1, Table 7.4).

Overall, the collective results show the lake and pond riparian zone to be 21% converted and 30% conserved, indicating 0.7 acres of habitat lost for every one acre conserved (CRI=0.7, Figure 1, Table 7.4). Conservation was greater than habitat loss across all pond and lake types, except small ponds (CRI=1.5) which were slightly more converted than conserved. The great lake class also showed the reverse pattern with 2.4 acres converted for every one acre conserved (CRI =2.4). Excluding the great lakes, lakes had only 0.5 acres lost for every acre conserved (CRI =0.1) whereas the ratio for ponds was almost 1:1 (CRI = 0.9). The pattern reversed when we considered only land conserved explicitly for nature (Gap1-2). This Nature Risk Index (NRI) was greater than one across all types and averaging 2.1 acres converted for every one acre conserved for nature. The NRI was highest for great lakes (7.5) and small ponds (4.1) and lowest for large lakes (1.4). In sum, waterbody riparian lands have more conservation than conversion although most of it is multiple use land.

Considering only the last decade (2011-2022) reveals an encouraging conservation trend (Table 7.5). The regional average (CRI =0.4) indicates that only 0.4 acres of natural lake or pond riparian habitat was converted for every one acre conserved. This was true for both subregions: Mid-Atlantic (CRI = 0.5), New-England and New York (CRI = 0.2). Further patterns by state can be explored with the digital appendix.

Figure 7.1. The distribution of riparian land cover and conservation by lake and pond type. In this chart, each bar represents the total area of riparian land in the habitat type. Land to the left of the center bar has been converted to development or agriculture; land to right of the center bar remains unconverted. Unconverted land is apportioned by conservation status and the % unconserved.

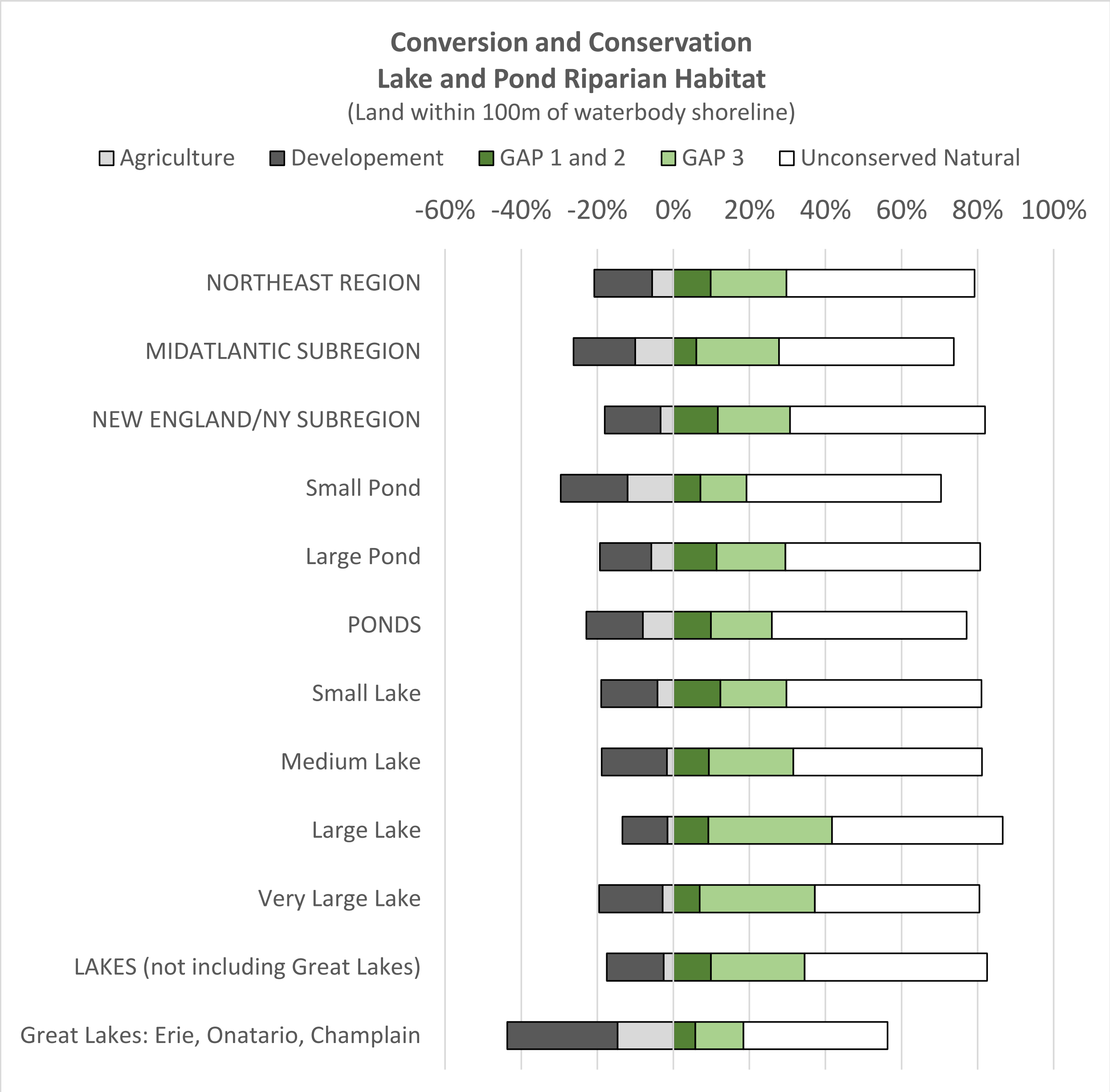


Table 7.4. Conservation Risk Index (CRI) and Nature Risk Index (NRI) for the Lake and Pond Riparian Land

CRI = the ratio of acres converted to development or agriculture to acres conserved (GAP1-3)

NRI = the ratio of acres converted to development or agriculture to acres conserved for nature (GAP1-2)

Habitat	Percent Converted (Dev & Ag)	Percent Protected (GAP 1 & 2)	Percent Conserved (GAP 1-3)	CRI	NRI
Small Pond	29.6	7.2	19.2	1.5	4.1
Large Pond	19.3	11.4	29.5	0.7	1.7
PONDS	**22.9**	**9.9**	**25.9**	**0.9**	**2.3**
Small Lake	19.0	12.4	29.7	0.6	1.5
Medium Lake	18.8	9.3	31.5	0.6	2.0
Large Lake	13.4	9.2	41.7	0.3	1.4
Very Large Lake	19.5	7.0	37.3	0.5	2.8
LAKES	**17.5**	**9.9**	**34.5**	**0.5**	**1.8**
Great Lakes: Erie, Onatario, Champlain	43.6	5.8	18.5	2.4	7.5
NORTHEAST REGION	**20.8**	**9.8**	**29.7**	**0.7**	**2.1**
MIDATLANTIC SUBREGION	26.2	6.1	27.8	0.9	4.3
NEW ENGLAND/NY SUBREGION	18.1	11.7	30.7	0.6	1.5

Table 7.5. Last Decade (2012-2022): Lake and Pond Riparian Conservation Land and Conservation Risk Index Negative number indicate habitat lost. CRI = the ratio of acres converted to development or agriculture to acres conserved (GAP1-3)

Habitat	2012-2022 Loss Acres (Dev & Ag)	2012-2022 Conserved Acres	% of Total Area Lost 2012-2022	% of Total Area Conserved 2012-2022	2012-2022 CRI
Small Pond	-1,995	5,033	1.4	0.4	0.6
Large Pond	-2,431	9,516	1.5	0.3	0.4
PONDS	**-4,426**	**14,550**	**1.5**	**0.3**	**0.4**
Small Lake	-763	2,660	1.0	0.3	0.3
Medium Lake	-561	3,660	1.3	0.2	0.2
Large Lake	-426	3,231	1.4	0.1	0.2
Very Large Lake	-359	1,335	1.2	0.3	0.3
LAKES	**-2,109**	**10,885**	**1.2**	**0.2**	**0.2**
Great Lakes: Erie, Onatario, Champlain	-148	776	2.4	0.2	0.5
NORTHEAST REGION	**-6,683**	**26,211**	**1.4**	**0.3**	**0.4**
MIDATLANTIC SUBREGION	-3,820	7,551	1.2	0.5	0.6
NEW ENGLAND/NY SUBREGION	-2,863	18,660	1.5	0.2	0.2

Conservation Status of Individual Lakes and Ponds

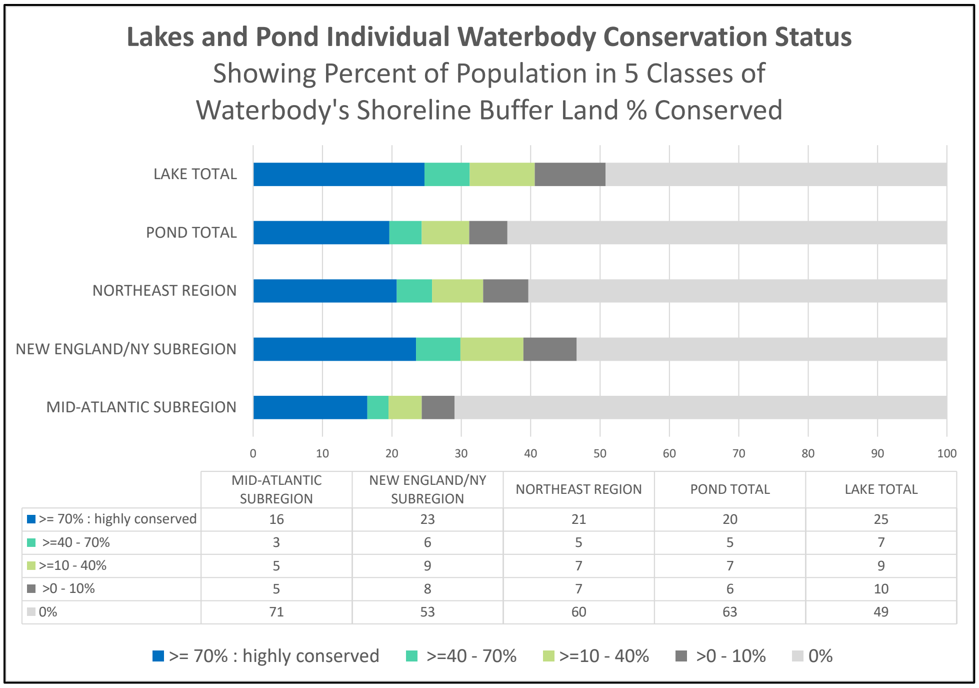
The conservation land in the lake/pond riparian habitat zone across the region is not distributed evenly across every waterbody in the region. For example, although 30% of this habitat type is conserved, not every waterbody has 30% of its riparian land conserved. To access which waterbodies were embedded in conservation land and had nearly their entire individual lake's riparian zone conserved, we quantified the amount and percent of conserved land (GAP 1-3) within the shoreline buffer (100m) of every individual waterbody.

To display the results, we placed individual waterbodies were into one of five 5 categories of conservation status (Map 7.2, Table 7.6) as follows*:*

- High = >70% of their shoreline buffer land in conservation,
- Moderate = 40-70% of shoreline buffer land in conservation,
- Low = 10-40% of their shoreline buffer land in conservation
- Very Low = >0-10% of their shoreline buffer land in conservation
- None = no conservation land in shoreline buffer.

Overall, 21% of all lakes and ponds scored high for conservation in their shoreline buffer, 5% scored moderate, 7% scored low, 7% scored very low and 60% had no conservation (Figure 7.2, Map 7.2, Table 7.6). Lakes scored slightly better, with 25% in the high class, and 49% had no conservation. Ponds were slightly less conserved, with 20% in the high class, and 63% with no conservation. New England and New York had more waterbodies with conserved riparian areas with 23% in the high class, compared to the Mid-Atlantic with 16% in the high class.

Figure 7.2. Lake and Pond Individual Waterbody Conservation Status: Showing Percent of a population (bar) falling in each of 5 classes based on the percent of an individual waterbody's 100m buffer land which is falling in conservation GAP 1-3 status.



	MID-ATLANTIC SUBREGION	NEW ENGLAND/NY SUBREGION	NORTHEAST REGION	POND TOTAL	LAKE TOTAL
>= 70% : highly conserved	16	23	21	20	25
>=40 - 70%	3	6	5	5	7
>=10 - 40%	5	9	7	7	9
>0 - 10%	5	8	7	6	10
0%	71	53	60	63	49

Map 7.2. Lake and Ponds by their Individual Waterbody Conservation Status. Conservation status for a waterbody is based on the percentage of its 100m shoreline buffer land that is under GAP 1-3 status conservation.

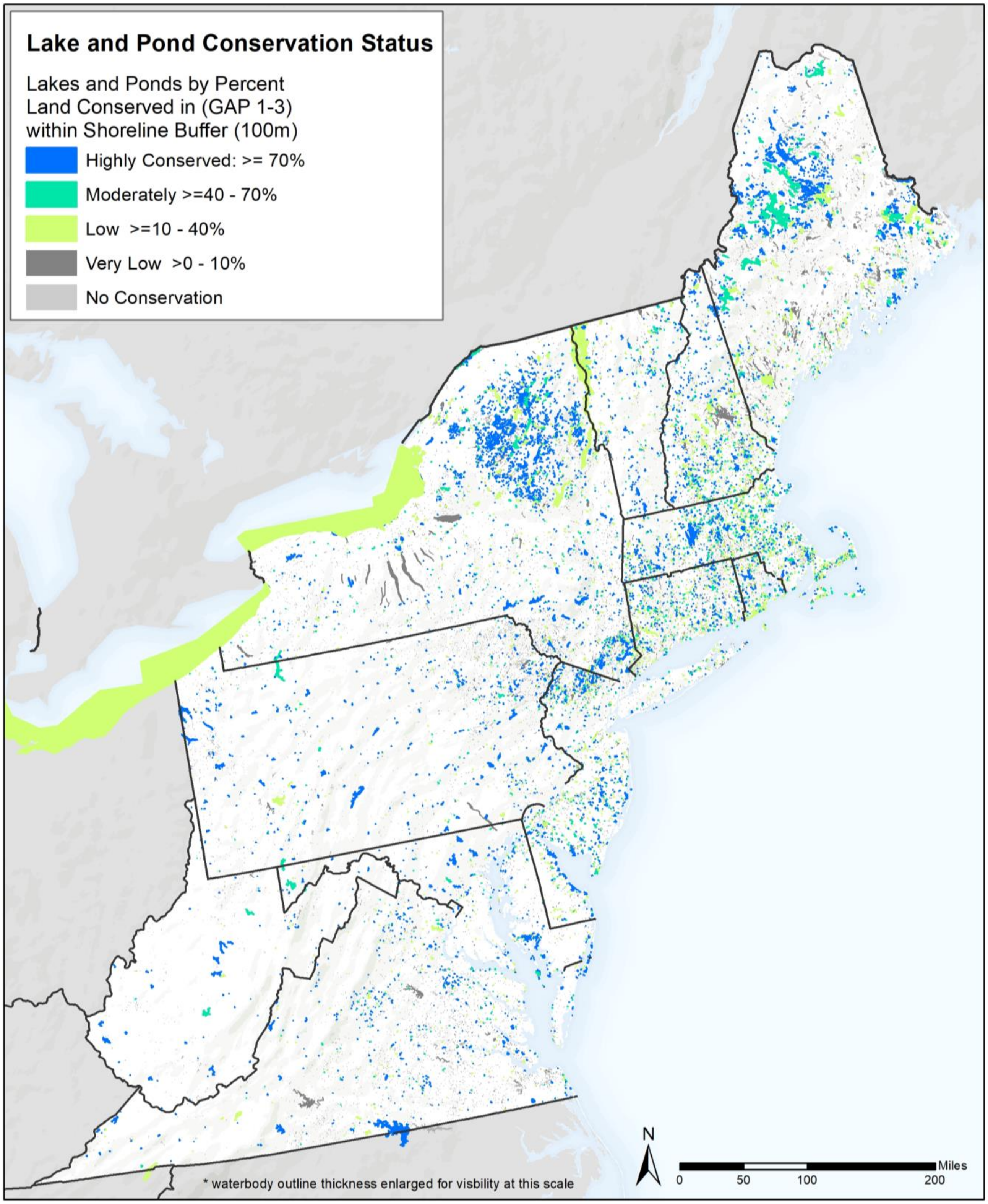


Table 7.6. Lakes and Ponds by Individual Waterbody Conservation Status

Individual Waterbody Conservation Status: Shoreline Buffer (100m) Land Area in Conservation Land GAP 1-3	1. Highly Conserved: >= 70% Waterbody's buffer land conserved		2. Moderately Conserved >=40 - 70%		3. Low Conservation >=10 - 40%		4. Very Low Conservation >0 - 10%		5. No Conservation		Total	
	Acres	Count	Acres	Count	Acres	Count	Acres	Count	Acres	Count	Acres	Count
1. Small Pond	14,541	2,686	3,275	615	4,803	900	3,875	741	56,348	11,333	82,842	16,275
2. Large Pond	129,225	2,958	33,346	729	60,634	1,063	48,671	846	206,878	6,880	478,754	12,476
POND TOTAL	**143,766**	**5,644**	**36,621**	**1,344**	**65,437**	**1,963**	**52,546**	**1,587**		**18,213**	**561,596**	**28,751**
3. Small Lake	42,722	1,454	11,709	359	15,029	444	14,052	400	82,501	3,223	166,014	5,880
4. Medium Lake	115,703	392	33,332	108	69,943	233	99,131	314	157,486	582	475,596	1,629
5. Large Lake	209,532	85	95,931	36	162,535	52	231,515	77	97,095	49	796,609	299
6. Very Large Lake	95,496	4	209,290	8	113,621	5	264,030	10	19,748	1	702,186	28
LAKE TOTAL	**463,453**	**1,935**	**350,263**	**511**	**361,129**	**734**	**608,729**	**801**		**3,855**	**2,140,405**	**7,836**
NORTHEAST REGION	**607,219**	**7,579**	**386,884**	**1,855**	**426,566**	**2,697**	**661,274**	**2,388**	**620,057**	**22,068**	**2,702,000**	**36,587**
MID-ATLANTIC SUBREGION	198,620	2,378	40,353	443	44,249	689	101,514	684	178,484	10,256	563,221	14,450
NEW ENGLAND/NY SUBREGION	408,599	5,201	346,531	1,412	382,317	2,008	559,760	1,704	441,572	11,812	2,138,779	22,137

We assessed the location of the waterbodies with high levels of conservation to understand the current distribution and the gaps (Map 7.3, Figure 7.3, Table 7.7). Across lake size classes large lakes over 1000 acres have the highest (28%) conserved shoreline, except for the very largest lakes over 10,000 acres which have the lowest (14%) as it is rare to find these huge waterbodies fully within conservation lands.

The most conserved groups, by size and subregion, include large, medium and very large lakes of the Mid-Atlantic, and small lakes of New England and New York (Figure 7.3, Table 7.7). This is partly explained by the fact that the Mid-Atlantic has fewer numbers of large waterbodies than New England and New York, and many of these serve as water supply and key recreational areas around which conservation lands have been developed. The least conserved lake and pond size types include very large lakes of New England and New York, small ponds, and small lakes of the Mid-Atlantic.

<u>Recent Trends in Riparian Shoreline Conservation</u>

Conservation in the last decade (2012-2022) shows promising trends, as 446 waterbodies moved into the highest category (>70% conserved) based on new conservation in their riparian shoreline (Table 7.7). This includes 300 waterbodies in New England and New York and 146 in the Mid-Atlantic. These newly conserved lakes and ponds make up 6% of the total conserved waterbodies. They are widely distributed across the regions (Map 7.4) with some in every state but West Virginia. Maine, Virginia, Massachusetts and New Hampshire showed the highest gains with over 40 newly conserved waterbodies in each of these states. Most of the newly conserved waterbodies are ponds which made up 83% of the total number gained. Small lakes (54) and medium lakes (21) account for fewer of the newly conserved waterbodies but a large% of the total area gained. Only two large lakes, Bald Mountain Pond, Maine, and Alcove Reservoir, New York, moved into the highly conserved category in the last decade.

In addition to the highly conserved shorelines, over 800 waterbodies showed over 10% increased conservation within the shoreline buffer zone in the last decade including 454 that increased between 50-69%. The latter got close to, but not quite over, the 70% threshold we set for being counted as "highly conserved".

Map 7.3. Highly Conserved Lakes and Ponds. Showing lakes and ponds with >70% of their shoreline buffer (100m) land in >= 70% GAP 1-3 Conservation Land

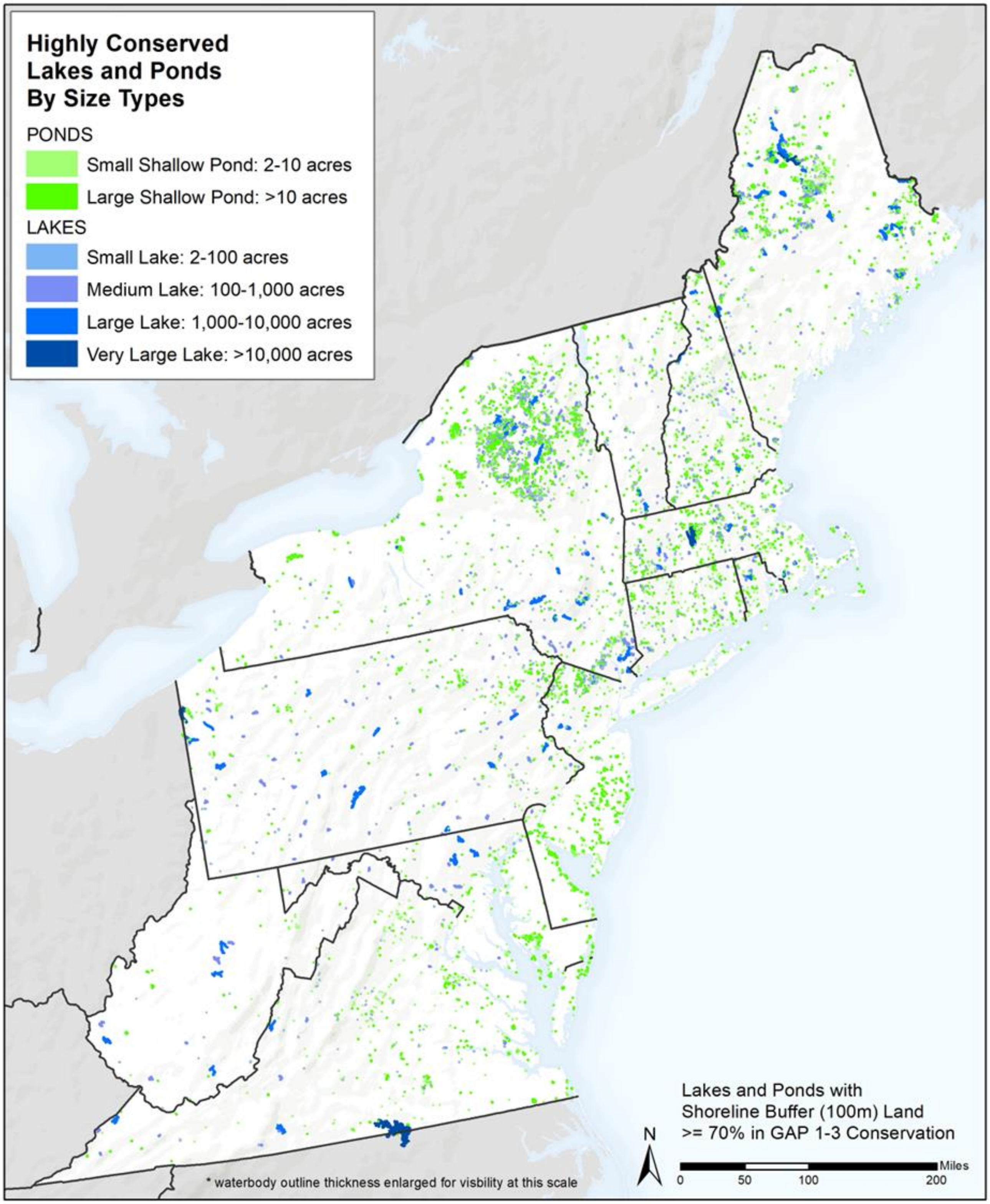


Figure 7.3. Highly Secured Lakes and Pond by Type and Subregion

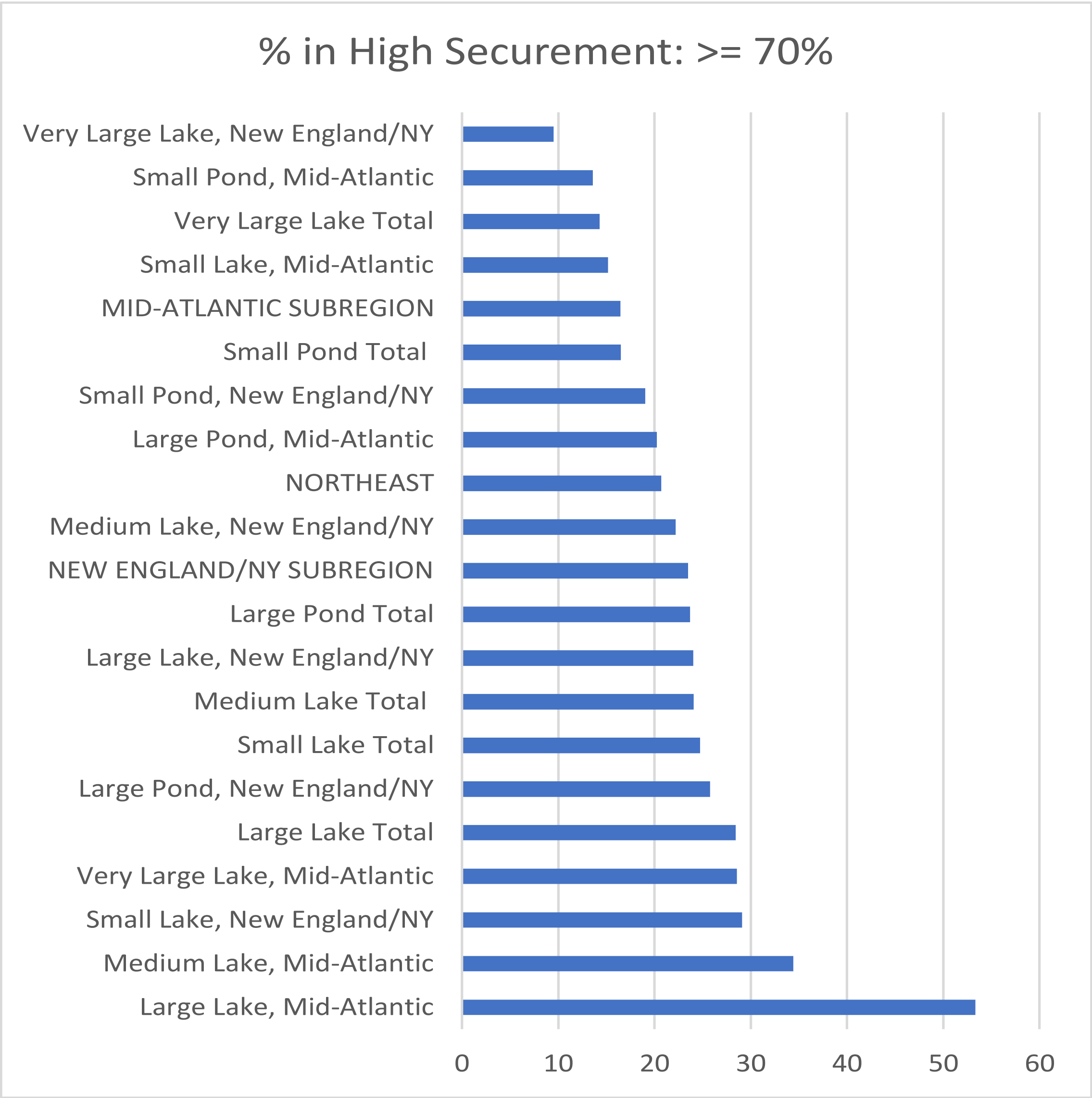
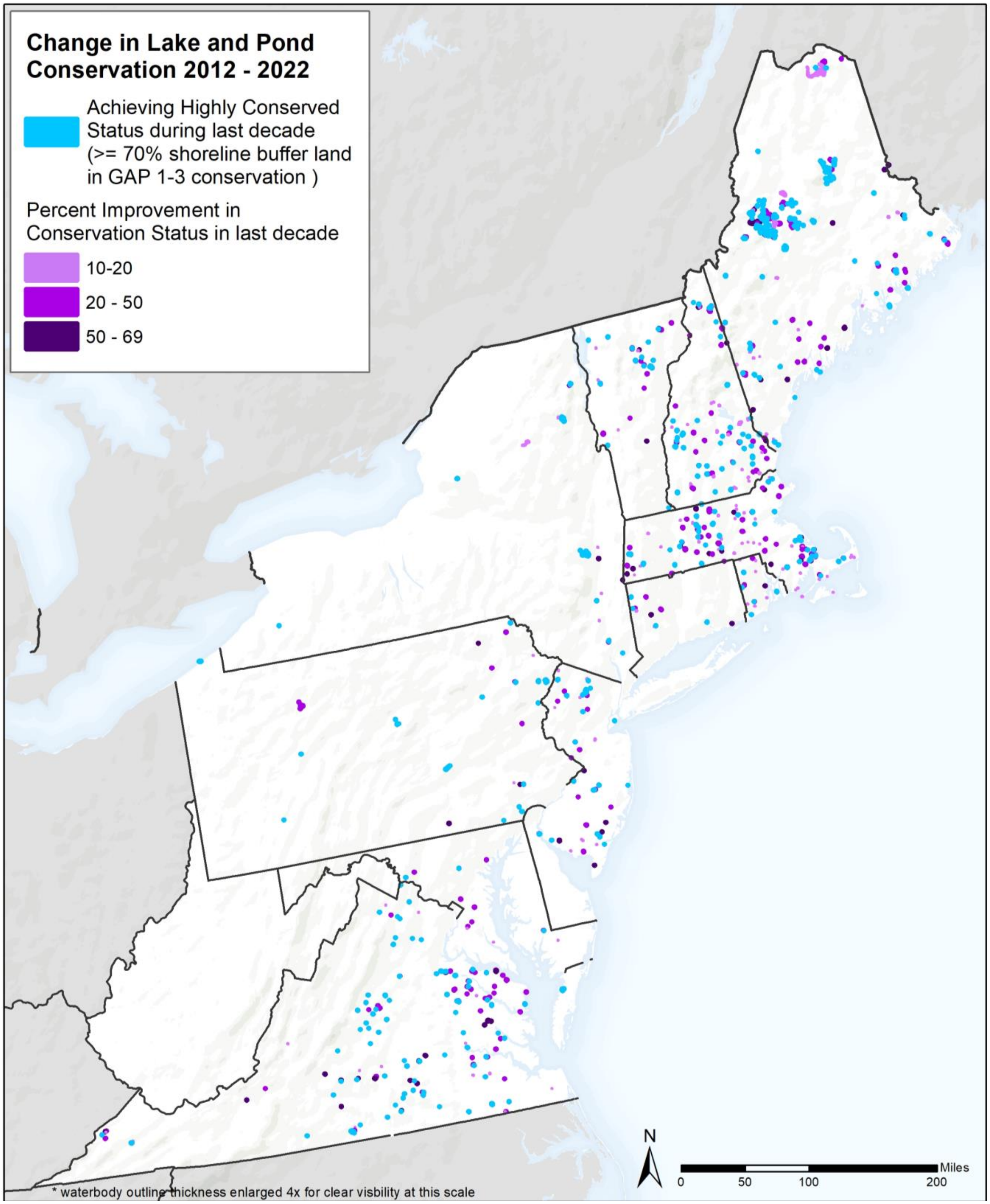


Table 7.7. Highly Secured Lakes and Pond by Type and Subregion.

Pond and Lake Types by Subregion	Total #	# in High Securement: >= 70%	% in High Securement: >= 70%	# entering High Securement Class between 2012 and 2022
1. Small Pond, Mid-Atlantic	7612	1036	14	77
1. Small Pond, New England/NY	8663	1650	19	121
1. Small Pond Total	16275	2686	17	198
2. Large Pond, Mid-Atlantic	4695	951	20	52
2. Large Pond, New England/NY	7781	2007	26	119
2. Large Pond Total	12476	2958	24	171
3. Small Lake, Mid-Atlantic	1841	279	15	11
3. Small Lake, New England/NY	4039	1175	29	43
3. Small Lake Total	5880	1454	25	54
4. Medium Lake, Mid-Atlantic	250	86	34	6
4. Medium Lake, New England/NY	1379	306	22	15
4. Medium Lake Total	1629	392	24	21
5. Large Lake, Mid-Atlantic	45	24	53	
5. Large Lake, New England/NY	254	61	24	2
5. Large Lake Total	299	85	28	2
6. Very Large Lake, Mid-Atlantic	7	2	29	
6. Very Large Lake, New England/NY	21	2	10	
6. Very Large Lake Total	28	4	14	
NORTHEAST	36587	7579	21	446
MID-ATLANTIC SUBREGION	14,450	2,378	16	146
NEW ENGLAND/NY SUBREGION	22,137	5,201	23	300

Map 7.4. Change in Conserved Lakes and Ponds in the last decade. Showing lakes and ponds meeting highly conserved status between 2012-2022, along with other lakes and ponds that had an increase in conservation lands in the last decade.



Lake Condition: Shoreline Disturbance

Shoreline development adds impervious surfaces, piers, wells, septic systems, and lawns along the edge of a waterbody. Removing native vegetation can decrease food and shelter for native species, increase erosion, and impervious surface runoff increases delivery of fertilizers, excess nutrients, pesticides and other pollutants into the lake or pond. Shoreline development has been linked to a number of changes in aquatic biota and ecosystems including measurable declines in fish abundance and diversity, loss of amphibian diversity, and avoidance by loons and some other waterfowl (Capiella and Schueler 2004, CLUE 2004).

The National Lake Assessment (NLA) uses "Lakeshore disturbance" as a key physical habitat assessment metric to evaluate lake and pond condition. In our previous Northeast Conservation Status report (Anderson and Olivero-Sheldon, 2011) we developed a landcover based shoreline disturbance index using a regression analysis to link GIS measurements of development to NLA field sampled lakeshore disturbance values. The field-measured scores had a statistically significant relationship to the GIS-based impact index (R squared = 0.56, $p < 0.0001$, log scale) and three reporting class thresholds were created to replicate the three reporting classes used in the NLA assessment.

We repeat here the calculation of that GIS based shoreline disturbance index, this time using a time sequence of NLCD 2001, 2011, and 2019 land cover to detect trends in disturbance on lands within the 100 m lakeshore buffer zone. Only lands consistently classified as land (not water) across all time periods were included for consistency in total land assessment area.

We use a numeric impact index that sums the percent of development and agriculture in the buffer zone (NLCD cover classes 81/82, 21/22, 23/24) and weights the categories to reflect the degree of impact as follows:

*SDI = 0.5 * % agriculture + 0.75* % low intensity development+ 1.0* % high intensity development*

The Shoreline Development Impact index (SDI) ranges from 100 for a lake with its shoreline zone completely developed, to 0 where the shoreline zone is completely composed of natural cover types. Reporting classes are as follows (Anderson and Olivero-Sheldon, 2011)

1. Low disturbance: SDI 0 < 3.7 (mean 1.3)
2. Moderate disturbance: SDI >= 3.7 < 15.0 (mean 8.4)
3. High disturbance: SDI >=15.0 (mean 26.2)

Applying the index to the region's waterbodies indicates that 33% fall in the low disturbance class, 23% in the moderate disturbance class, and 44% in the high disturbance class. (Figure 7.4, Table 7.8, Map 7.5). Lakes had fewer waterbodies in the high disturbance class (41%) than ponds (45%) Similarly, New England and New York also had fewer waterbodies in the high disturbance class (37%) than the Mid Atlantic (55%). Small ponds had a high level of shoreline impacts (51%), possibly reflecting their dispersed distribution often within suburban neighborhoods and agricultural landscapes. Very large lakes had 54% in the high disturbance class reflecting recreational development along their shorelines.

Map 7.5. Lakes and Ponds by Disturbance Class.

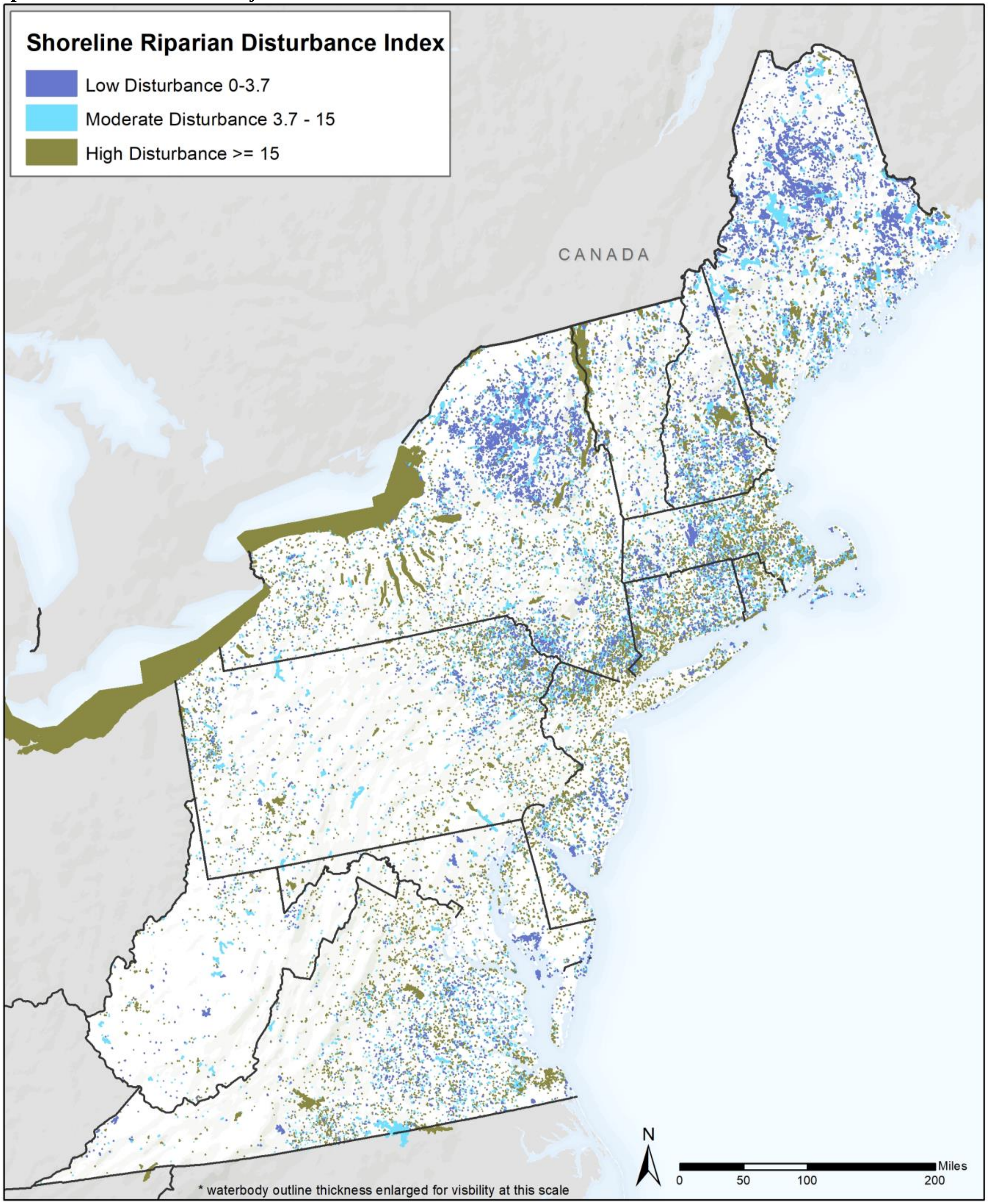


Figure 7.4. The percentage lakes and ponds that fall within each shoreline disturbance class.

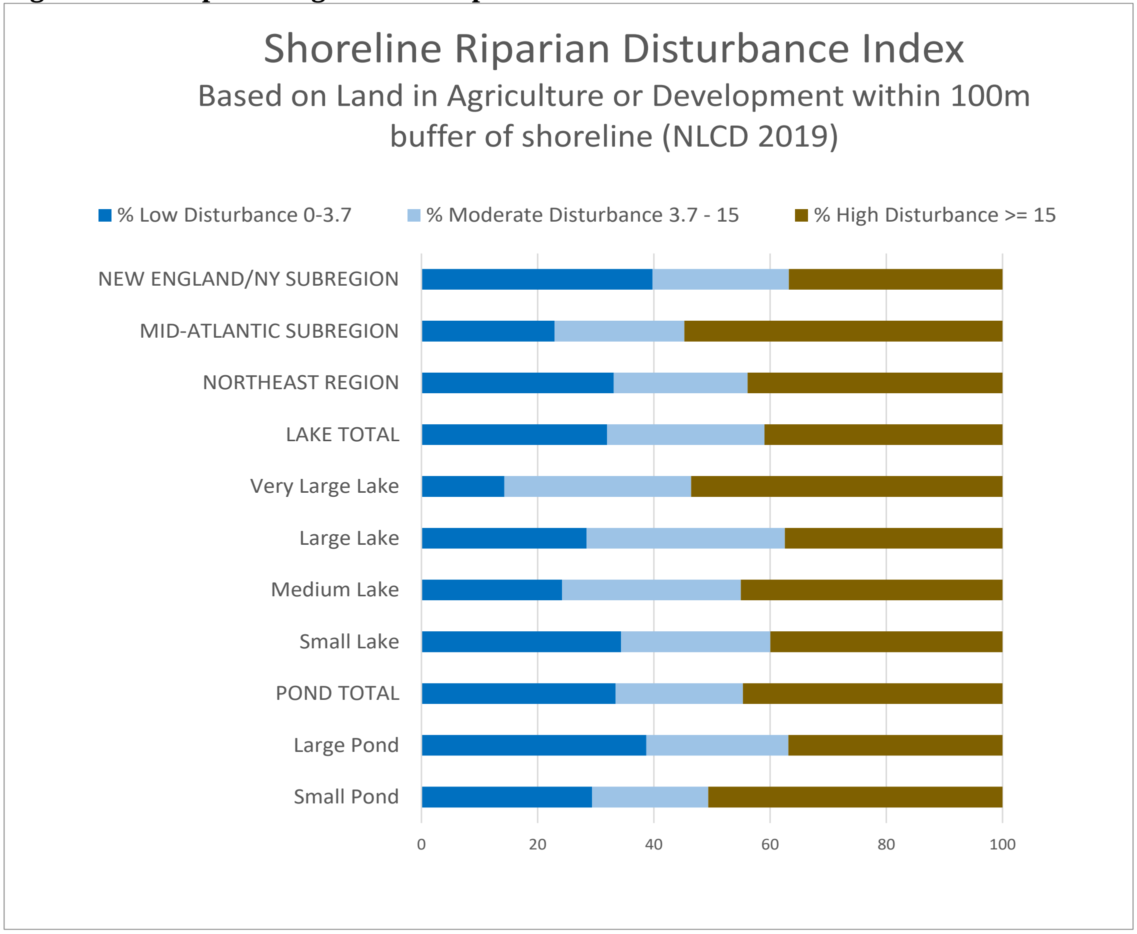


Table 7.8. The percentage and number lakes and ponds that fall within each shoreline disturbance class.

Shoreline Riparian Disturbance Index	% Low Disturbance 0-3.7	% Moderate Disturbance 3.7 - 15	% High Disturbance >= 15	# Low Disturbance 0-3.7	# Moderate Disturbance 3.7 - 15	# High Disturbance >= 15	# Waterbodies Total
Small Pond	29	20	51	4,780	3,251	8,244	16,275
Large Pond	39	24	37	4,830	3,049	4,597	12,476
POND TOTAL	33	22	45	9,610	6,300	12,841	28,751
Small Lake	34	26	40	2,019	1,511	2,350	5,880
Medium Lake	24	31	45	394	501	734	1,629
Large Lake	28	34	37	85	102	112	299
Very Large Lake	14	32	54	4	9	15	28
LAKE TOTAL	32	27	41	2,502	2,123	3,211	7,836
NORTHEAST REGION	33	23	44	12,112	8,423	16,052	36,587
MID-ATLANTIC SUBREGION	23	22	55	3,309	3,228	7,913	14,450
NEW ENGLAND/NY SUBREGION	40	23	37	8,803	5,195	8,139	22,137

We found strong correspondence between the highly conserved lakes and ponds (>70% conserved shoreline) and low shoreline disturbance index, with 65% falling in the low disturbance category. However, 35% fell in the moderate or high shoreline disturbance category suggesting that intense development may be present along the unconserved portion of the shore (<30%) or perhaps some fragmentation in the multi-use conservation lands. Waterbodies with less than 70% of their shoreline conserved had only 25% in the low impact category and nearly four times as many in the high disturbance category.

<u>Recent Trends in Shoreline Disturbance</u>

Over the last 20 years (2001-2022) habitat conversion in the shoreline has continued, and 36% of the region's lakes and ponds (13,182 waterbodies) had a higher shoreline disturbance index in 2019 than in 2001. Although 796 remained in the low shoreline disturbance category despite small increases in agriculture or development, many saw more extensive changes in their shoreline disturbance index. Since 2001, 235 waterbodies changed from a low to moderate disturbance class, 488 moved into the high disturbance class, and many other decreased in score but remained in the same class. Overall 4% of waterbodies have had increased disturbance at a level raising their index value by >5 points and another 9% have had increased disturbance at a level raising their index by >1 point (Map 7.6, Table 7.9). In total, 13% waterbodies that increased in disturbance have change over 1 point (9%) or 5 points (4%). The waterbodies that changed at over 5 points (red and orange in Map 7.6) are spread across the region but appear closer to suburban areas and major road corridors. Those waterbodies that have had the most change (>5 points) since 2011 (red on Map 7.6) represent 1% of all waterbodies (Table 7.9), with a higher percentage in the Mid-Atlantic where 1.6% of all waterbodies are in this more recent high disturbance change class.

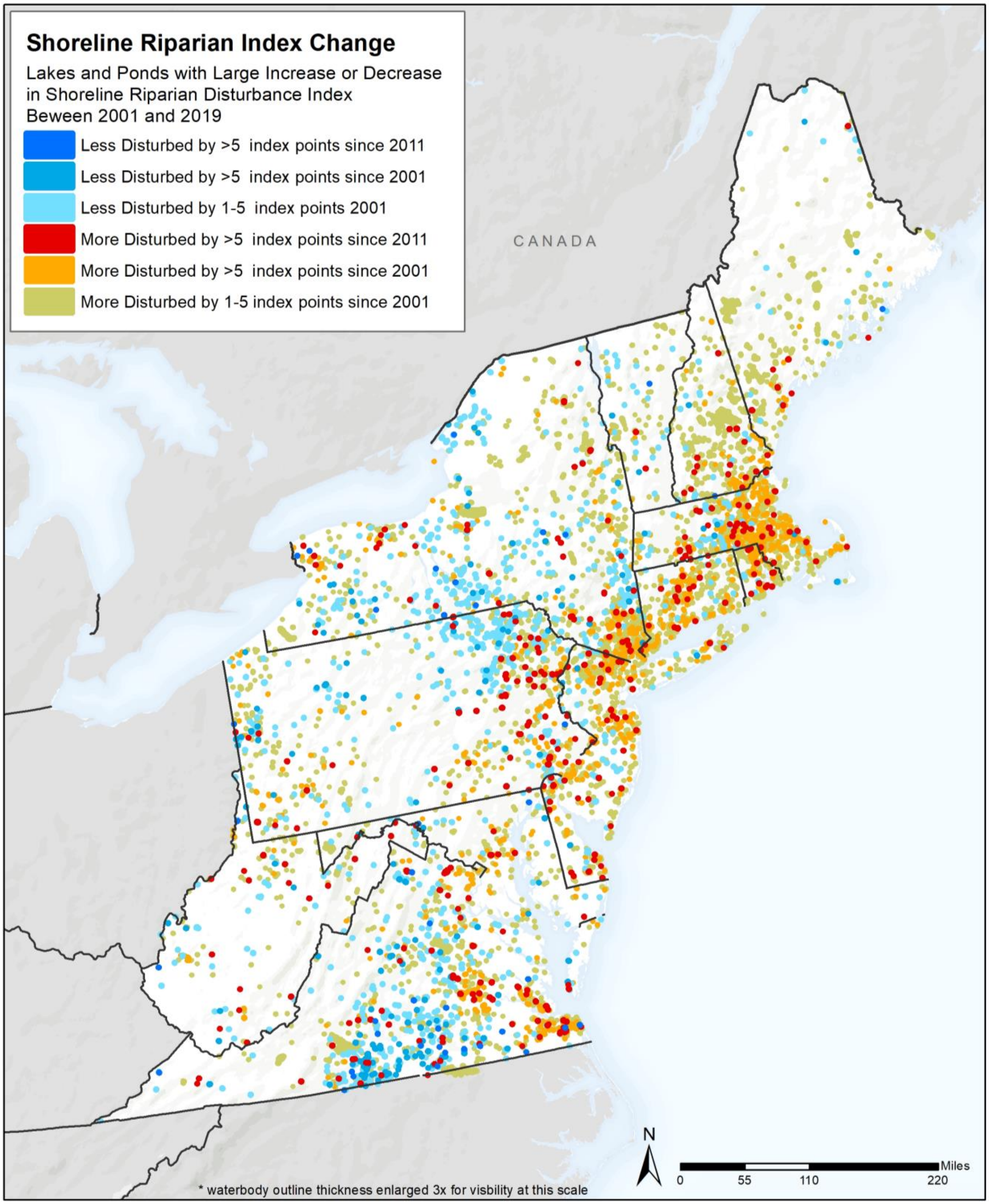
A small group of 2,261 lakes and ponds (6%) improved in their shoreline disturbance index since 2001. Of these 1,187 improved over one point and 227 (17 lakes and 210 ponds) improved over five points (Map 7.6, blue points, Table 7.9). Land use data indicates that these improvements are mostly due to less agriculture.

Table 7.9. Lakes and ponds that have had a large change in their shoreline disturbance index 2001-2019.

Lakes and Ponds with Large Increase or Decrease in Shoreline Riparian Disturbance Index Beween 2001 and 2019		# More Disturbed by >5 index points since 2011	# More Disturbed by >5 index points since 2001	# More Disturbed by >1-5 index points since 2001	Total # of More Disturbed Classes	# Less Disturbed by >5 index points since 2011	# Improved, Less Disturbed >5 points since 2001	# Less Disturbed by >1-5 index points since 2001	Total #of Less Disturbed Classes	Total # of Waterbodies
Mid-Atlantic	Pond	208	437	1122	1767	27	128	523	678	12307
	Lake	21	57	252	330	2	10	89	101	2143
Mid-Atlantic Subregion		229	494	1374	2097	29	138	612	779	14450
New England/NY	Pond	119	515	1267	1901	12	43	286	341	16444
	Lake	31	124	602	757	1	4	62	67	5693
New England/NY Subregion		150	639	1869	2658	13	47	348	408	22137
POND TOTAL		327	952	2389	3668	39	171	809	1019	28751
LAKE TOTAL		52	181	854	1087	3	14	151	168	7836
NORTHEAST TOTAL		379	1133	3243	4755	42	185	960	1187	36587

Lakes and Ponds with Large Increase or Decrease in Shoreline Riparian Disturbance Index Beween 2001 and 2019		% More Disturbed by >5 index points since 2011	% More Disturbed by >5 index points since 2001	% More Disturbed by >1-5 index points since 2001	% In Total of More Disturbed Classes	% Less Disturbed by >5 index points since 2011	% Improved, Less Disturbed >5 points since 2001	% Less Disturbed by >1-5 index points since 2001	% In Total of Less Disturbed Classes
Mid-Atlantic	Pond	1.7	3.6	9.1	14.4	0.2	1.0	4.2	5.5
	Lake	1.0	2.7	11.8	15.4	0.1	0.5	4.2	4.7
Mid-Atlantic Subregion		1.6	3.4	9.5	14.5	0.2	1.0	4.2	5.4
New England/NY	Pond	0.7	3.1	7.7	11.6	0.1	0.3	1.7	2.1
	Lake	0.5	2.2	10.6	13.3	0.0	0.1	1.1	1.2
New England/NY Subregion		0.7	2.9	8.4	12.0	0.1	0.2	1.6	1.8
POND TOTAL		1.1	3.3	8.3	12.8	0.1	0.6	2.8	3.5
LAKE TOTAL		0.7	2.3	10.9	13.9	0.0	0.2	1.9	2.1
NORTHEAST TOTAL		1.0	3.1	8.9	13.0	0.1	0.5	2.6	3.2

Map 7.6. Lakes and Ponds by Shoreline Disturbance Index Change. This map highlights lakes and ponds that have had a large increase or decrease in their shoreline riparian disturbance index between 2001 and 2019.



Lake Condition: Impervious Surfaces

Lake and pond ecosystems are influenced by upstream terrestrial processes given their low landscape position and the upstream flow paths of both ground and surface waters that contribute to their volume. The proportion of impervious surfaces (e.g. roads, parking lots, driveways) in a lake's upstream watershed has been associated with the degradation of water quality, ecological processes, and loss of diversity (CWP, 2003). Reduced infiltration of rainwater leads to more frequent overland flow and increased sediment loading. Chemical pollution also tends to be higher in areas with higher impervious surfaces (Dugan et al. 2017). Although less research has been done on lakes than on streams, many studies have found detectable impacts on aquatic biota at impervious surface levels above 10% of the upstream watershed area, while others have detected significant impacts and loss of taxa at levels lower levels of 2% of the watershed or even 0.5% (Southerland and Stranko 2008, King and Baker 2010).

In the previous Northeast Conservation Status report (Anderson and Olivero-Sheldon, 2011), the 2001 NLCD impervious surface dataset was used to assess the upstream impacts on lakes and ponds. We repeat that metric in this study using data available from the US EPA LakeCat database which provides the upstream watershed percent imperviousness for each NHD-Plus V2.1 waterbody based on the reprocessed and consistently calibrated National Land Cover Impervious Surface Datasets 2001-2019, (Hill et al. 2018, LakeCat imperviousness dataset 1/7/2023). Only lakes and ponds in the source NHD-Plus V2.1 medium resolution dataset linked to LakeCat were included in this analysis. This excluded a number of smaller lakes (28) and ponds (4,105) in our regional dataset that had come from finer scale waterbody datasets such as NWI and other sources.

We grouped each lake or pond into one of four impervious impact categories guided by the thresholds found in King and Baker (2010) and as used in the 2011 regional Conservation Status report (Anderson and Olivero-Sheldon 2011).

- Class 1: Undisturbed or Least impacts: 0 < 0.5% impervious.
- Class 2: Low impacts: >=0.5-2% impervious.
- Class 3: Moderately impacted: >=2-10% impervious.
- Class 4: Highly impacted: >=10% impervious.

The results revealed that in 2019, 38% of all lakes and ponds were in the least impacted impervious surface impact category and 26% were in the next least impacted class (Map 7.7, Figure 7.5, Table 7.10). Conversely, 14% were in the most highly impacted class and 21% in the next most impacted class. Lakes had more waterbodies in the least impacted class (43%) than ponds (37%) and similarly ponds had more waterbodies in the highest impact class (16%) than lakes (9%), highlighting that ponds with their smaller watersheds were more sensitive to impervious impacts. Large and very large lakes had the most occurrences in the least impacted class (46%).

New England and New York had more lakes and ponds in the least impacted class (43%) than the Mid-Atlantic (30%, Map 7.7, Table 7.10). The two subregions had quite similar amounts in the most impacted class with 16% in the Mid-Atlantic and 14% in New England and New York. The states of Maine, Vermont, New Hampshire, New York, and Pennsylvania all had less than 10% of both their lakes and ponds in the most severely impact class. New Jersey, Virginia, and West Virginia had less than 10% of their lakes in the most severely impact class.

Map 7.7. Lakes and Ponds by Impervious Surface Impact Class (NLCD 2019)

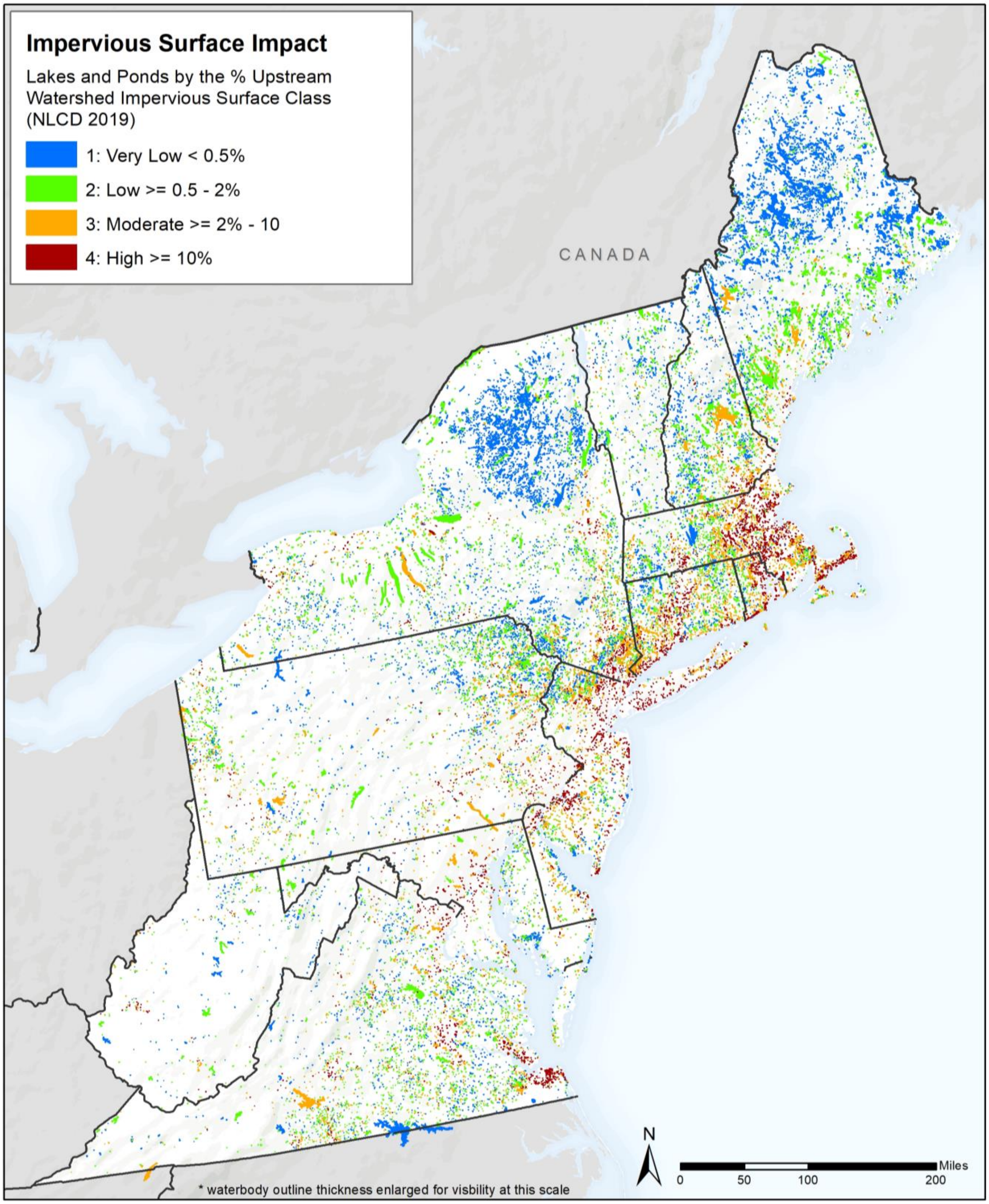


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Figure 7.5. Percentage of Lakes and Ponds by Upstream Impervious Class 2019

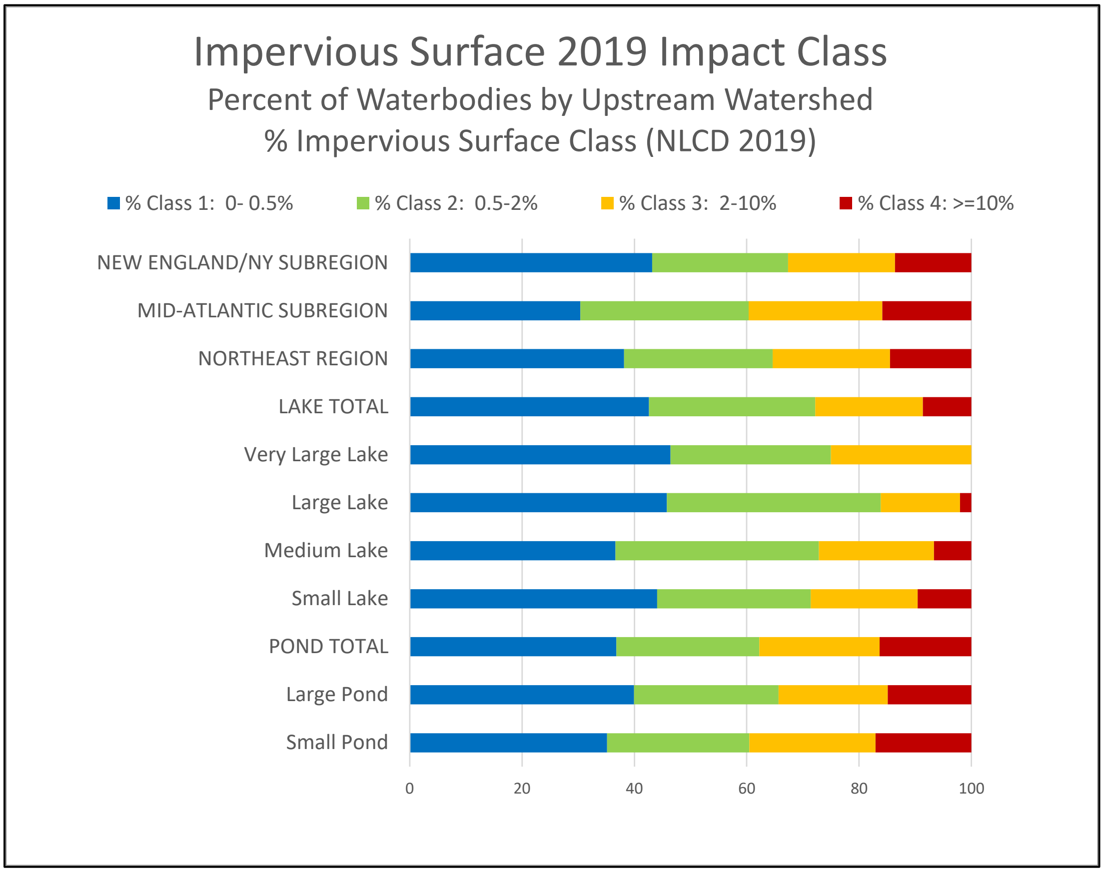


Table 7.10. Number and % of Lakes and Ponds by Upstream Impervious Class 2019

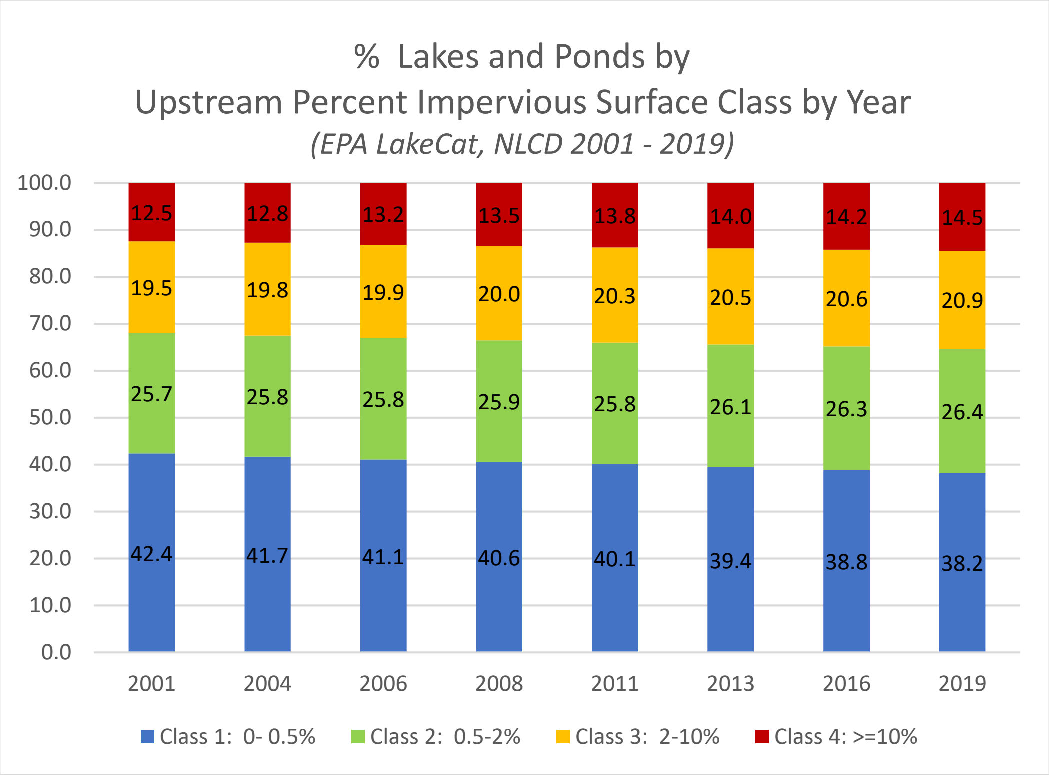
Percent Upstream Watershed Imperviousness (2019)	% Class 1: 0- 0.5%	% Class 2: 0.5-2%	% Class 3: 2-10%	% Class 4: >=10%	# Class 1: 0-0.5%	# Class 2: 0.5-2%	# Class 3: 2-10%	# Class 4: >=10%	# Waterbodies Total
Small Pond	35	25	22	17	5,699	4,101	3,639	2,770	16,209
Large Pond	40	26	19	15	3,368	2,171	1,641	1,257	8,437
POND TOTAL	37	25	21	16	9,067	6,272	5,280	4,027	24,646
Small Lake	44	27	19	10	2,582	1,603	1,115	562	5,862
Medium Lake	37	36	20	7	594	587	332	108	1,621
Large Lake	46	38	14	2	136	113	42	6	297
Very Large Lake	46	29	25	0	13	8	7		28
LAKE TOTAL	43	30	19	9	3,325	2,311	1,496	676	7,808
NORTHEAST REGION	38	26	21	14	12,392	8,583	6,776	4,703	32,454
MID-ATLANTIC SUBREGION	30	30	24	16	3,828	3,780	2,996	2,002	12,606
NEW ENGLAND/NY SUBREGION	43	24	19	14	8,564	4,803	3,780	2,701	19,848

Recent Trends in Impervious Surfaces

Over the last two decades (2001-2019), impervious surfaces have increased consistent with the expansion of development and suburban sprawl in the northeast. The two most impacted classes each grew from 32% in 2001 to 35% of all lakes and ponds in 2019 (Figure 7.6). Considering the last decade 2011-2019, in total 4% of all lakes and ponds were in a more impacted class in 2019 compared to their class in 2011. Effected waterbodies are widely distributed across the region with only lands under conservation very remote and mountainous areas seeing no change (Map 7.8, Table 7.11). No waterbodies changed to a lower impervious surface class, highlighting how difficult it is to remediate impervious surfaces.

There was good correspondence between the highly conserved lakes and ponds (>70% conserved shoreline) and low impervious surfaces, with 66% falling in the lowest disturbance category in 2019, much higher than the regional average (38%). Overall, 85% of highly secured lakes had less than 2% impervious surfaces upstream. There were, however 289 highly secured lakes (4%) that fell in the highly impacted class. They highlight that although these waterbodies may be locally situated within conservation land, their upstream watersheds can still have significant amounts of impervious surfaces, along with possible negative effects on the biota and ecosystem. These 289 lakes and ponds however make up just 6% of the total 4,703 waterbodies in the most highly impacted impervious class.

Figure 7.6. Percent of Lakes and Ponds by Impervious Surface Impact Class 2001-2019



Map 7.8. Lakes and Ponds by Change in Impervious Surface Impact Class (NLCD 2019)

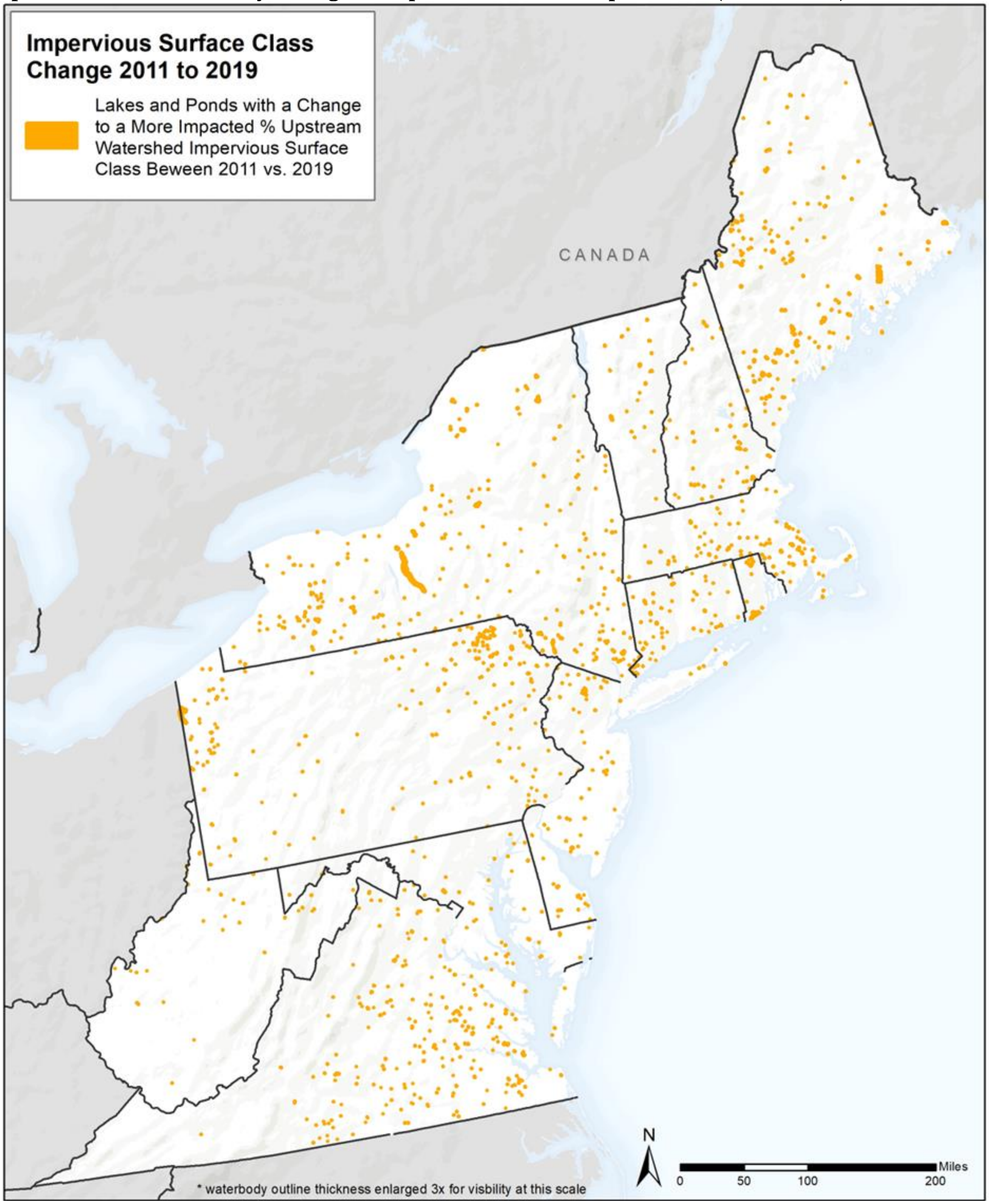


Table 7.11. Number and Percent of Lakes and Ponds by Impervious Surface Impact Class Change 2011-2019

Lakes and Ponds with a Change to More Impacted % Upstream Watershed Impervious Surface Class Beween 2011 vs. 2019		# Waterbodies Changed	Total Population of Waterbodies	% of Waterbodies Changed to a more impacted class
Mid-Atlantic	1. Pond	470	10,473	4.5
	2. Lake	112	2,133	5.3
Mid-Atlantic Total		582	12,606	4.6
New England/NY	1. Pond	481	14,173	3.4
	2. Lake	188	5,675	3.3
New England/NY Total		669	19,848	3.4
NORTHEAST TOTAL		1,251	32,454	3.9

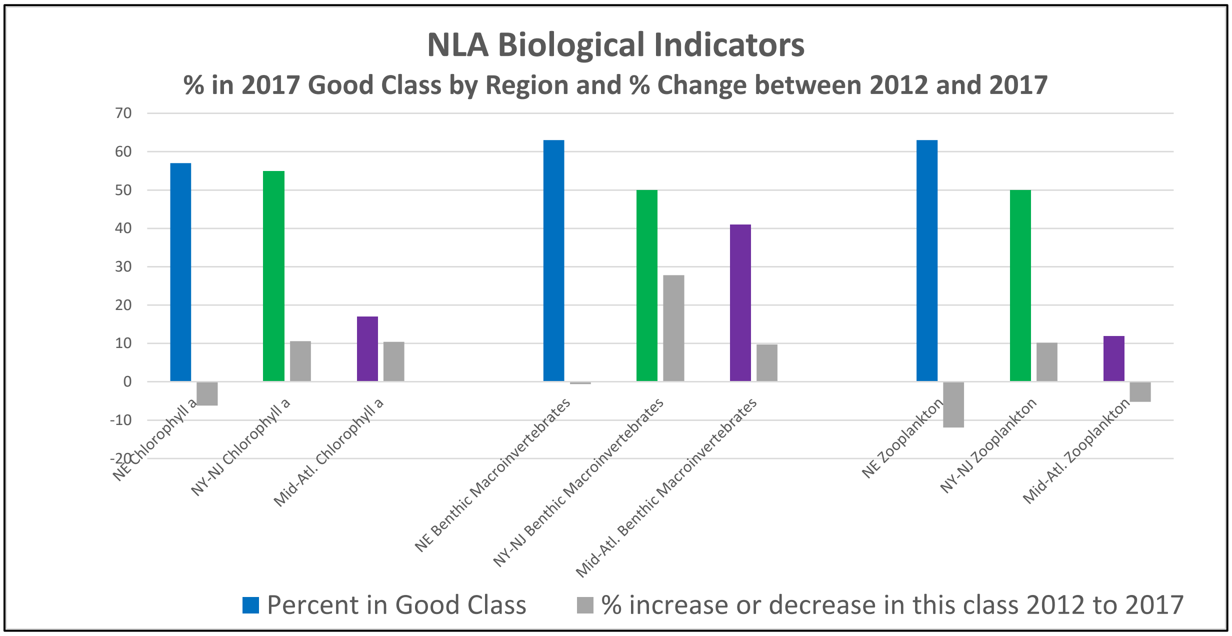
Lake Condition: National Lake Assessment

The National Lakes Assessment (NLA) is a statistical survey of the condition of our nation's lakes, ponds, and reservoirs. It is designed to "provide information on the extent of lakes that support healthy biological condition and recreation, estimate how widespread major stressors are that impact lake quality, and provide insight into whether lakes nationwide are getting cleaner" (USEPA, 2022). The assessment develops ecoregion specific condition criteria for a variety of biological, chemical, and physical metrics and places sampled waterbodies into categories of good, fair, and poor condition for each metric.

The NLA has consistently sampled a small population of 140 lakes in the northeast at repeated intervals. We report here a summary of three key biological, chemical, and physical metrics (Table 7.12) using the EPA National Lake Assessment Dashboard which provides the percent of waterbodies falling in good, fair, and poor from the most recent 2017 survey, along with the change between the results of the 2012 survey. The NLA dashboard does not allow reporting at state levels due to small sample sizes, but does provide summaries by EPA regions, ecoregions, and water resource regions. The full dashboard reports for this region can be found at the end of this chapter. https://nationallakesassessment.epa.gov/dashboard/?&view=indicator&studypop=al&subpop=epa+region+1&label=pe&condition=good&diff=2v3

For the biological indicators of chlorophyll a, benthic macroinvertebrates, and zooplankton (Figure 7.7), the data suggest that both New England and New York/New Jersey have over 50% of waterbodies in the good biological condition class for all three metrics, while the Mid-Atlantic has 12% in good zooplankton condition, 17% in good chlorophyll condition and 41% in good benthic macroinvertebrate condition. Although change between 2012 and 2017 was not statistically significant, the New York-New Jersey region did show some improvement with more waterbodies in the good class in 2017 for all metrics. New England showed a small decrease in all metrics, and the Mid-Atlantic showed increases for chlorophyll and benthic macroinvertebrates and a decrease for zooplankton.

Figure 7.7: NLA 2017 Biological Indicators. The figure shows the percent of waterbodies > 1 ha (2.47 acre) scoring in "Good Condition" for each metric for the 3 geographic regions in 2017. The change in the percent of lakes categorized as Good Condition between 2012 and 2017 is shown by the gray bar to represent if more (+) or less (-) percent of lakes categorized as Good Condition in 2017.



Chemical indicators show a large percentage of waterbodies in good condition with respect to dissolved oxygen, ranging from 74% in New England to over 90% in New York, New Jersey and the Mid-Atlantic. Nitrogen and phosphorus are in good condition for roughly half the waterbodies in New England, New York and New Jersey, and 12-13% for the Mid-Atlantic. Between 2012 and 2017, New England had a significant 37% decrease in the number of waterbodies in good condition for nitrogen. New England also showed larger but non-significant declines in oxygen and phosphorus than the Mid Atlantic which had very small increases or decreases. The decrease in the number of waterbodies scoring in good condition for oxygen, nitrogen, and phosphorus will be important to monitor.

Physical habitat variables of lakeshore disturbance, riparian vegetation cover, and habitat complexity based on the sampled waterbodies show patterns similar to our spatially comprehensive analysis presented earlier. In general, less than half of waterbodies score in good condition (compared to 33% in our GIS analysis). Only 5% of Mid-Atlantic lakes scored in good condition for lakeshore disturbance compared to our 23%. New England, New York and New Jersey were relatively similar in lakeshore disturbance and riparian vegetation cover with 37-54% of waterbodies in good condition for these metrics, and New York scoring particularly high for habitat complexity. Change was relatively consistent between 2012-2017 for each geographic regions with all three indicators improving for New York and New Jersey but decreasing for New England. The Mid Atlantic decreased for lakeshore disturbance and habitat complexity but increased slightly for riparian vegetation cover.

Figure 7.8: NLA 2017 Chemical Indicators The figure shows the percent of waterbodies scoring in "Good Condition" for each indicator in each geographic region in 2017. Change in the percent of lakes in Good Condition between 2012 and 2017 is shown by the gray bar to represent if more (+) or less (-) lakes changed in 2017.

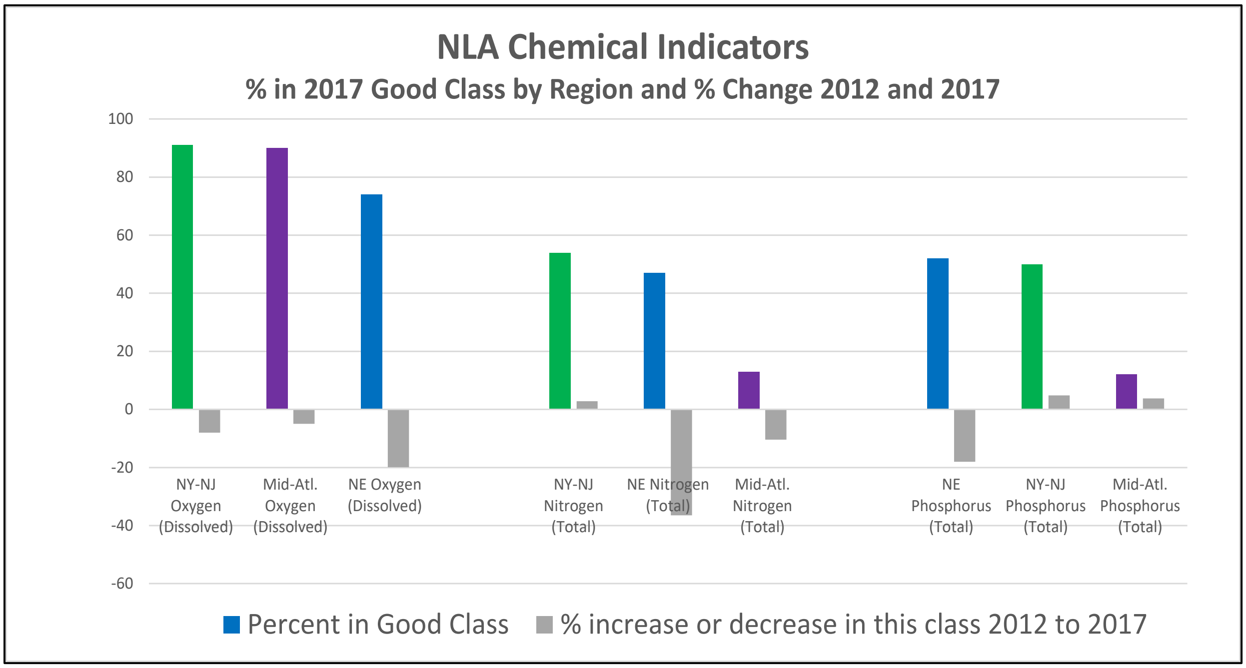


Figure 7.9: NLA 2017 Physical Indicators. The figure shows the percent of waterbodies scoring in "Good Condition" for each indicator in each geographic region in 2017. Change in the percent of lakes in Good Condition between 2012 and 2017 is shown by the gray bar to represent if more (+) or less (-) lakes changed in 2017.

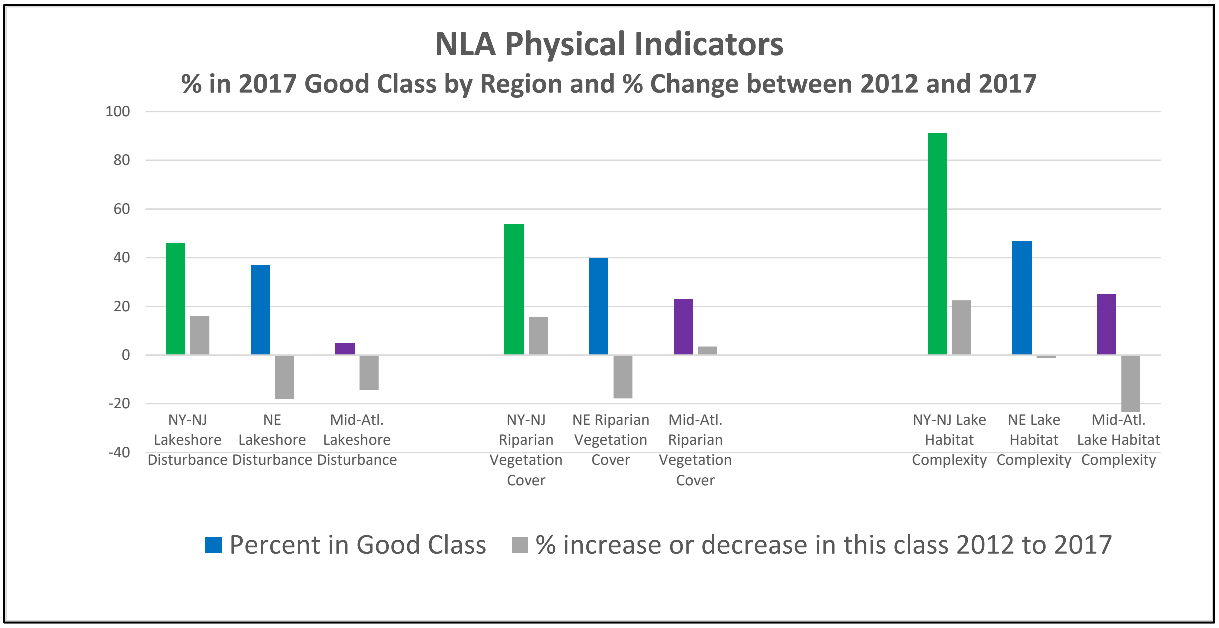


Table 7.12: Summary of Select 2017 National Lake Assessment Biological, Chemical, and Physical Condition Metrics.

All lakes >1 hectare (2.47 acres)		2017 Percent of Total Good	Fair	Poor	Change from 2012 2017 Good	Fair	Poor
New England		% in each class			% in each class increase or decreased by X		
Biological Indicators	Chlorophyll a	57	8	35	-6.2	-11.6	17.9
	Benthic Macroinvertebrates	63	7	30	-0.6	-9.3	13.9
	Zooplankton	63	11	27	-11.9	-5.1	17
Chemical Indicators	Oxygen (Dissolved)	74	2	24	-19.9	-3.8	23.8
	Nitrogen (Total)	47	24	29	-36.5	11.2	25.3
	Phosphorus (Total)	52	18	30	-18	-2.9	20.9
Physical Indicators	Lake Habitat Complexity	47	38	15	-1.2	10.3	-9.1
	Lakeshore Disturbance	37	57	7	-18	13.8	4.2
	Riparian Vegetation Cover	40	55	5	-17.8	34.7	-16.9
NY-NJ							
Biological Indicators	Chlorophyll a	55	2	44	10.6	-14.4	3.8
	Benthic Macroinvertebrates	50	40	7	27.8	22.2	-31.3
	Zooplankton	50	43	8	10.2	-7.8	-2.5
Chemical Indicators	Oxygen (Dissolved)	91	8	2	-8	7.5	1
	Nitrogen (Total)	54	1	44	2.8	-4.1	1.4
	Phosphorus (Total)	50	5	45	4.8	-1.8	-3.1
Physical Indicators	Lake Habitat Complexity	91	2	6	22.5	-13	-9.5
	Lakeshore Disturbance	46	46	9	16.1	-16.5	0.3
	Riparian Vegetation Cover	54	41	4	15.7	4.5	-20.2
Mid-Atlantic							
Biological Indicators	Chlorophyll a	17	3	80	10.4	-17	6.6
	Benthic Macroinvertebrates	41	50	9	9.7	29.3	-33.7
	Zooplankton	12	56	27	-5.2	26.9	-26.3
Chemical Indicators	Oxygen (Dissolved)	90	7	3	-5	5.3	1
	Nitrogen (Total)	13	13	74	-10.4	-5.6	16
	Phosphorus (Total)	12	13	75	3.8	8.5	-12.2
Physical Indicators	Lake Habitat Complexity	25	50	25	-23.4	16.5	6.9
	Lakeshore Disturbance	5	79	16	-14.3	17.7	-3.4
	Riparian Vegetation Cover	23	54	24	3.5	19.4	-22.9
					orange = Indicates statistically significant difference (95% confidence) between time periods compared		

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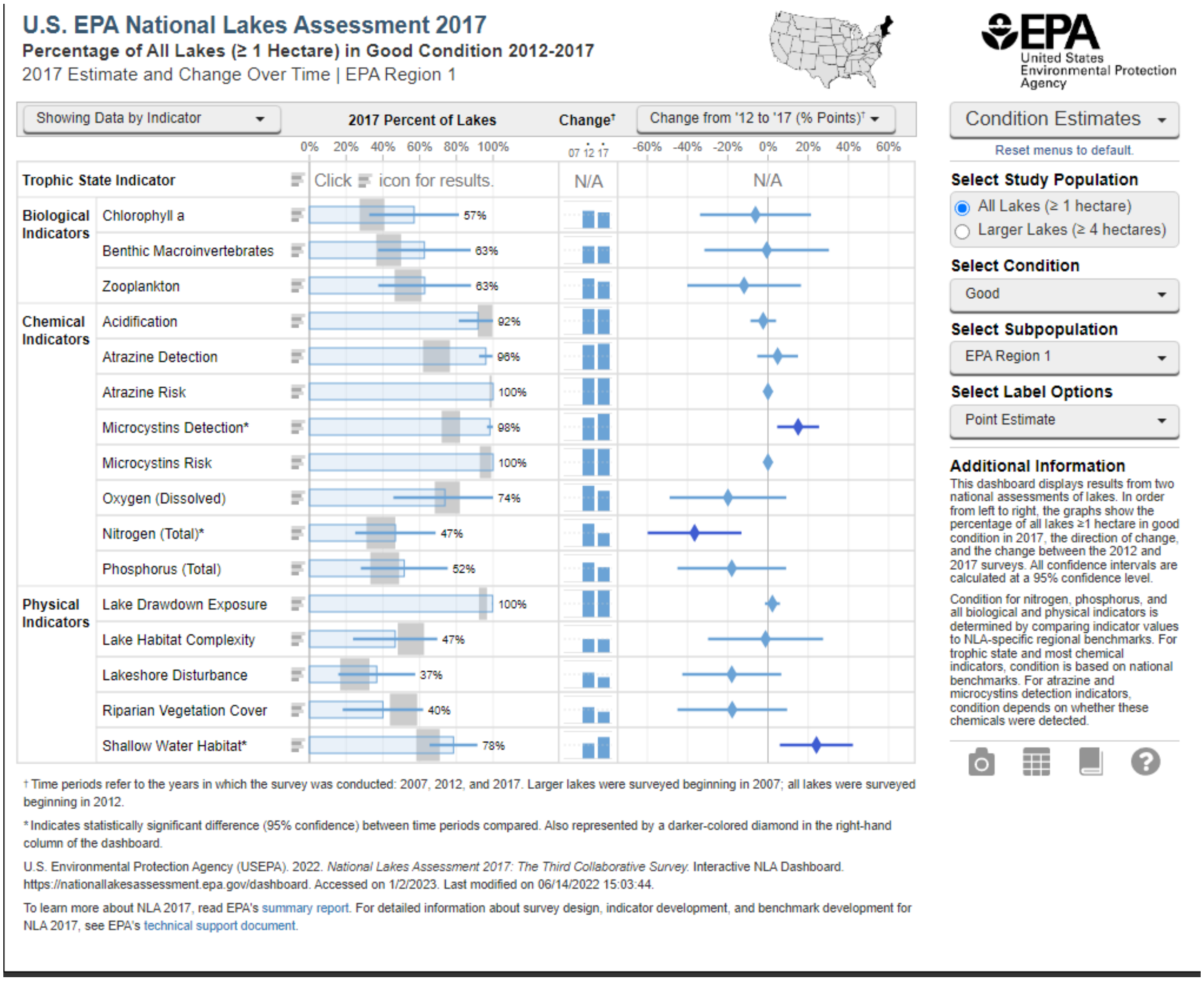
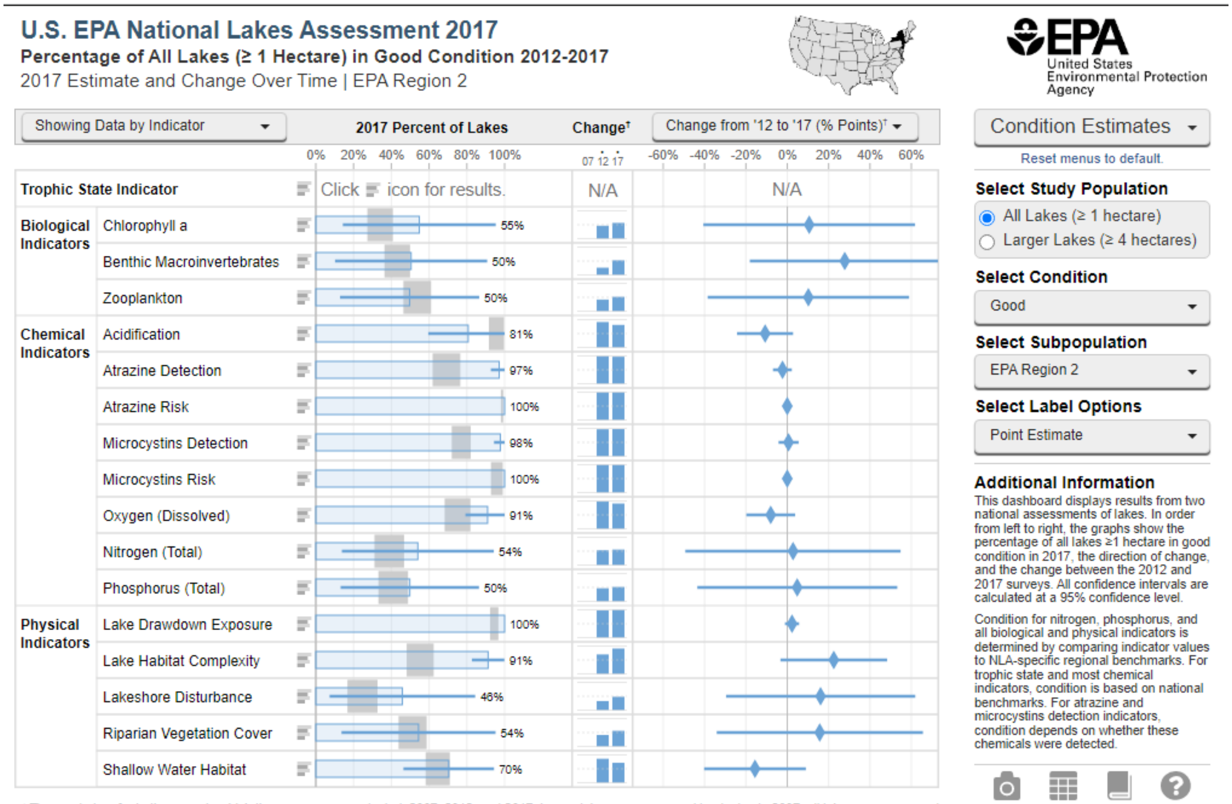
Appendix 7.1. All 2017 National Lake Assessment Metrics by Region and Condition Class

EPA National Lake Assessment Dashboard for EPA region 1 (New England), EPA Region 2 (NY-NJ), and EPA Region https://nationallakesassessment.epa.gov/dashboard/?&view=indicator&studypop=al&subpop=epa+region+1&label=pe&condition=good&diff=2v3



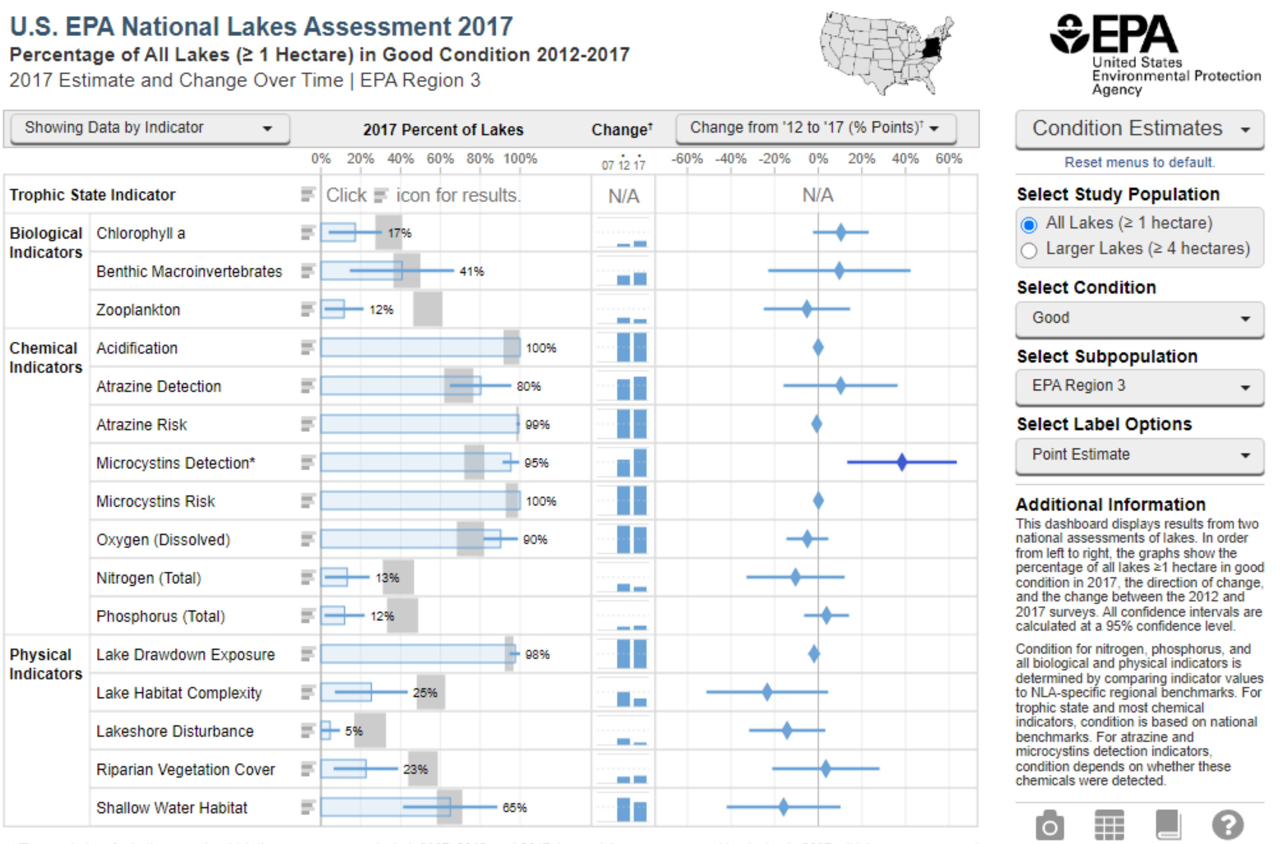


† Time periods refer to the years in which the survey was conducted: 2007, 2012, and 2017. Larger lakes were surveyed beginning in 2007; all lakes were surveyed beginning in 2012.

* Indicates statistically significant difference (95% confidence) between time periods compared. Also represented by a darker-colored diamond in the right-hand column of the dashboard.

U.S. Environmental Protection Agency (USEPA). 2022. *National Lakes Assessment 2017: The Third Collaborative Survey.* Interactive NLA Dashboard. https://nationallakesassessment.epa.gov/dashboard. Accessed on 1/2/2023. Last modified on 06/14/2022 15:03:44.

To learn more about NLA 2017, read EPA's summary report. For detailed information about survey design, indicator development, and benchmark development for NLA 2017, see EPA's technical support document.



† Time periods refer to the years in which the survey was conducted: 2007, 2012, and 2017. Larger lakes were surveyed beginning in 2007; all lakes were surveyed beginning in 2012.

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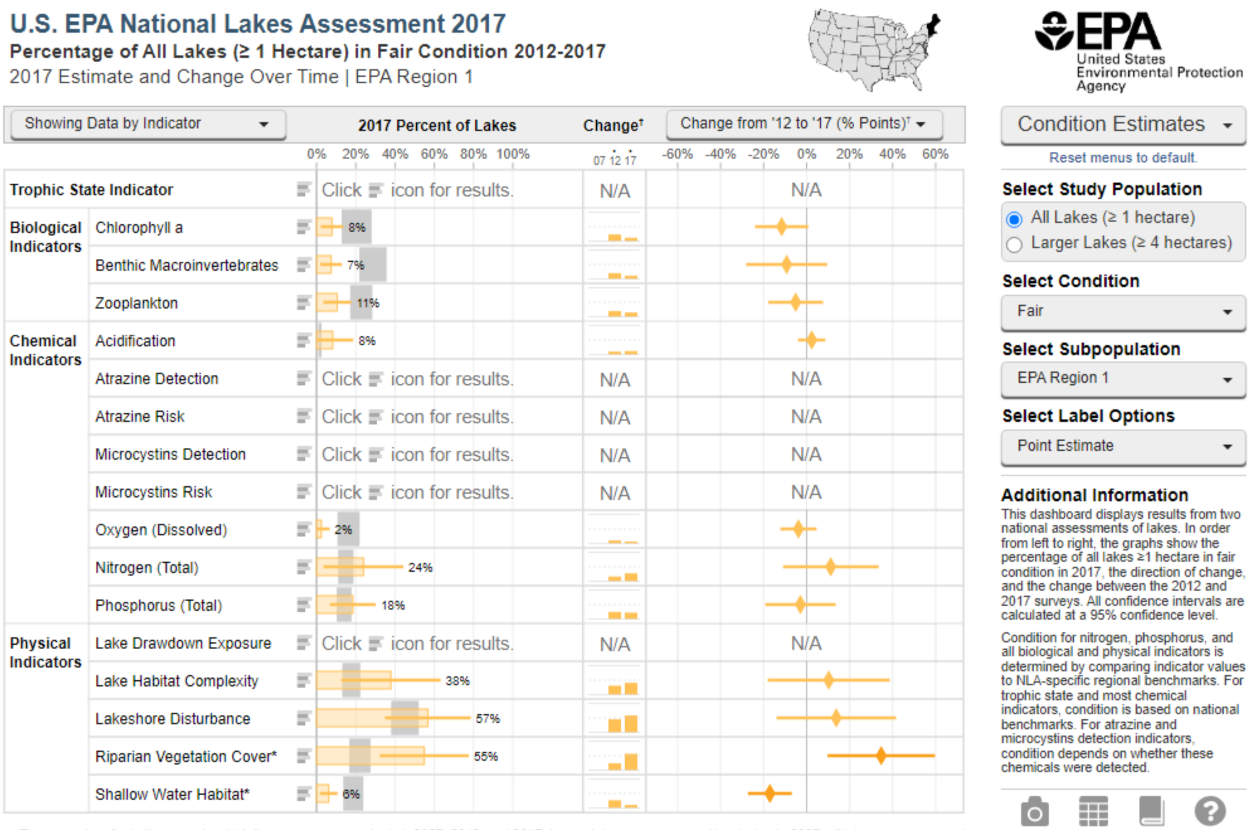

† Time periods refer to the years in which the survey was conducted: 2007, 2012, and 2017. Larger lakes were surveyed beginning in 2007; all lakes were surveyed beginning in 2012.

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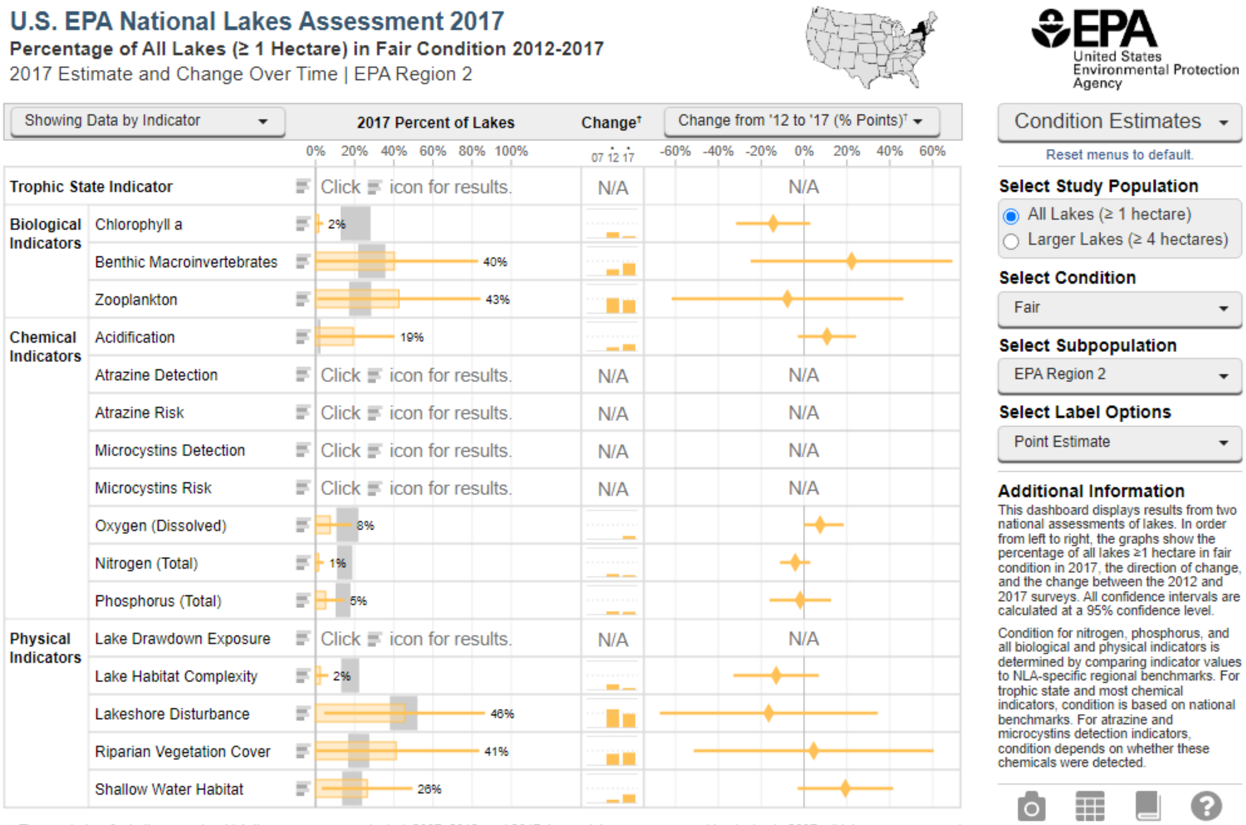

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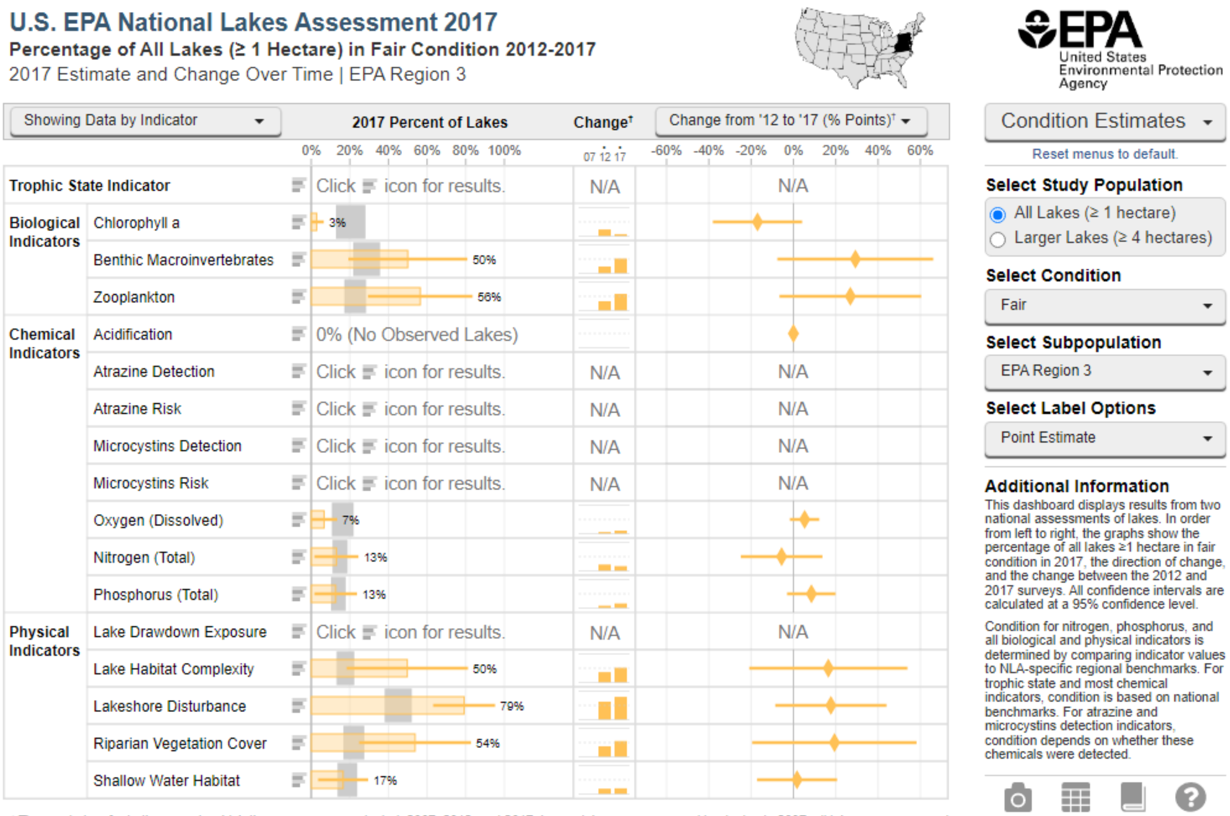

† Time periods refer to the years in which the survey was conducted: 2007, 2012, and 2017. Larger lakes were surveyed beginning in 2007; all lakes were surveyed beginning in 2012.

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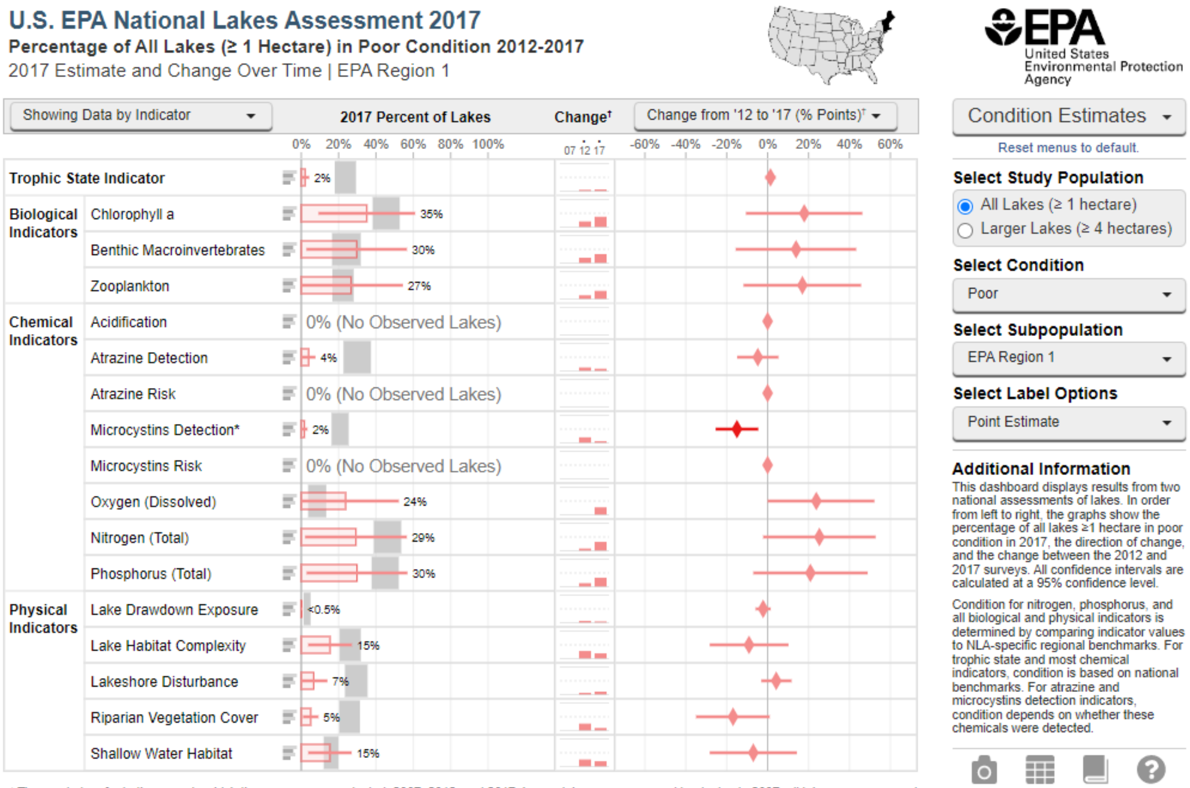

† Time periods refer to the years in which the survey was conducted: 2007, 2012, and 2017. Larger lakes were surveyed beginning in 2007; all lakes were surveyed beginning in 2012.

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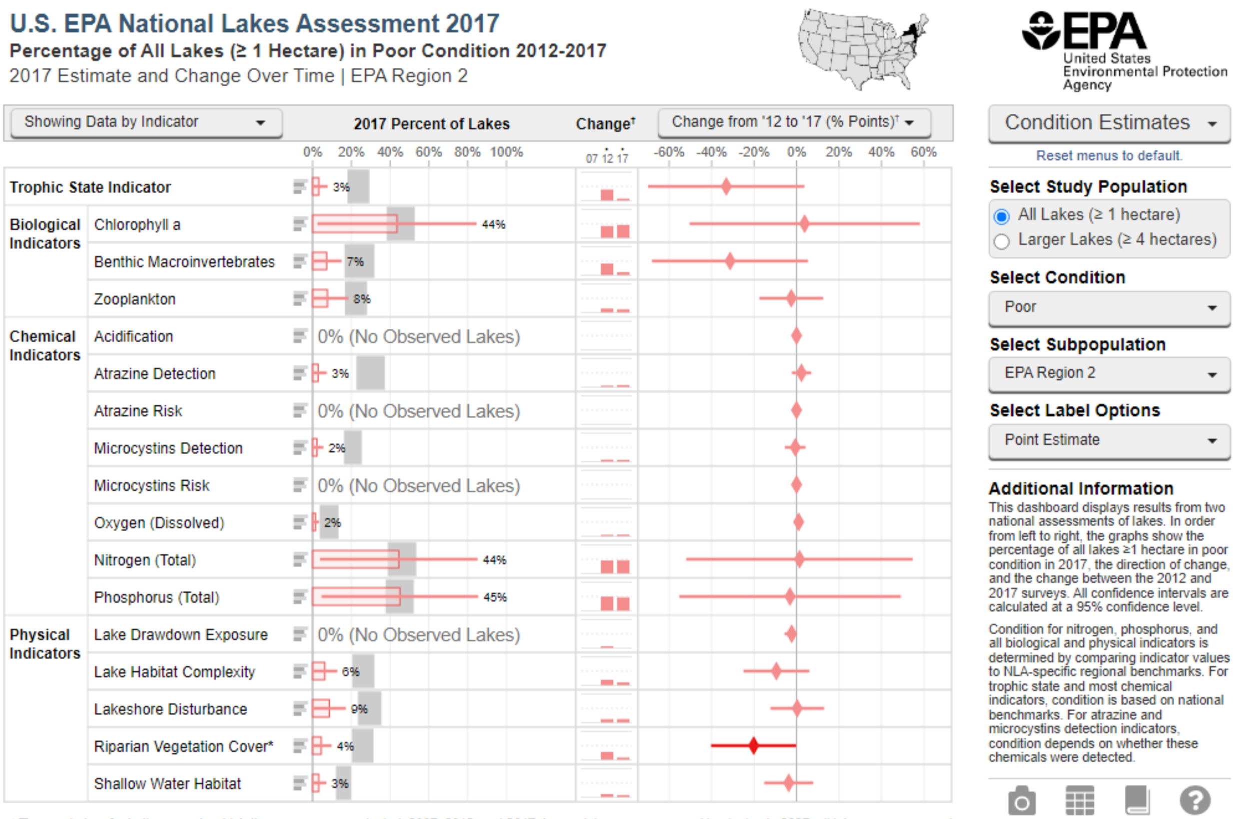
U.S. Environmental Protection Agency (USEPA). 2022. *National Lakes Assessment 2017: The Third Collaborative Survey.* Interactive NLA Dashboard. https://nationallakesassessment.epa.gov/dashboard. Accessed on 3/2/2023. Last modified on 10/27/2022 09:19:04.

To learn more about NLA 2017, read EPA's summary report. For detailed information about survey design, indicator development, and benchmark development for NLA 2017, see EPA's technical support document.



† Time periods refer to the years in which the survey was conducted: 2007, 2012, and 2017. Larger lakes were surveyed beginning in 2007; all lakes were surveyed beginning in 2012.

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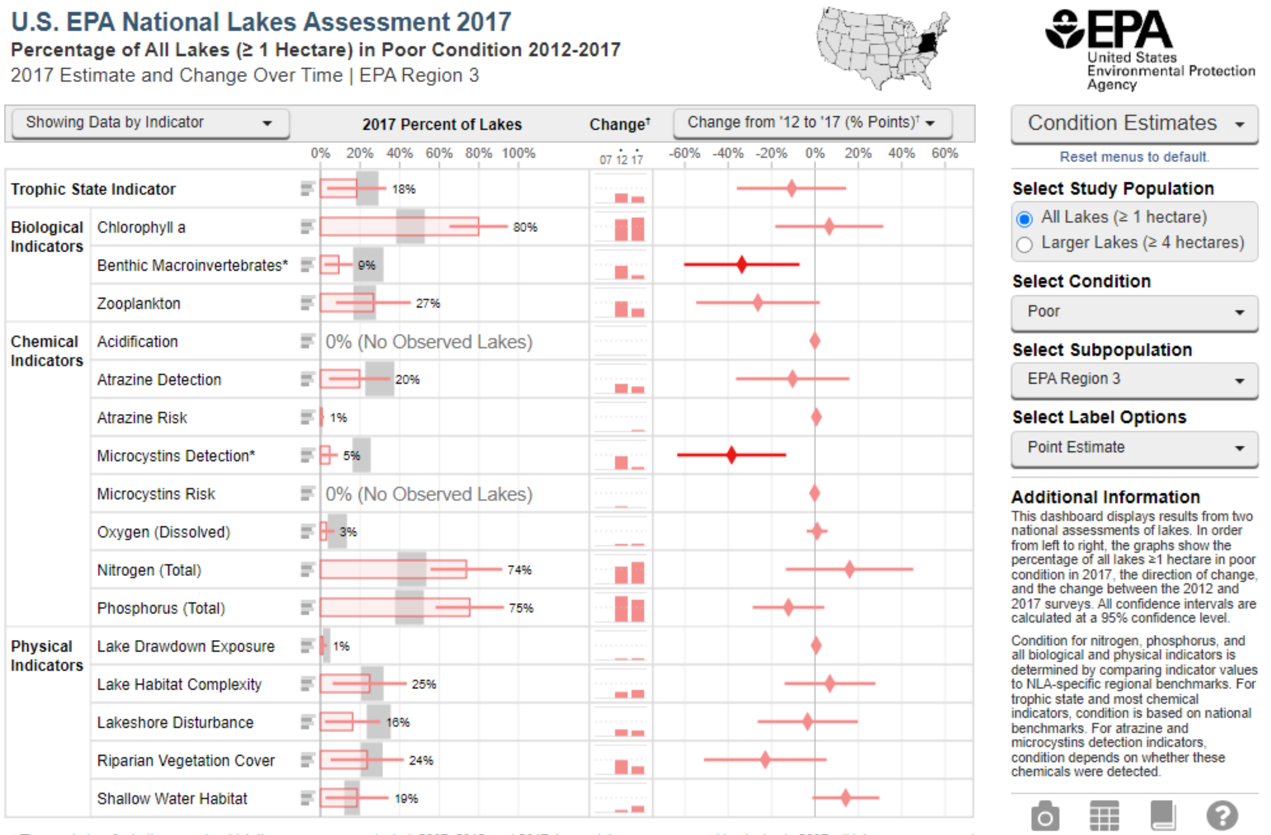

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To learn more about NLA 2017, read EPA's summary report. For detailed information about survey design, indicator development, and benchmark development for NLA 2017, see EPA's technical support document.

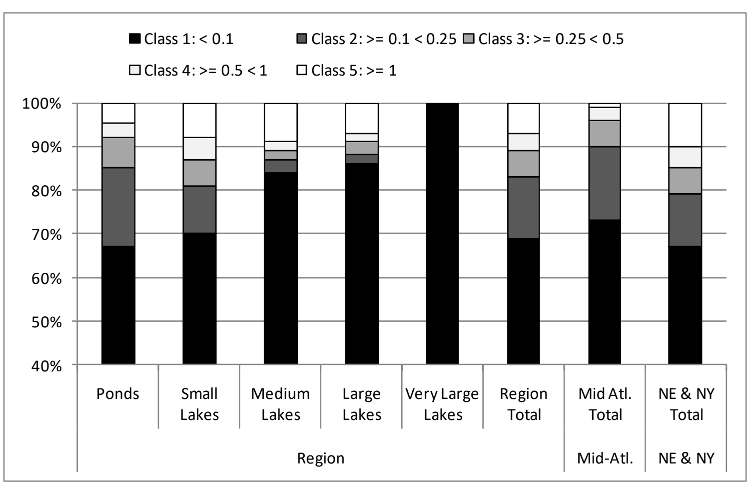
Appendix 7.2. Additional Metrics, 2011. *With approval of the project steering committee, we chose to focus our 2022 analysis on the highest priority metrics, those we expected to see more change in, and/or that were not covered in other recent reports (e.g. birds). These metrics are from the previous 2011 Conservation Status of Fish, Wildlife and Natural Habitats in the Northeast Landscape report (Anderson and Olivero-Sheldon 2011). They may be of interest to some readers looking for additional information on lakes and ponds.*

Isolation from Roads: Access to a lake from a road or trail is correlated with the loss of native species, and with the presence of non-native species (Silk and Ciruna 2004). Field surveys to document the presence of non-indigenous species in lakes only cover a handful of the lakes and ponds in the region, so we used the minimum distance from a mapped road as an estimate of potential introductions. We assumed that the more difficult the lake is to access, the less likely it is to contain non-indigenous species, as the primary entry point for many lake exotics are citizens seeking to create a local sport fishery, inadvertently transporting species attached to boats or discarding excess bait.

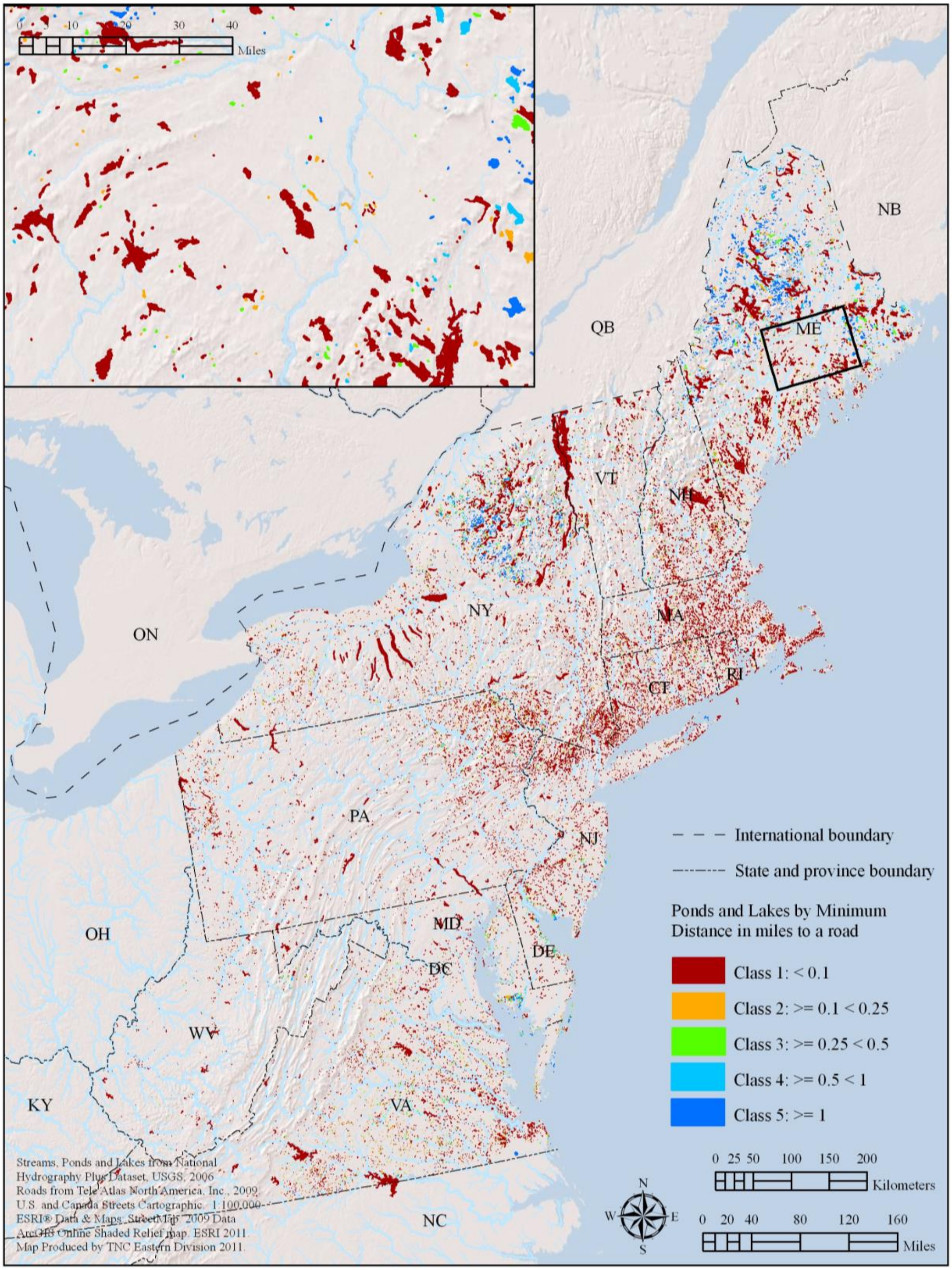
For each waterbody, we tabulated the distance to the nearest road including major highway, local thoroughfares, neighborhood connectors, and rural roads. Four-wheel drive roads and other trails were not included due to inconsistencies in their mapping across the region in the source dataset. Source data sets are described in the appendix A (Tele Atlas North America, Inc. 2009).

The results indicated that ponds and lakes in this region were highly accessible to people; 83 percent were within a quarter mile of a road and 69 percent were within one-tenth of a mile. Only 11 percent of lakes in the region were more than a half mile from a road and only 7 percent were greater than a mile from a road (Figure 7.2.1, Map 7.2.1). The Mid-Atlantic had fewer remote lakes with only 4 percent being more than one-half mile from a road compared to 15 percent for New England and New York. The larger the lake, the closer roads were to it: regionally 67 percent of ponds, 70 percent of small lakes, 84 percent of medium lakes, 86 percent of large lakes, and 100 percent of very large lakes have a road within one-tenth of a mile (Figure 7.2.1). This pattern was found in both sub-regions.

Figure 7.2.1. The proportion of each lake type in each distance to road class (in miles). Few lakes and ponds are over 1 mile from a road (Class 5, 7 percent). Most are less than one tenth mile from a road (Class 1, 69 percent).



Map 7.2.1. Ponds and lakes by minimum distance (in miles) to a road.



Presence of Dams: Dams within formerly natural lakes or reservoirs have been linked to significant negative ecological impacts on both plant and animal communities (see Vaux 2005, Jiffry 1984, Jansson et al 2000). Dams alter lake habitat by augmenting or reducing water levels depending on the operation of the inflow and outflow dams; impounded lakes also often experience altered temperature, oxygen, and sedimentation regimes. Further, dams that fragment connected networks of streams and lakes disrupt the natural dispersal patterns of many aquatic plant and animals. For example, dams have resulted in a substantial reduction in the amount of lake spawning habitat for diadromous species (such as alewife) and migratory freshwater species (such as brook trout).

To evaluate the impacts of dams, we compiled a database of dams for the entire region using a variety of state sources (see data sources) and queried the database for any lake with a dam within 500 m. This buffer distance was necessary to account for spatial inconsistencies between the mapped dams and the lakes upon which they were located, and it allowed us to consider the adverse effect a nearby dam might have on a lake upstream or downstream from it.

Results of the analysis indicate that 17 percent of all lakes and ponds in the region have a dam directly upstream or downstream. The percentage of dammed waterbodies increases as the lakes increase in size, only 11 percent of ponds are dammed but 70 percent of very large lakes have a dam directly associated with it (Figure 7.2.2, Table 7.2.1).

Figure 7.2.2. The percentage of lakes and ponds in the region with a dam directly upstream or downstream.

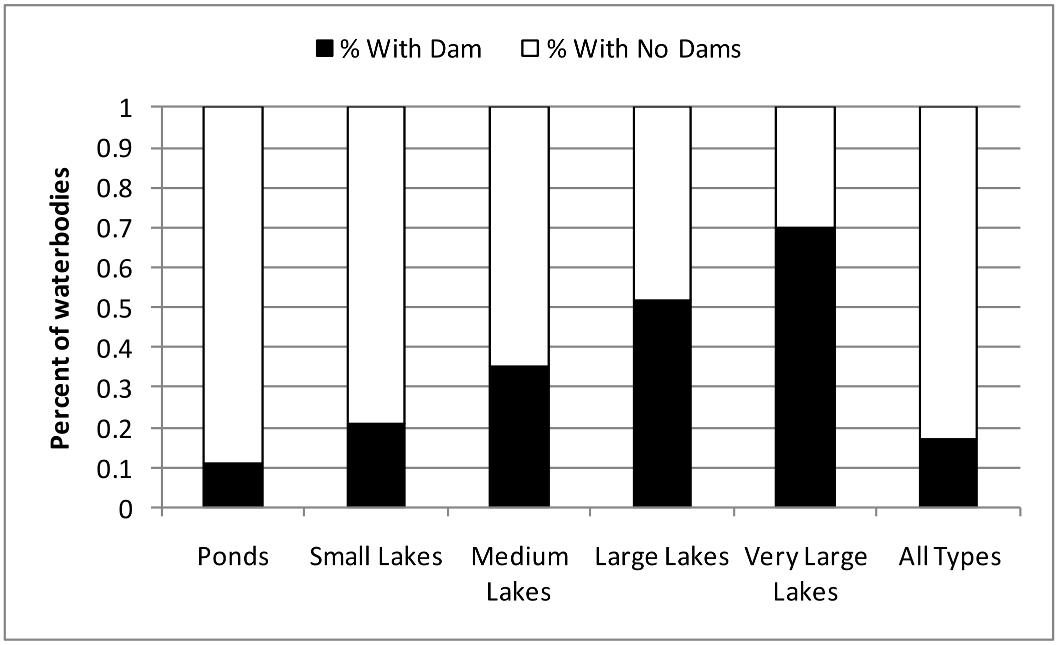


Table 7.2.1. The percentage of lakes with upstream or downstream dams, arranged by type and sub-region.

	Region		Mid-Atlantic		New England & New York	
	% With No Dams	**% With Dams**	**% With No Dams**	**% With Dams**	**% With No Dams**	**% With Dams**
Ponds	89%	11%	92%	8%	87%	13%
Small Lakes	79%	21%	75%	25%	82%	18%
Medium Lakes	65%	35%	53%	47%	67%	33%
Large Lakes	48%	52%	44%	56%	48%	52%
Very Large Lakes	30%	70%	33%	67%	29%	71%
Totals	83%	17%	85%	15%	82%	18%

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Figure 7.2.3. The percentage of lakes and ponds in the region with a dam directly upstream or downstream.

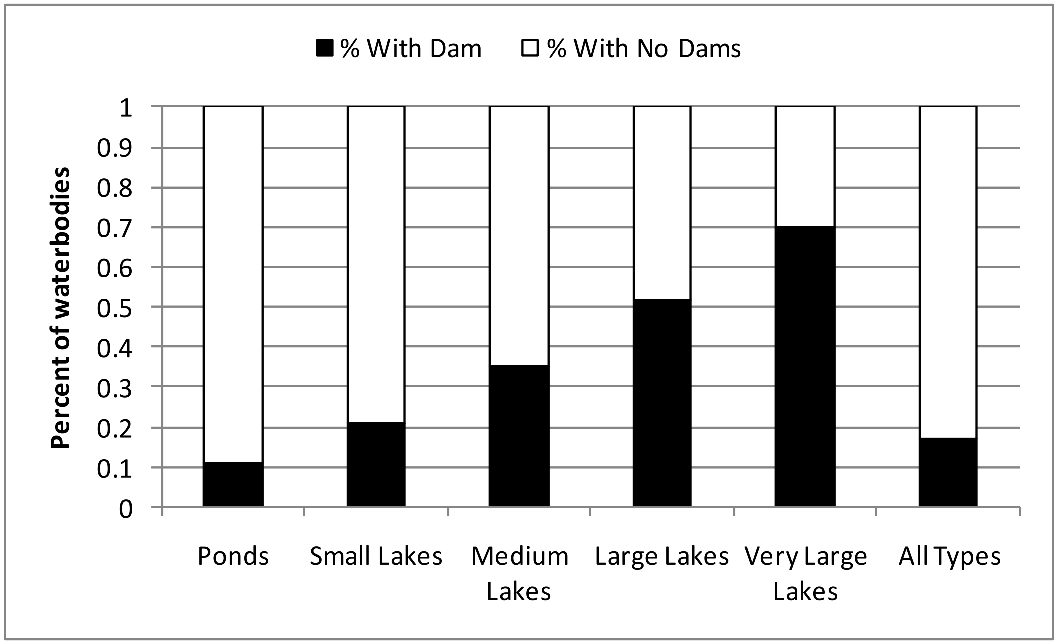

Table 7.2.2. The percentage of lakes with upstream or downstream dams, arranged by type and sub-region.

	Region		Mid-Atlantic		New England & New York	
	% With No Dams	**% With Dams**	**% With No Dams**	**% With Dams**	**% With No Dams**	**% With Dams**
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CHAPTER

Climate Resilience 8

Characteristics and Conservation Status Feb 2023

M. G. Anderson, M. Clark, and A. Olivero

Motivated by declines in biodiversity exacerbated by climate change, The Nature Conservancy has worked with over 287 scientists to identify and map the characteristics and places that provide climate resilient land for species while supporting dynamic shifts in ranges and changes in ecosystem composition. In this chapter, we review those characteristics - representation, site resilience, connectivity, biodiversity value, and carbon – and overlay each map with the 2022 conservation lands to assess the conservation status of each. We end the chapter with a look at where the region stands towards meeting the 2020 America the Beautiful initiative and Global 30 by 30 goals

Climate Resilient Sites: The region's existing conservation lands are already strongly focused on sites with connected microclimates that buffer plants and wildlife from the direct effects of climate change. Conserved forests and wetlands score twice as high for site resilience when compared to unconserved ones, and those on GAP 1 land score higher than 84% of their counterparts in the ecoregion. Lands conserved before 2001 score substantially higher for site resilience than recent conservation lands.

Marsh Migration Space: Tidal marsh is one of our most conserved habitats, but projections suggest we could lose over 75% due to inundation from sea level rise, unless they can migrate landward. Using an independent study that identified 640,000 acres of critical marsh migration space, we found that 37% it is already conserved, as is 61% of the resilient marshes adjacent to the migration space. More conservation, as well as good management is needed to ensure these marshes can migrate.

Connectivity and Flow: As the climate changes, nature is beginning to rearrange. We assessed how the current conservation lands facilitate the flow of nature, using a wall-to-wall analysis to simulate the gradual movement of species in response to climatic gradients across a human-modified landscape. We found forests and wetlands already carried more flow than 69% of the region, and that conserved forests and wetlands had even higher flow density.

Recognized Biodiversity Value: State Wildlife Agencies and The Nature Conservancy have identified and mapped a portfolio of opportunity areas that represent the best places to conserve the regions wildlife, habitats, and other biodiversity. We found that 41% of them are now conserved.

30 by 30, Biodiversity, and Carbon: Scientists and world leaders have challenged us to conserve 30% of the country by 2030 to sustain biodiversity and critical services. In the U.S., over 280 scientists, led by The Nature Conservancy have mapped a national blueprint for such conservation that covers 36% of the northeast. To date, 38% of the network is conserved (19% of the region's area) safeguarding an estimated 1.8 billion metric tons of carbon.

Introduction

The goal of this section is to explore the characteristics of land that build resilience to climate change, assess their distribution in the northeast, and take stock of their conservation status. This section is meant to be used along with The Nature Conservancy's (TNC) Resilient Land Mapping Tool (https://maps.tnc.org/resilientland/) where users can view, and explore the individual datasets, and quantify the properties of places that interest them. Each authoritative dataset can also be downloaded from TNC's Center for Resilient Conservation Science (CRCS) website (https://crcs.tnc.org/). Links to all the published papers and geographic reports appears in Appendix 1. This introduction is extracted from Anderson et al. (2023).

Biodiversity Loss and Climate Change: Over the last decade (2012-2022) it has become alarmingly clear that conservationists are not winning the battle to sustain biological diversity in the US. Despite broad public support and unprecedented bipartisan agreement on Earth Day 1970, followed by landmark environmental laws, expanded regulatory efforts, and the establishment of hundreds of private conservation organizations, the species and ecosystems that characterize our natural world continue to decline. In North America, the abundance of birds has fallen 29% since 1970; 32% of insect taxa are in decline; and 56% of mammalian carnivore and ungulates have shown notable range contractions since 1950 (Rosenberg et al. 2019; Crossley et al. 2020; Liebert and Ripple 2004). Amphibians have declined an average of 33% since 2002 (Muths 2012). Of the 51,936 species of plants, vertebrates, and macroinvertebrates tracked by NatureServe for the conterminous United States, 9% are ranked vulnerable, 12% imperiled, and 1% possibly extinct (NatureServe 2022).

Changes in climate are exacerbating species declines, especially for small, isolated populations. As temperature and moisture regimes change, species ranges are shifting with speed and magnitude unprecedented in recent millennia. In the eastern United States, trees have shifted their centers of distribution 10 km north and 11 km west per decade since 1980. Southern bird ranges have shifted northward by an average of 23.5 km per decade (Fei et al. 2017). These changes are on par with global shifts of 10 km north and 11 m upslope per decade across taxa groups (Chen 2011). While the adaptive strategy of moving has worked in ancient times of rapid climate change, the modern landscape is heavily fragmented by roads, development, industrial agriculture, commercial forestry, and energy infrastructure, making it difficult for species populations to move and find new suitable habitat.

Land and water conservation efforts have the capacity to reverse these trends when strategically located and enabled by the necessary investments. In North America, billions of dollars spent on wetland restoration and management, combined with more stringent hunting regulations, have reversed bird-abundance declines in wetlands (Rosenberg et al. 2019). Globally, conservation investment from 1996 to 2008 reduced the extinction risk for mammals and birds by a median value of 29% (Brondizio 2019). However, as climate change drives changes in species distributions and ecosystem composition, conservation plans based on current biodiversity patterns may become less effective at sustaining species. In particular, the current configuration of protected areas may fail to adequately provide access to the diverse climatic conditions needed for species populations to persist amid changing regional climates and to the connections needed for nature to rearrange.

In recognition of these twin crises, the Convention on Biological Diversity (CBD 2020) Target 2 calls for the global protection of well-connected and effective systems of protected areas covering at least 30% of the planet and focused on biodiversity. Similarly in the United States, the Biden-Harris Administration has launched America the Beautiful, a call to work together to conserve, connect, and restore 30 percent of our lands and waters by 2030, not only for nature but for the sake of our economy, our health, and our well-being (Biden Administration 2021). These initiatives inspire people to act and challenge us to coordinate our actions to conserve nature and maintain a habitable planet.

From a science perspective, the key to sustaining biodiversity lies not in the 30%, although that number gets all the attention, but in the basic principles expressed in the CBD language as a representative, well-connected, effective, and biodiverse network.

Climate Resilience and Conservation

Conservation: The Northeast region has a long history of public and private conservation. In this section we assess the relationship between climate resilience factors and conservation land by overlaying the 2022 TNC conserved lands dataset (described in the Conservation Lands chapter) on maps of resilience factors:

- Site Resilience
- Marsh Migration Space
- Connectivity and Flow
- Recognized Biodiversity
- Resilient & Connected Network
- Carbon

For each section we explain the significance of the concept to resilience, explain our data sources and analysis, and review the results. Terminology for the conservation lands is shown in the box on the right.

Conservation Land Terminology

Conserved (GAP 1-3): The land is permanently secured against conversion to development.

Conserved for Nature (GAP 1): The land is conserved for nature and natural processes.

Conserved for Nature (GAP 2): The land is conserved for nature with management.

Conserved for Multiple Uses (GAP 3): The land is secured AND the intent of the management is for multiple uses, including forest management. This land may provide implicit conservation value such as connectivity or providing stream buffers.

CRI = Conservation Risk Index = %Conv / %GAP1-3

NRI = Nature Risk Index = % Conv / %GAP 1-2

Site Resilience

Site resilience is the capacity of a site to support biological diversity and ecological functions even as the biotic composition changes in response to climate change (Anderson et al. 2014). If adequately conserved, resilient sites are expected to sustain their species and communities for a longer time, and have a slower turnover rate, than less resilient sites.

As climate change drives rapid shifts in species distributions, land and water conservation based on current biodiversity patterns may become less effective in sustaining diversity. Resilient sites are places where microclimatic buffering allows species to persist longer, utilizing local climatic variability, slowing the rate of turnover, and helping species flourish under a changing climate. These natural strongholds also improve connectivity because thriving populations create dispersal pressure, the engine that powers movement across the landscape. The characteristics that create climatic options are features of the land (topography, aspect, hydrology, elevation), which ensures that that site will benefit biodiversity under many future climate scenarios.

Assessing Site Resilience

We used the TNC resilience data which estimates a site resilience score for every 30 m cell in the region as a function of **landscape diversity** that creates persistent microclimates, and **local connectedness** that ensures access to the microclimates (Map 8.1). Detailed methods on how these factors were mapped and integrated into a resilience score may be found in Anderson et al. 2014. Anderson et al. 2023, Anderson et al. 2012). You can explore and download the data on TNC's Climate Resilience webiste.

Landscape Diversity: Resilient sites are those that provide resident species the maximum opportunity to respond on-site to climate change and slow down the rate of change and transition as new species arrive and establish. Evidence continues to grow that spatial heterogeneity in microclimates creates such opportunities and represents an important buffer for species in response to climate change (Weiss et al. 1988; Willis and Bhagwat 2009; Dobrowski 2010; Suggitt. et al. 2018). As precipitation and temperature patterns change, organisms disperse along moisture and temperature gradients, to stay within their preferred climatic regimes. Having a greater diversity of microclimates, resilient sites are likely to offer microsites that species find suitable for establishment and growth. Thus, the variety of microclimates present in a landscape is positively correlated with the capacity of the site to maintain species. Landscape diversity was modeled from a 30 m landform model using topography, elevation, land position, slope, aspect, moisture accumulation, and existing wetlands,

Local Connectedness: The local connectedness metric is a measure of the hardness of barriers, the connectedness of natural cover, and the arrangement of land uses, summed into an integrated metric (Anderson et al. 2014). It is not species specific but defined by the permeability of the landscape measured as the degree to which regional landscapes, encompassing a variety of natural, semi-natural, and developed land cover types, will sustain ecological processes and are conducive to the movement of many types of organisms (Meiklejohn et al. 2010). Local connectedness was modeled using a resistance grid created from 30 m spatial information on roads, powerlines, energy infrastructure, industrial forest, commercial agriculture and more, with each feature assigned a weight reflecting its relative resistance to the movement of native wildlife and plants.

The two metrics were assessed separately and then combined equally into a resilience score (Map 8.1).

Map 8.1. Site Resilience. The map shows the areas in the region that have the most connected microclimates relative to their ecoregions and geophysical setting.

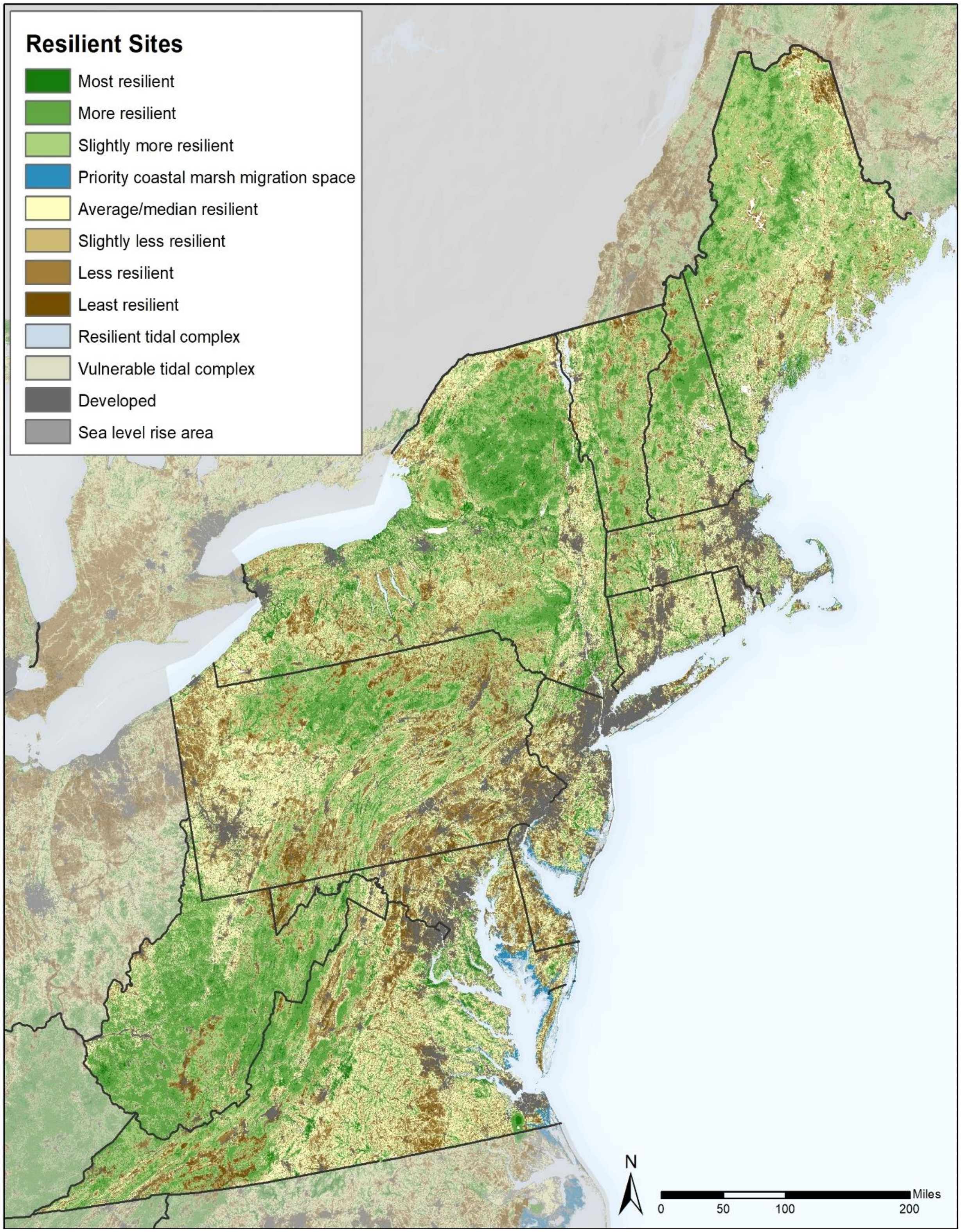
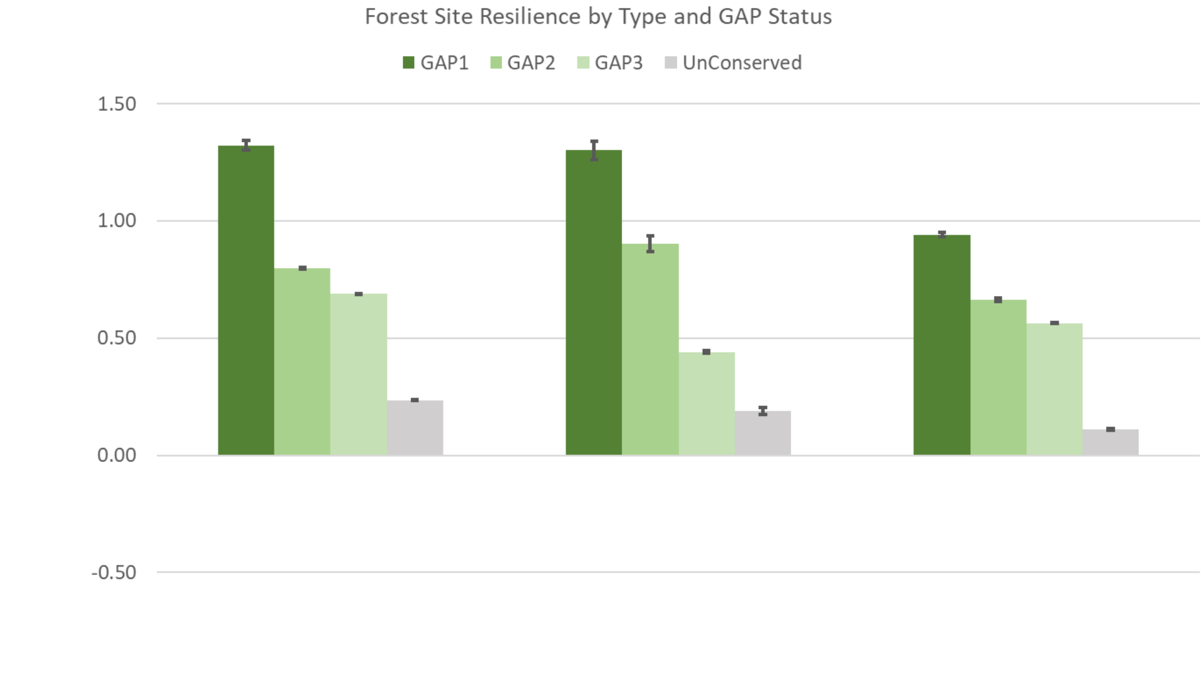


Figure 8.1. Site Resilience by Forest Type and GAP status. The chart shows the average resilience score for each forest type within each class of conservation land (See Forest Chapter). Scores are in standard deviations relative to the mean score of the ecoregion where the forest occurs.



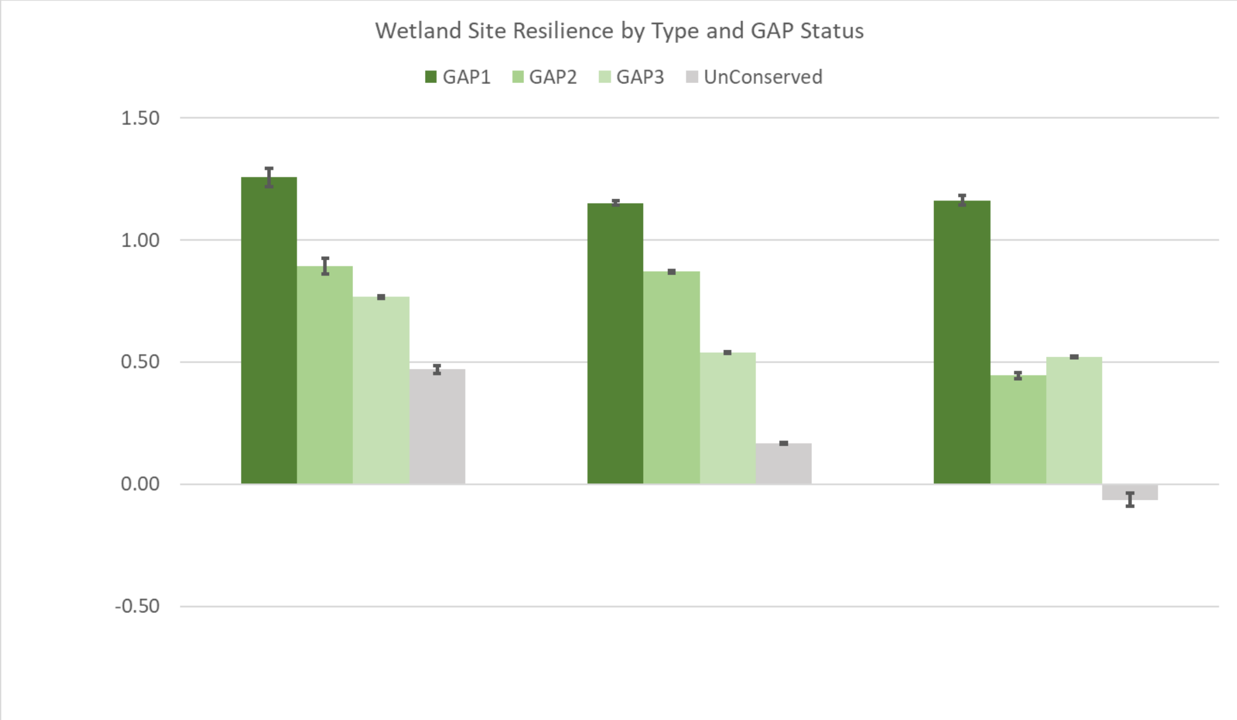
	Northern Hardwood and Conifer Forests	Boreal Upland Forest	Central Oak Pine Forest
GAP1	1.32	1.30	0.94
GAP2	0.80	0.90	0.66
GAP3	0.69	0.44	0.56
UnConserved	0.24	0.19	0.11

Looking only at unconserved forest (grey columns), all three forest types had mean resilience scores slightly higher than the average for the region (Figure 8.1): Northern Hardwood (0.24 SD), Boreal Upland (0.19) and Oak-Pine (0.11). Forests on conservation land scored considerably better for resilience, with those on GAP 1 scoring higher than 84% of the region (>1 SD). GAP 3 multiple use lands scored lower but were still above 69% of the region (> 0.5 SD). GAP 2 were intermediate.

Wetlands showed a very similar pattern (Figure 8.2). For unconserved wetlands (grey), alluvial wetlands scored considerably higher than other types (>0.5 SD), probably reflecting their characteristic setting adjacent to flowing streams and rivers. Woody basin wetlands scored close to the average for the region, and emergent wetland scored a little below average (-0.06 SD). Although basin wetlands are low in topographic diversity, they make up for it by collecting and storing water, a moderator of local climate.

Wetlands occurring on conservation land scored considerably higher, with those on GAP 1 scoring well above 1 SD and better than 84% of the region. Wetlands on GAP 3 multiple use lands scored lower but still above 69% of the region (> 0.5 SD) while wetlands on GAP 2 land scored intermediate between GAP 1 and GAP 3.

Figure 8.2: Site Resilience by Wetland Type and GAP status. The chart shows the average resilience score for each wetland type within each class of conservation land. Scores are in standard deviations relative to the mean score of the ecoregion where the wetland occurs.

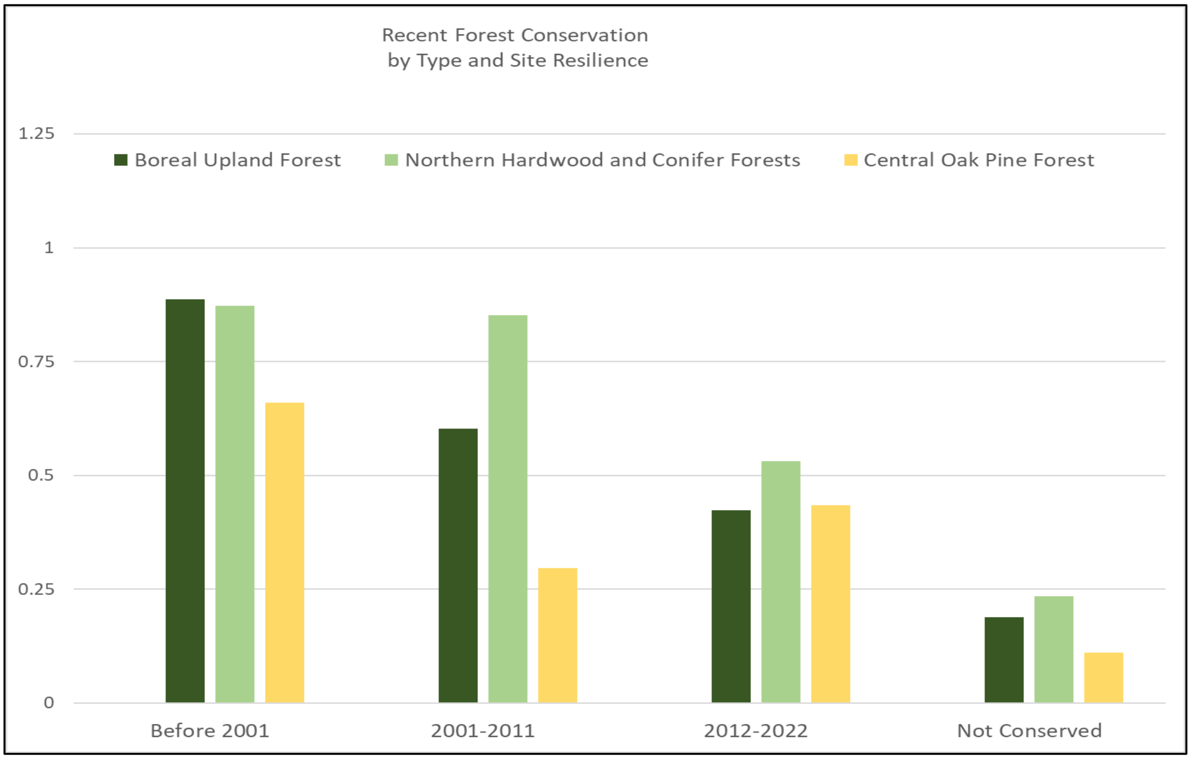


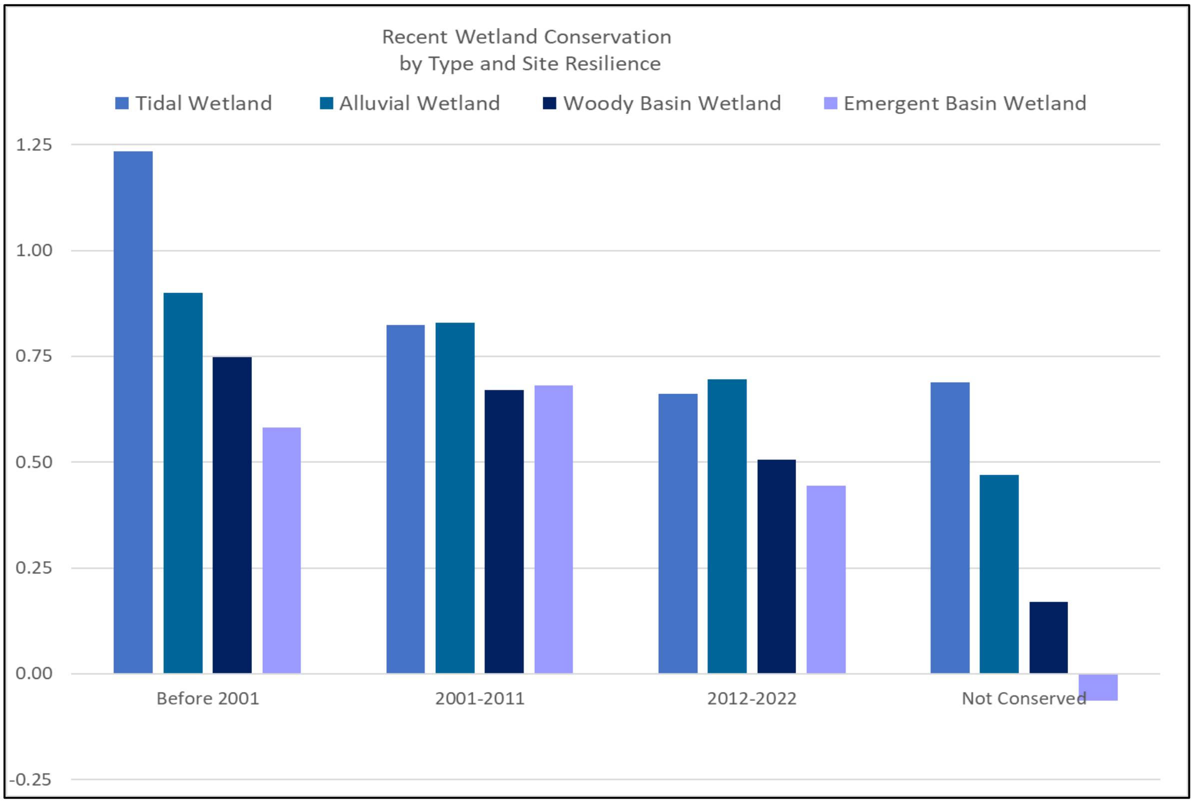
	Alluvial Wetland	Woody Basin Wetland	Emergent Basin Wetland
GAP1	1.26	1.15	1.16
GAP2	0.89	0.87	0.45
GAP3	0.77	0.54	0.52
UnConserved	0.47	0.17	-0.06

The higher resilience scores for conserved forest and wetland reflected both higher landscape diversity and greater connectedness. Landscape diversity scores consistently from GAP1 to unconserved (0.72 to -0.04 SD for forest, 0.73 to 0.25 SD for wetland.) Local connectedness which also decreased consistently from GAP 1 to unconserved (1.65 to 0.31 SD for forest, 1.68 to 0.19 SD for wetland). As the local connectedness scores spanned a greater range, they account for most of the variation in resilience scores. The results suggest that conservation has preserved, maintained, or improved the local connectedness of forests and wetlands boosting their resilience.

It is hard to determine if conservation lands continue to rank higher for resilience because they were selected for better condition and more microclimatic diversity, or if they have improved in resilience from being conserved. As an ecosystem matures or recovers from disturbance it becomes more connected, and its local connectedness score can increase. Looking across time, there is unequivocal evidence that recently conserved conservation lands score lower for site resilience than the older ones, and this pattern is apparent in both terrestrial and wetland conservation lands (Figure 8.3). Compared to the unconserved land, recent forest conservation lands still score higher on average (0.46 SD vs 0.18 SD), but not as high as last decades (0.58 SD) and only half as high as conservation before 2001 (0.81 SD). Wetlands show the same trend suggesting that conservation lands improve over time, or conversely that the overall landscape has degraded over time. Likely is it a little of both.

Figure 8.3: Resilience Score and Conservation Year. These charts show the relationship between resilience score and when the conservation took place for both forest (upper) and wetland (lower) habitats.





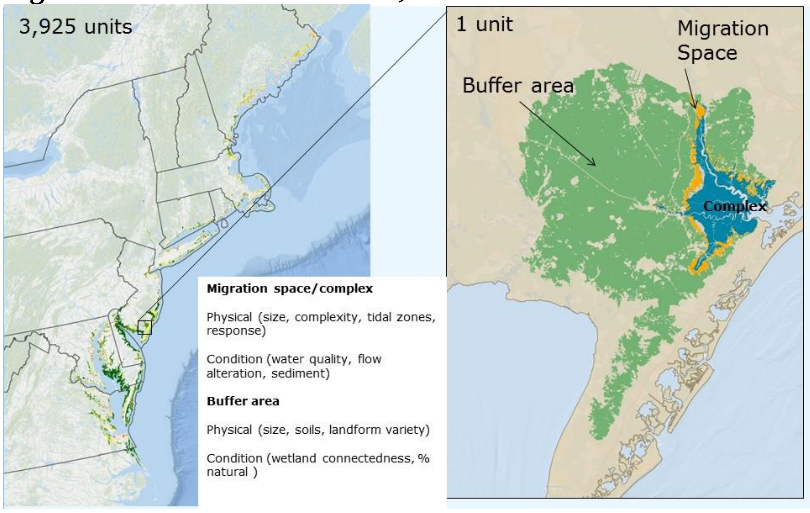
Tidal Wetland and Migration Space

Climate change threatens to alter the ecology of coasts in the Northeastern US. Rising sea levels combined with changing temperature and precipitation regimes threaten to rearrange or destroy habitat and creates novel conditions for the fish and wildlife that inhabit the coastal zone. For this reason, we assessed tidal wetland separately using different data sources.

Coastal areas provide critical habitat for wildlife and are home to more than 40 percent of the U.S. population, but sea levels are rising, and coastal sites vary widely in their ability to accommodate such change. The Nature Conservancy in partnership with 35 scientists from USFW, NOAA, and State Agencies evaluated over 3,000 coastal sites along the Atlantic Seaboard for their capacity to sustain biodiversity and natural services under increasing inundation from sea level rise. Each site received a resilience “score” based on the likelihood that its coastal habitats can and will migrate to adjacent lowlands. A coastal site was considered more resilient if it had more options for adapting to, or accommodating risk, and more vulnerable if it had less options.

Areas with the right combination of characteristics (Figure 8.4) should support native species longer by offering more climatic options to current occupants. Conservation of these resilient sites is critical if we are to sustain nature’s diversity and benefits into the future.

Figure 8.4. Distribution of the 3,925 coastal units and zoom-in of a single unit.



We overlaid TNC’s Northeast Resilient Coastal Sites dataset with the 2022 conservation lands data to evaluate how well we have conserved resilient marshes and their migration space.

Details on the mapping methods, analysis, and web tools can be found below:

- Northeast: Resilient Coastal Sites for Conservation: Report
- Northeast Resilient Coastal Sites – Strategy Map
- Northeast: Resilient Coastal Sites – Web Map
- Northeast: Resilient Coastal Sites for Conservation - Website

Map 8.2. Resilient Coastal Sites. This map shows a zoom-in for Delaware and Chesapeake Bay, two areas that support a lot of resilient tidal marsh with ample marsh migration space.

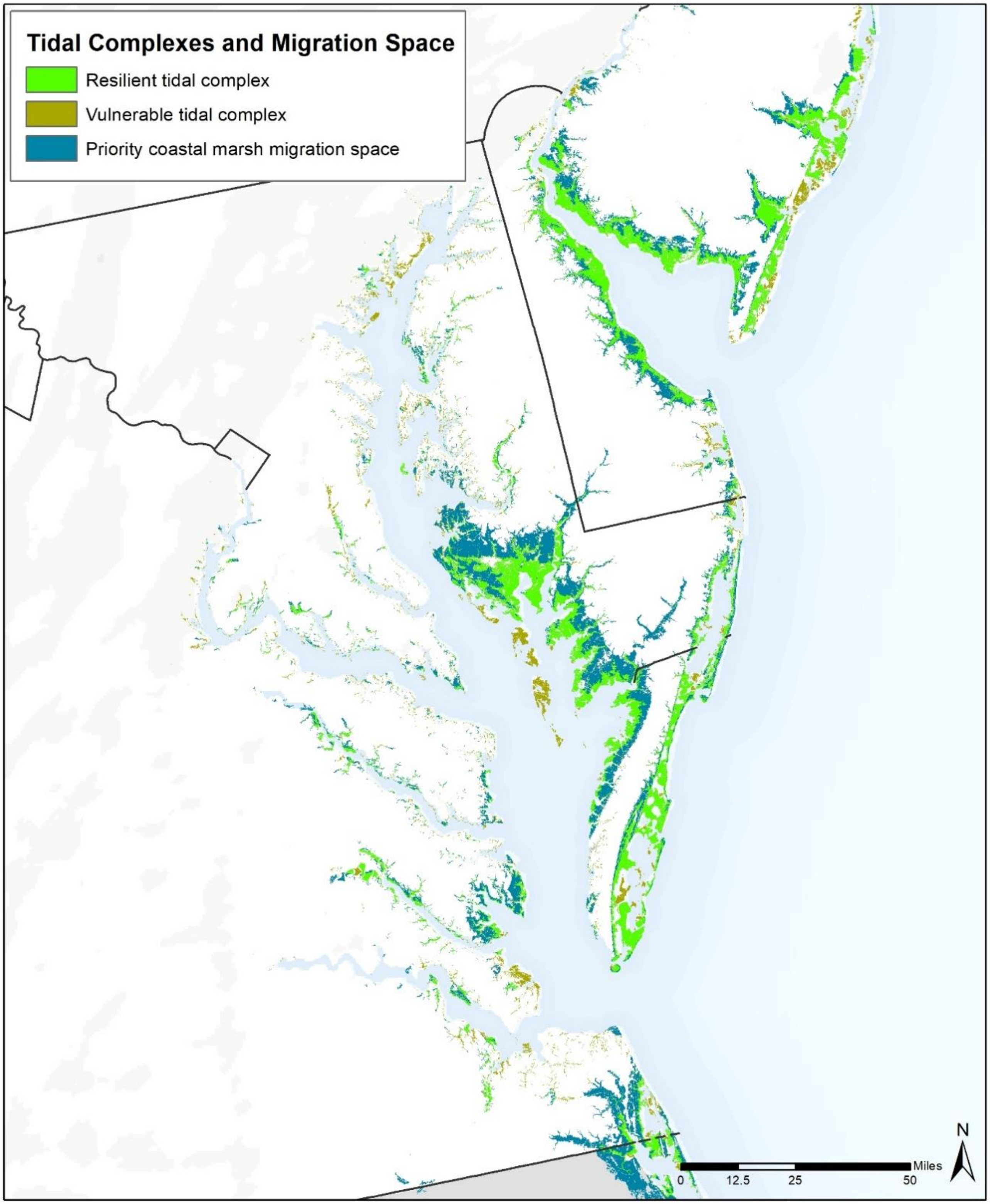
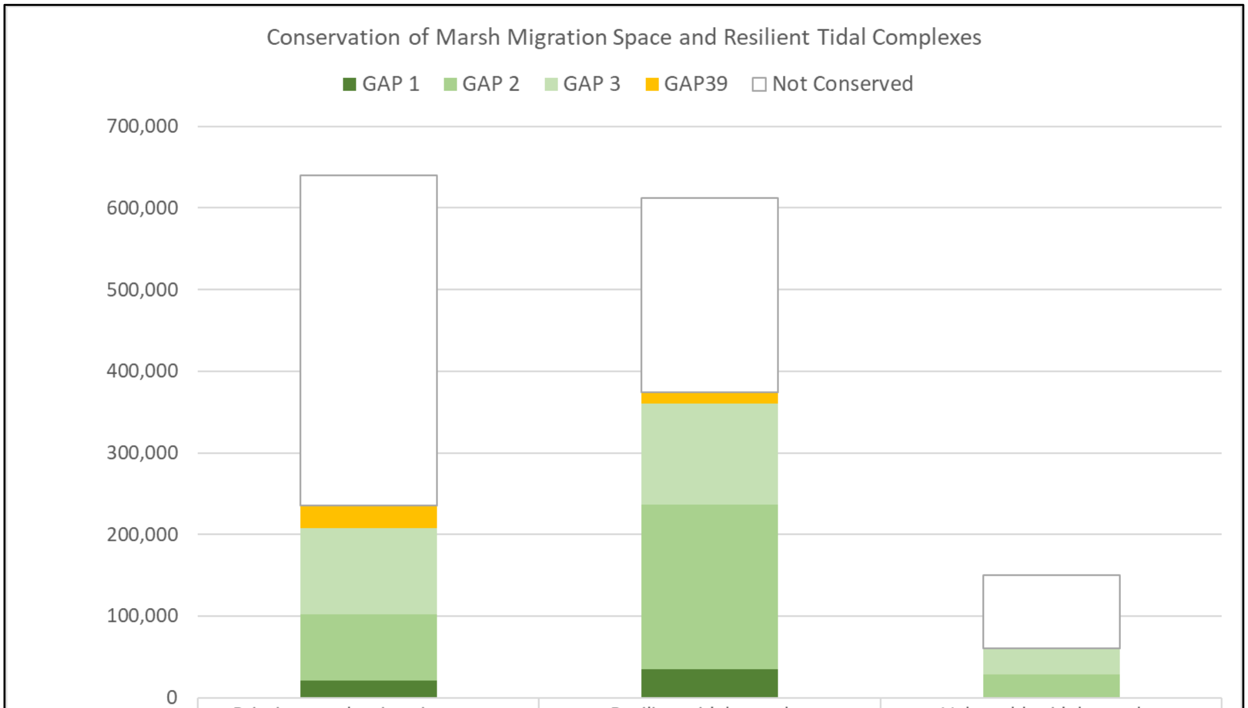


Figure 8.5: Resilient Coastal Sites and Conservation. The chart shows the amount of conversation land for three critical features: 1) Priority Marsh Migration Space: physically suitable land adjacent to an existing tidal marsh that is likely to facilitate and support new marsh in the future as sea levels rise. 2) Resilient tidal complexes: marshes with ample adjacent priority migration space. 3) Vulnerable tidal complexes: tidal marsh systems that do not have adjacent migration space and are likely to diminish as sea level rises. GAP 39 land is a subtype of GAP 3 multiple use land that is focused on farmland.



	Priority marsh migration space	Resilient tidal complex	Vulnerable tidal complex
Not Conserved	404,678	238,411	89,316
GAP39	27,648	14,316	868
GAP 3	105,953	122,955	31,357
GAP 2	80,621	202,192	27,150
GAP 1	21,433	34,903	1,087

The resilient coasts study (Anderson and Barnett 2017) found that with no action, the region could see an estimated 83% loss of existing tidal habitats to severe inundation, yet there are thousands of individual sites where tidal habitats could increase and expand through landward migration, reversing this trend. With conservation and proper management, these resilient sites could offset over 50% of tidal habitat loss, providing critical habitat for wildlife, and buffering people from the effects of storms and floods.

Results of our overlay indicate that the Northeast has 640,000 acres of priority migration space, of which 37% is already conserved (Figure 8.5). This is good news. Tidal marsh is the Northeast's most conserved habitat, but it was uncertain whether we had conserved the critical adjacent migration space that will allow marshes to adapt rising sea levels. The resilient tidal marshes associated with this migration space (middle column) are also well conserved with 61% under some form of conservation. There are also vulnerable sites under conservation (40%) but this is not necessarily a bad thing. Although the vulnerable marshes will likely contract over time, they may still provide suitable habitat for many years for species like salt marsh sparrow as new marsh forms.

Connectivity and Climate Flow

In conservation terms, connectivity refers to actions that maintain or increase the permeability of the landscape allowing species to move and facilitating the rearrangement of ecosystems. Species move to find resources both daily for food and water, and seasonally in migrations that follow changing resources. Adolescents disperse to establish new territories and find mates, and adults move when existing habitat becomes unsuitable. Climate flow refers to connectivity across climate gradients that are most likely to facilitate adaptive movements in response to changing climatic conditions.

Climate change is an ambient change in the condition of the Earth, particularly the temperature and moisture regimes that limit the distribution of many species. In response to new conditions, most species move, leading to changes in community composition or the rearrangement of whole ecosystems. Species persisted under past climatic changes through in situ refugia combined with range shifts to track suitable climates (Gill et al. 2015; Jackson and Overpeck 2000; Krosby et al. 2010). Rapid warming projected for the next century will likely require many species to adapt in a similar way (Moritz and Agudo 2013; Thuiller et al. 2005; Nunez et al. 2013), and many species' ranges are already shifting (Chen et al. 2011; Hitch and Leberg 2007). However, high levels of habitat loss and fragmentation due to anthropogenic activities are isolating populations and creating barriers to species movement that were not present during past periods of rapid climate change (Thomas et al. 2004; Peters and Darling 1985; Corlett and Westcott 2013). Protecting connectivity is essential for effective conservation under climate change, as connectivity facilitates movement and gene flow, bolstering adaptive capacity by maintaining genetic diversity (Hoffmann and Sgro 2011; Sgro et al. 2011; McRae and Beier 2007).

Assessing Connectivity and Climate Flow
We used the TNC Connectivity and Climate Flow dataset which maps the gradual movement of species in response to climatic gradients across a human-modified landscape (Map 8.3, Anderson et al. 2023). The dataset modeled movement potential as a continuous surface based on degree of human modification and geographical climatic gradients using a minor adaptation of the software program, Circuitscape (Shah and McRae 2008). The software models movement as if it was electric current flowing across a surface of mixed resistance which allows for the creation of wall-to-wall connectivity maps that emphasize variations in the density of current flow corresponding to variations in resistance by barriers and roads.

You can view, map, and download the data on TNC Climate Resilience website.

Methods are described in detail in: Anderson, M.G., Barnett, A., Clark, M., Prince, J., Olivero Sheldon, A. and Vickery B. 2016. Resilient and Connected Landscapes for Terrestrial Conservation. The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA.

Approach**:** This approach was first developed through a shared grant from USFW North Atlantic LCC. Anderson, M.G. Clark, M. and McRae, B.H. 2015. Permeable Landscape for Climate Change. The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA.

The work was guided by a literature review: Maintaining a Landscape that Facilitates Range Shifts

Map 8.3. Connectivity and Climate Flow. This map was created using wall-to-wall Circuitscape to model the gradual movement of species in response to climatic gradients across a human-modified landscape. Areas in dark blue have the highest flow, which may indicate a concentration area or pinch point important for conservation.

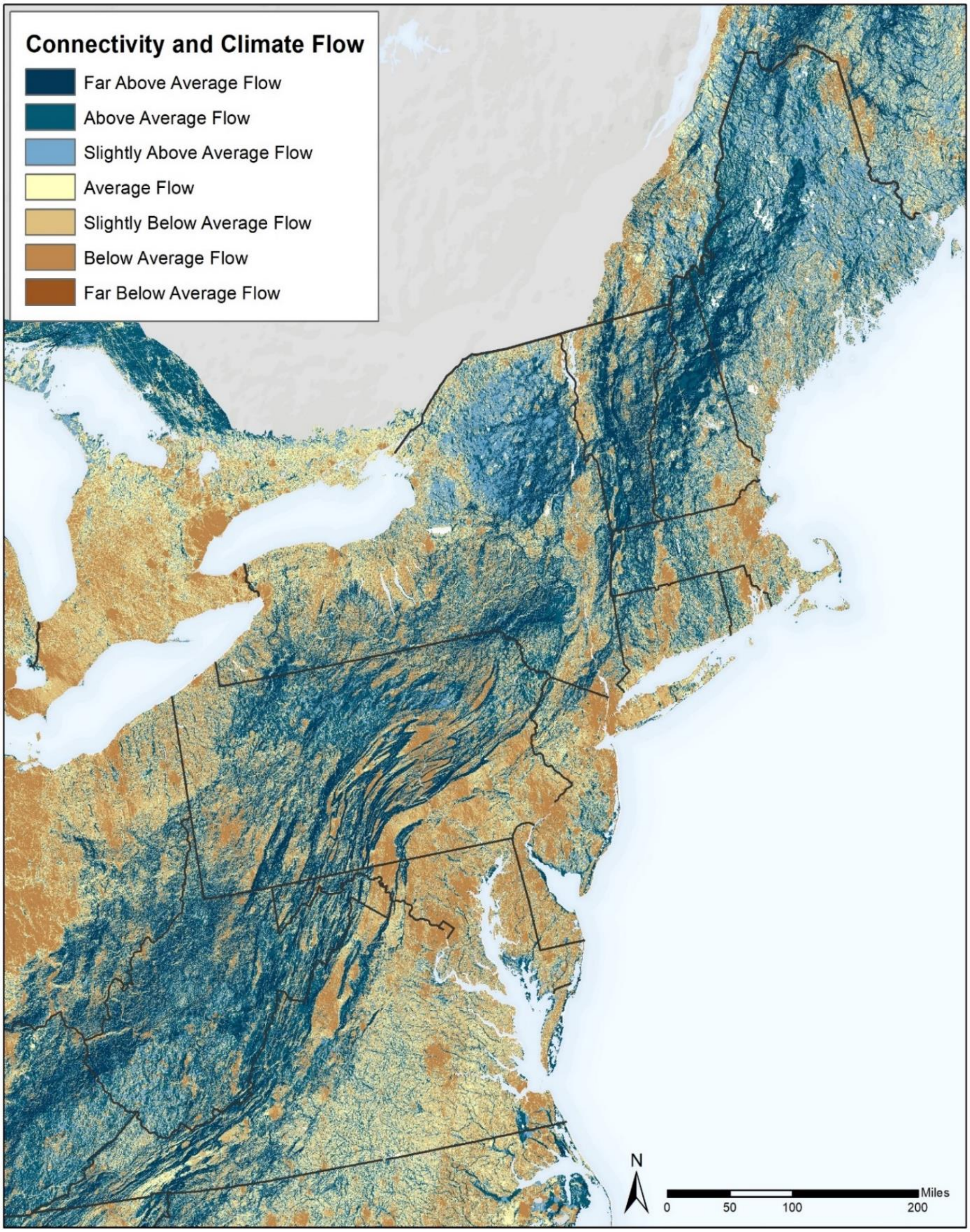
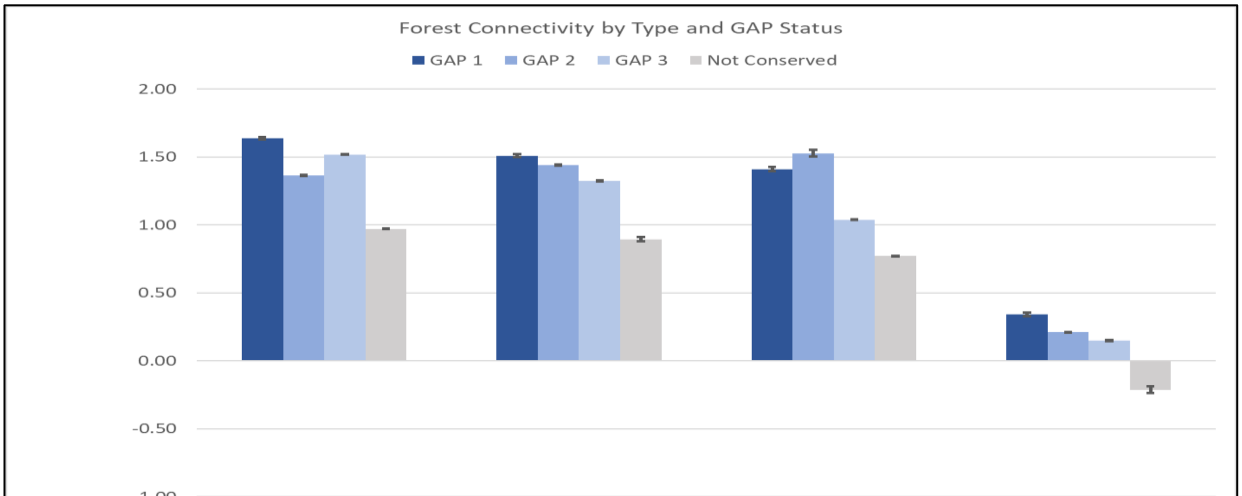
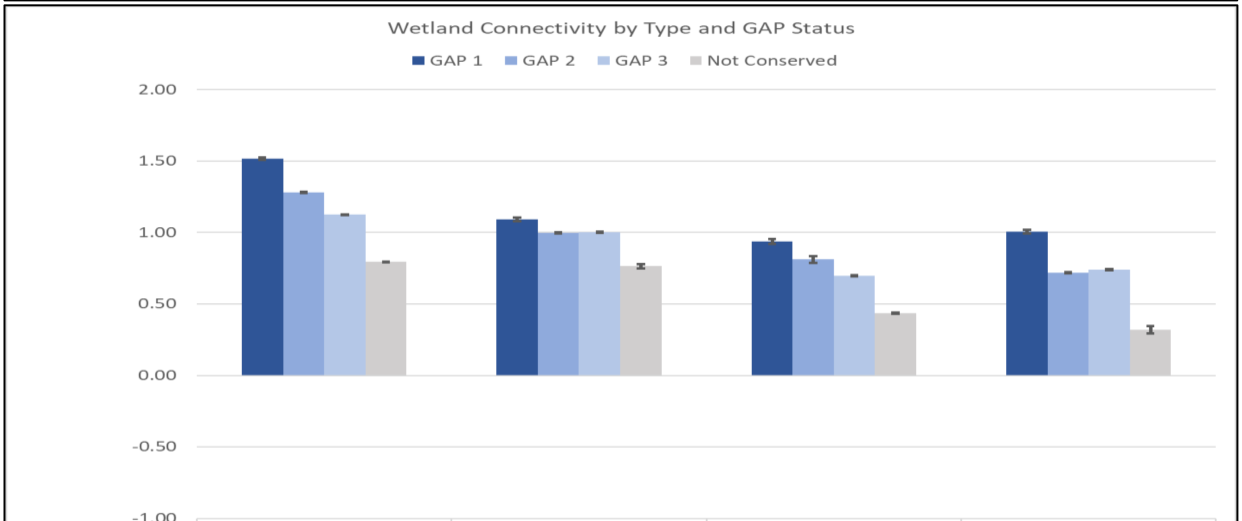


Figure 8.6: Regional Flow by Forest/Wetland Type and GAP Status. These charts show average amount of climate flow per forest or wetland type. Flow patterns are fundamentally spatial. Interpreting them statistically can be challenging because high flow usually indicates channeled and concentrated flow while average flow can be equally high but more diffuse as through a intact landscape.



	Central Oak Pine Forest	Northern Hardwood and Conifer Forests	Boreal Upland Forest	Plantation
GAP 1	1.64	1.51	1.41	0.34
GAP 2	1.36	1.44	1.53	0.21
GAP 3	1.52	1.32	1.04	0.15
Not Conserved	0.97	0.89	0.77	-0.21



	Tidal Wetland	Alluvial Wetland	Woody Basin Wetland	Emergent Basin Wetland
GAP 1	1.52	1.09	0.94	1.01
GAP 2	1.28	1.00	0.81	0.72
GAP 3	1.13	1.00	0.70	0.74
Not Conserved	0.79	0.76	0.43	0.32

Results of the overlay of conservation lands on the flow map (Figure 8.6) suggest that conservation lands tend to have more connectivity and facilitate more climate flow than unconserved land, and flow density correlated with GAP status. Forest tended to have slightly more flow (1.4 SD) than wetlands (0.99 SD) but the differences were not dramatic. Oak-pine forest, had the highest flow among forest types, which likely reflects its being the most intact natural cover in a landscape of mixed fragmentation.

Biodiversity Value

Biodiversity refers to the totality of biological life on earth in all its organized forms: species, communities, and ecosystems (Norse and McManus 1980). Collectively, biodiversity underlies all the earth's life processes and cycling of organic materials. Living plants produce the oxygen we breath, chemicals for medicine, materials for building, and by extracting carbon from the air, they create the sugars, carbohydrates, and fats that form the base of Earth's food webs. Ancient plants and algae are the base of coal and petroleum. Insects, birds, and bats pollinate our crops and are responsible for the colors of flowers. Fungi and invertebrates decompose waste and recycle nutrients, building the healthy productive soils and clean water we need.

In conservation, recognized biodiversity value is usually measure of the quality and condition of wildlife and habitats for their intrinsic worth, such as a viable species population, high quality habitat for breeding, or an intact and compositionally complete example of a community or ecosystem.

Measures of site resilience and connectivity have become integral to identifying places for maintaining nature's dynamics, but to sustain biodiversity, a conservation network must also include sites that support living biotic assemblages of sufficient quality to persist. This includes high-quality ecosystems, communities, and species to ensure that any conservation network is embedded with elements of biodiversity that provide the capacity to adapt.

To identify areas recognized for their biodiversity value, we compiled data from 104 published assessments from two main sources: TNC Ecoregional Assessments and State Wildlife Action Plans (Map 8.4). TNC's portfolio of biodiversity sites was developed through separate ecoregional assessments completed between 1999 and 2010. Each assessment developed a comprehensive list of targets for the ecoregion consisting of rare or specialist species and characteristic natural communities. Natural Heritage Program element occurrences were used to identify multiple locations of each target, and viability criteria were used to rank each occurrence. Representation goals were set based on the distribution, rarity, and spatial pattern of the targets. A spatial portfolio of sites was identified for each ecoregion that aimed to meet representation goals for all viable target occurrences. This resulted in a set of sites that, if conserved, would collectively protect the biological diversity of the ecoregion. The portfolio datasets have a high degree of consistency, as the target lists and sites were reviewed by knowledgeable experts.

We also incorporated sites recognized in 38 state-based wildlife and habitat assessments. The majority were Conservation Opportunity Areas (COAs) mapped as part of each state's Wildlife Action Plan, but where COAs had not been mapped, we also compiled comparable state-wide assessments if they were spatially explicit and had clearly defined terrestrial targets. The state datasets varied widely in terms of conservation targets and expansiveness. Some COAs were identical to the TNC portfolio, while others incorporated different priorities identified through multiple assessments with their own objectives and methods. Most COAs focused on nongame animal species and habitats.

We integrated these two sources into a single map showing which source they were derived from and where they overlap (Map 8.4). Lists of targets are available for each site from the original source reports or TNC data. For this section we overlaid the 2022 conservation land data on the biodiversity map to assess the status of the biodiversity sites.

Map 8.4. Recognized Biodiversity Value.

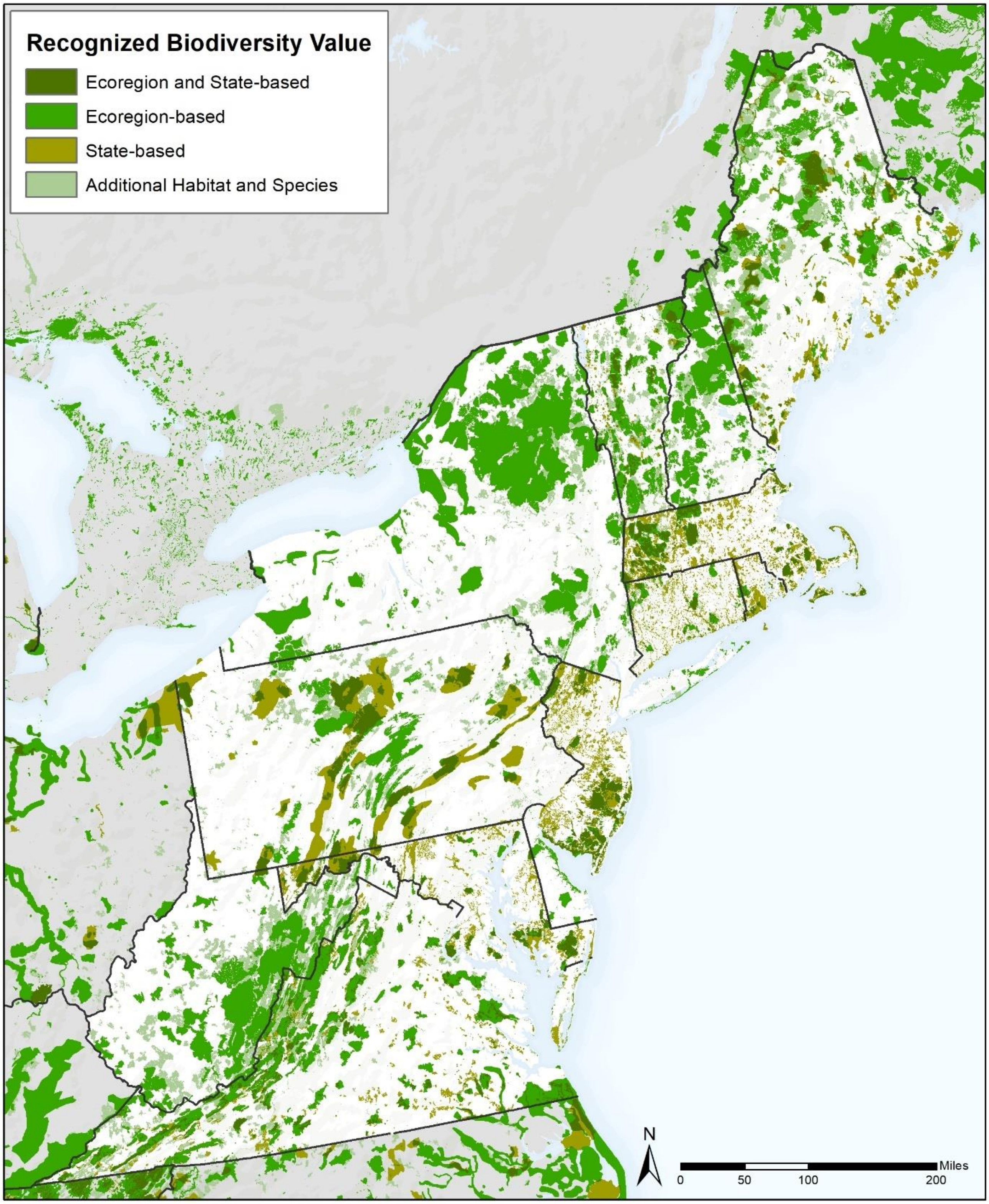
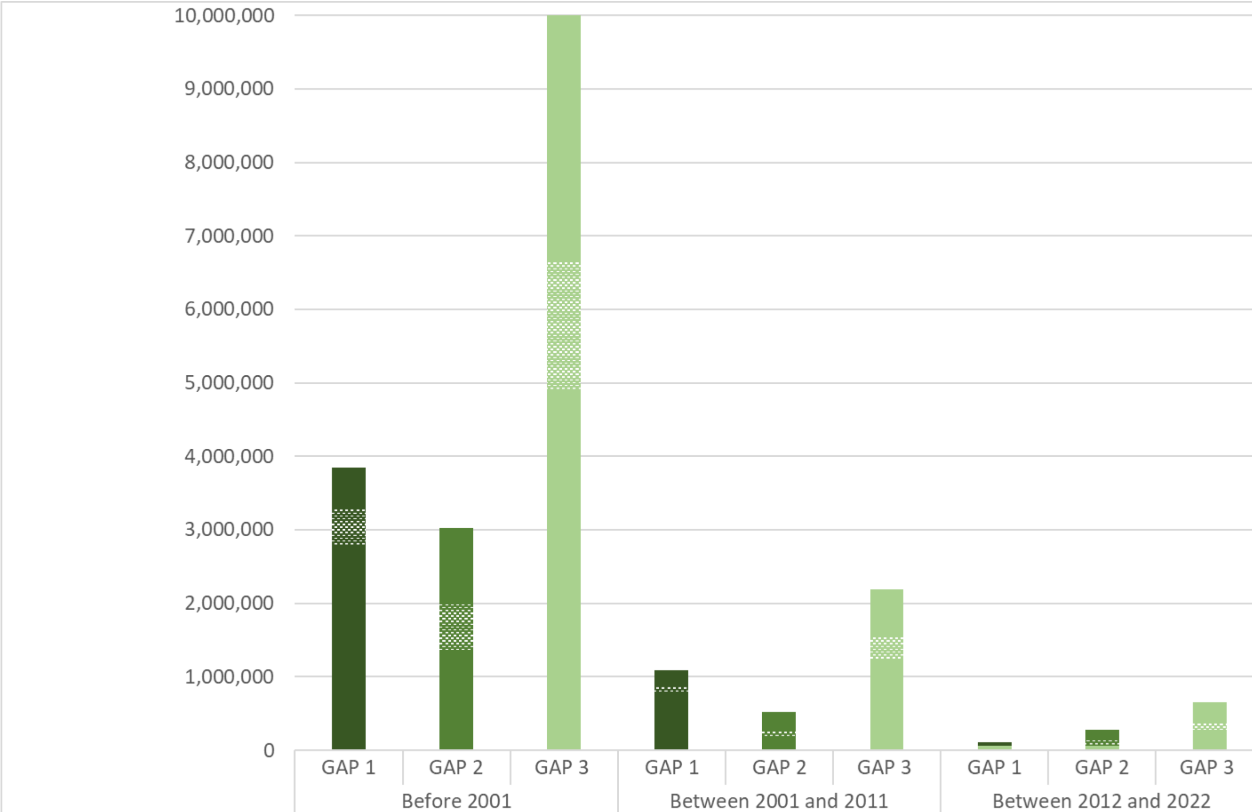


Figure 8.7. Conservation of Biodiversity Areas by GAP status and Decade. The bar show the amount of conservation of biodiversity site were achieved each decade and before 2001. The upper half of the bar corresponds to state-based sites and the lower half to ecoregional sites. The hatched area in the middle shows where the sites overlap



	Before 2001 GAP 1	Before 2001 GAP 2	Before 2001 GAP 3	Between 2001 and 2011 GAP 1	Between 2001 and 2011 GAP 2	Between 2001 and 2011 GAP 3	Between 2012 and 2022 GAP 1	Between 2012 and 2022 GAP 2	Between 2012 and 2022 GAP 3
State-based	566,278	1,034,748	3,506,592	224,363	251,795	660,308	29,301	148,400	278,294
Ecoregion and State-Based	476,084	628,170	1,732,480	77,025	101,390	298,453	20,759	72,694	96,046
Ecoregion-based	2,801,059	1,366,934	4,912,769	792,346	166,967	1,235,689	56,631	60,378	283,923

Almost 22 million acres of conservation has occurred on land recognized for its biodiversity value, including 50% of the conservation achieved in the last decade. Most of the conservation was achieved through multiple use land but together GAP 1 and 2 collectively total about 40% of each time-period, and that ratio has stayed relatively consistent (41%, 42%, 37%).

Resilient and Connected Network

"Ensure that at least 30 percent globally of land areas…especially areas of particular importance for biodiversity and its contributions to people, are conserved through *effectively and equitably managed, ecologically representative, and well-connected systems* of protected areas and other effective area-based conservation" - *Convention on Biological Diversity (CBD 2030 Target 2)*

Motivated by declines in biodiversity exacerbated by climate change, The Nature Conservancy identified a network of conservation sites designed to provide resilient habitat for species while supporting dynamic shifts in ranges and changes in ecosystem composition. The 12-year effort to identify and map the network involved 289 scientists in 11 geographic regions and all 50 states. The results identify 34% of the conterminous US and represents all habitats. The intent was to support local, regional, and national-scale conservation decisions in conserving biodiversity. The methods and results for the conterminous U.S. were published in the Proceedings of the National Academy of Science (Anderson et al. 2023, Map 8.6). The supporting science has been published in five peer-reviewed scientific journal articles and 11 geographically specific reports (Appendix 1).

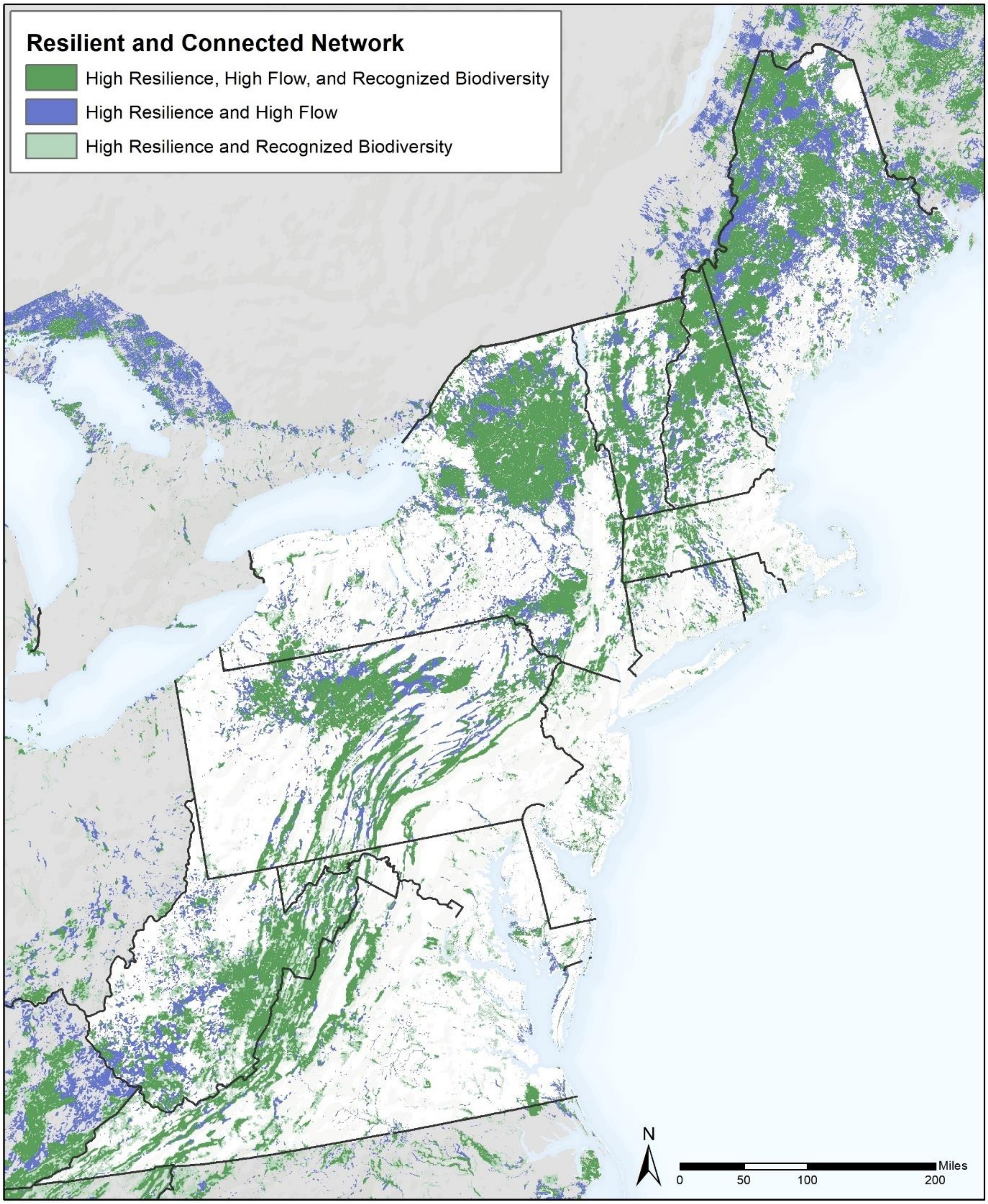
America the Beautiful and 30 by 30

In 2019, nineteen prominent scientists challenged the world to forge a Global Deal for Nature (GDN) in a landmark paper that advanced a science-driven plan to save the diversity and abundance of life on Earth (Dinerstein et al. 2019). The GDN targets 30% of Earth to be formally protected by 2030, plus an additional 20% designated as climate stabilization areas to ensure the temperature change stays below 1.5°C. The authors argue that pairing the GDN and the Paris Climate Agreement would avoid catastrophic climate change, conserve species, and secure essential ecosystem services. In the U.S. the Biden-Harris Administration's America the Beautiful initiative called for the country to work collaboratively to conserve and restore the lands, waters, and wildlife that support and sustain the nation, and to pursue the first-ever national conservation goal – a goal of conserving 30 percent of US lands and waters by 2030 (Biden Administration 2021).

To date, the 30 by 30 calls have not gotten into the specifics of *where*, but for the initiative to sustain the county's wildlife and plants under a changing climate, the places matter. TNC's Resilient and Connected Network can serve as a blueprint for this work because it integrates the key principles of conservation science with the characteristics of resilience and connectivity into a single network. Specifically:

- **Representation**: Sites representing an ecologically meaningful portion of every ecoregion distributed across geophysical settings
- **Site Resilience**: Sites with a high diversity of connected topoclimates linked by natural cover and accessible to species (Map 8.1)
- **Connectivity** and Climate Flow: Sites positioned along climatic gradients within areas of low human modification (Map 8.2 and 8.3)
- **Recognized Biodiversity Value**: Sites supporting biotic assemblages characteristic of their geophysical setting (Map 8.4)
- **Carbon**: The network in the Northeast contains over 4.2 billion metric tons of forest carbon, 51% of the region's carbon (Map 8.7)

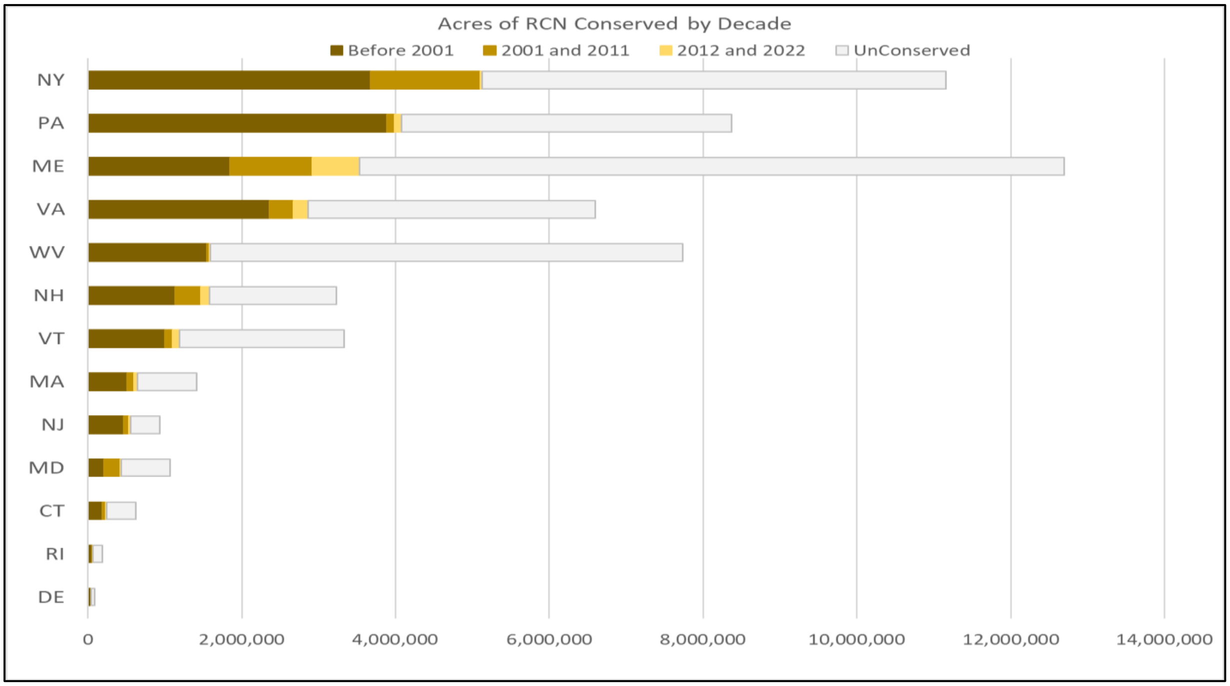
Map 8.5. Resilient and Connected Network The network covers 36 % of the northeast and is designed to provide resilient habitat for species while supporting dynamic shifts in ranges and changes in ecosystem composition.



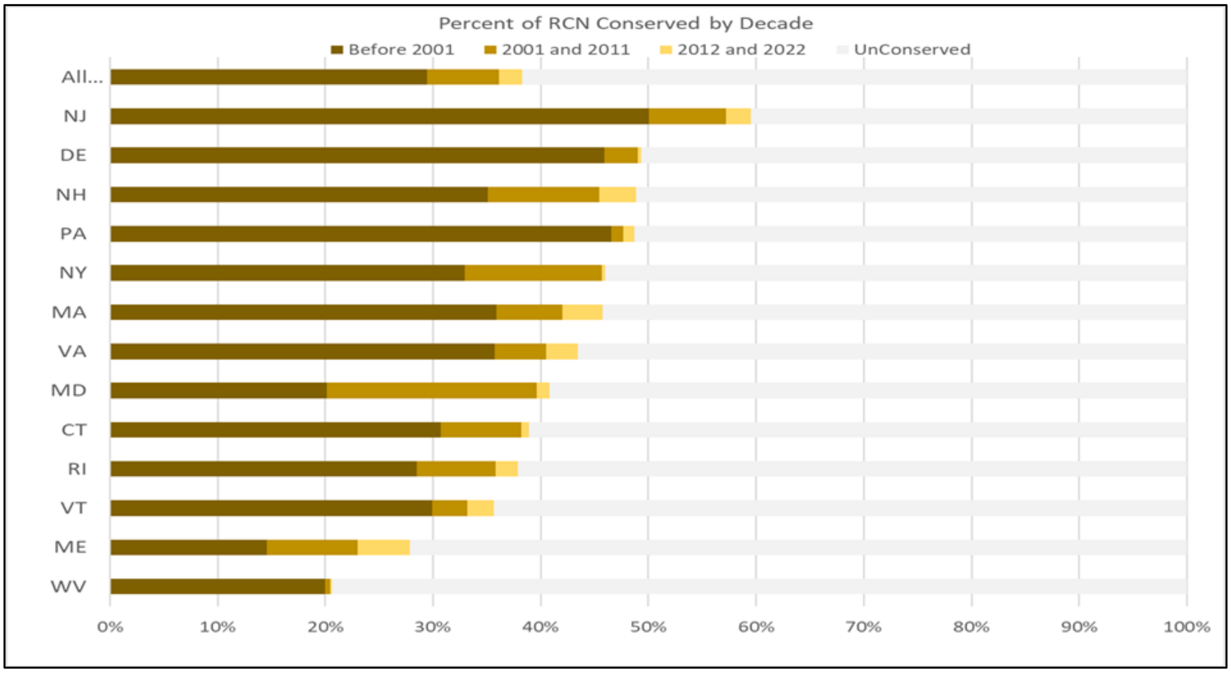
Over 38% of the Resilient and Connected Network is already under conservation from independent efforts by the states (Figure 8.8). Most of that conservation happened before 2001 but in the last decade another 1.2 million conservation acres were added, mostly by private conservation organizations.

Figure 8.8: Conserving the Resilient and Connected Network. Acres of the network vary by state. The two charts show the area conserved in each decade by acres (top) and percent (bottom)

Acres



Percent



Carbon

Carbon is an essential chemical element that underlies all organic compounds like proteins, sugars, carbohydrates, and fats. All plants and animals consist of carbon cells and need to consume carbon to live and grow. Animals consume carbon through eating other sources of it. Plants and algae extract carbon directly out of the air as carbon dioxide (CO^2), releasing the oxygen and converting the carbon to sugars and carbohydrates, which are then transferred throughout the plant and burned or converted to biomass.

To retain a habitable planet for people and nature we must curtail the excessive release of carbon into the atmosphere. Most Intergovernmental Panel on Climate Change (IPCC) scenarios of how we can limit warming to below 2 °C assume large-scale use of carbon dioxide removal methods, plus reductions in greenhouse gas emissions. The cheapest and most mature carbon dioxide removal method is improved land stewardship and conservation (Griscom et al. 2017). Forests, bogs, swamps, marshes, and grasslands are naturally sequester and store carbon and have been doing it for millions of years. Yet confusion persists about the specific set of actions that should be taken to both increase carbon sinks with improved land stewardship and reduce emissions from land use activities. Thus, it has become imperative that we track the carbon implications of our activities. The carbon benefits of land protection and improved management have risen to the forefront of conservation discussions.

<u>Mapping Forest Carbon</u> The estimates of 2010 Forest carbon stock and components -aboveground, coarse woody debris, and soil/other – used in this chapter are from Williams et al. (2021) following methods described for the Southeast US in Gu et al. (2019). They are available for exploration and quantification on the resilient land mapping tool: https://maps.tnc.org/resilientland/

To estimate carbon stock, attributes were determined for all forested 30-m pixels in the conterminous United States. A forest carbon cycle model trained to match Forest Inventory and Analysis (FIA) data was used to predict carbon stocks for 2010 based on site-level attributes of forest type group, years since disturbance, and site productivity class. Results were iterated backward in time to provide continuous, annual reporting of forest carbon dynamics for each pixel. Most prior studies lacked spatial detail on the age of forest stands that persisted in a forested condition during the satellite data era, but this study used remotely sensed biomass to estimate the stand age condition of these persisting, intact forests, distinguishing relatively young stands (e.g., 30 to 50 years old) from older stands.

Mapping results estimate that the region boasts and estimated 9.8 billion metric tons of forest carbon (8,403,294,831 mt) distributed roughly as above-ground (30%), below-ground (50%) and debris (20%) (Map 8.6) According to EPA that is equivalent to 8 billion passenger vehicles driven for one year. The Williams et al (2021) model estimates carbon sequestration by 2050 if those forest grew undisturbed, and although that may be unrealistic under climate change and current harvest patterns, forest growth could potentially add another 1.4 billion metric tons of carbon to the existing stock.

Map 8.6. Estimated Forest Carbon Stocks for 2010. Model from Williams et al 2020.

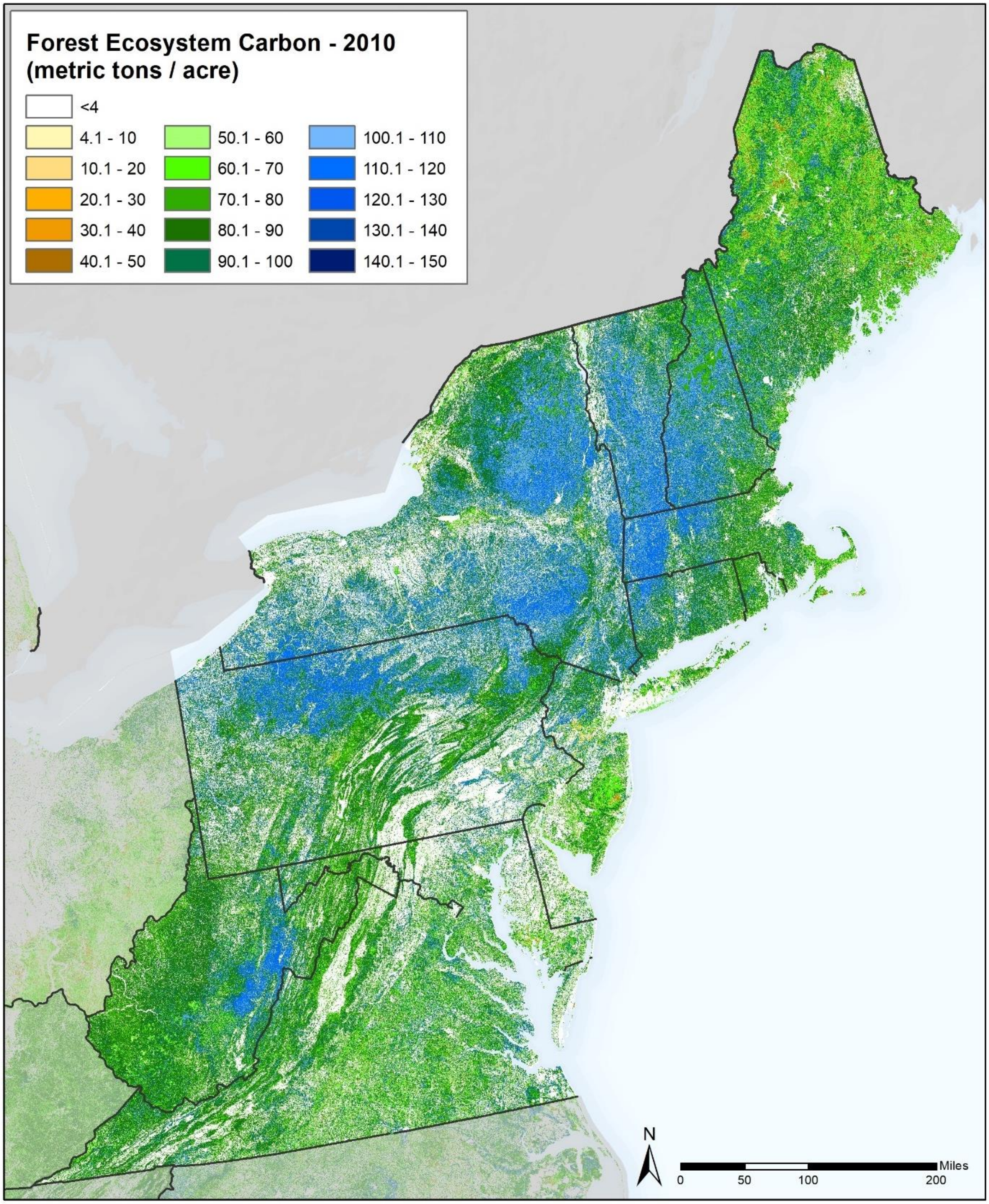
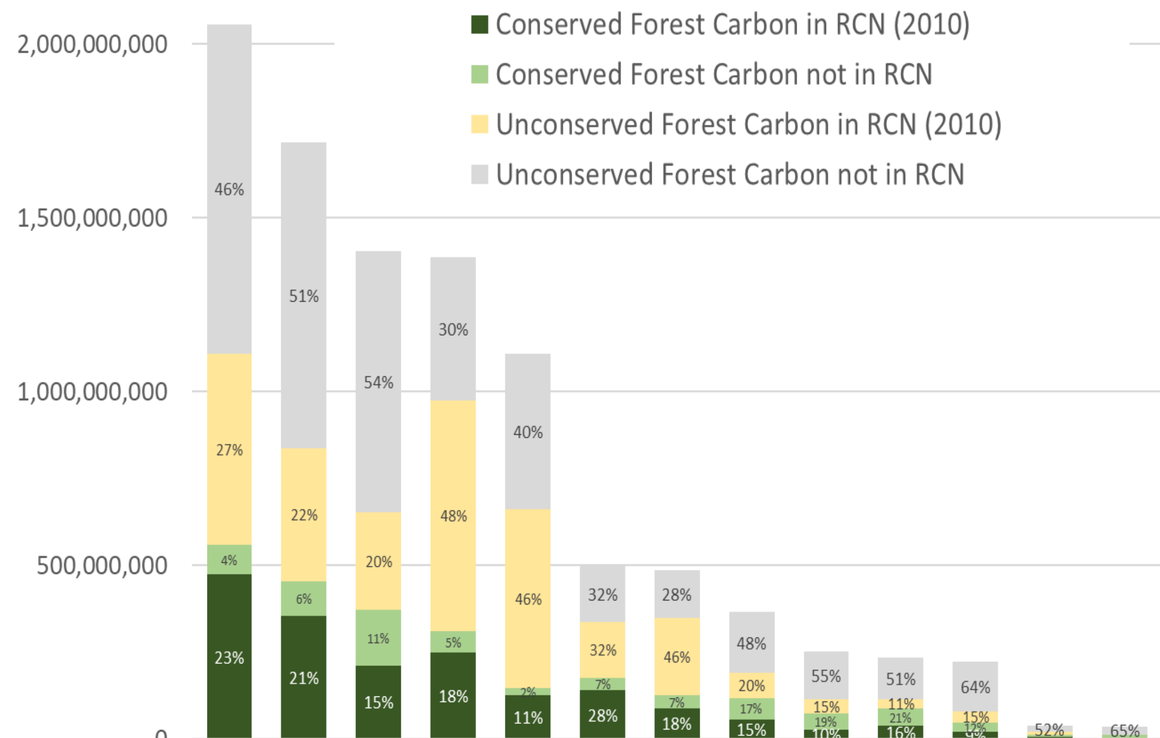


Figure 8.9. Forest Carbon Stocks by State and RCN. Forest carbon stocks vary widely with the size of the state and the amount of forest cover. Most states have already conserved a large proportion of their forest carbon, and most of that was in the RCN.



	NY	PA	VA	ME	WV	NH	VT	MA	MD	NJ	CT	RI	DE
Unconserved Forest Carbon not in RCN	947,180,244	882,853,724	752,525,337	415,181,831	448,933,145	159,793,446	135,644,044	173,963,725	138,602,709	120,578,987	143,451,875	20,414,202	23,015,426
Unconserved Forest Carbon in RCN (2010)	550,444,197	380,890,047	279,634,271	661,733,149	514,834,388	160,119,245	224,177,711	72,905,570	38,716,881	26,689,383	34,500,188	8,521,240	1,952,203
Conserved Forest Carbon not in RCN	86,434,157	101,809,604	160,394,151	63,308,431	19,784,690	37,112,841	36,047,733	61,820,756	48,130,284	50,430,016	25,891,527	5,413,800	8,602,964
Conserved Forest Carbon in RCN (2010)	472,864,776	352,643,995	210,952,169	247,829,371	125,312,384	139,292,357	88,779,527	55,856,397	26,206,531	37,635,684	19,287,966	4,912,165	1,947,230

TNC's Resilient and Connected Network was design using extensive representation goals organized by Ecoregion (ecologically homogenous areas with similar physical conditions). As a result, the network has almost perfect representation of all the country's habitats (99.7%, Anderson et al 2023) with examples chosen for their site resilience, connectivity, and biodiversity value. One consequence of this approach is that the network is unevenly distributed by state. States with several different ecoregions (for example, coastline, river valleys, mountains) may contain more of the RCN than more uniform states. States, however, are the centers of action for conservation and it is instructive to look at how the goals cross state boundaries with an eye toward matching state and ecoregional biodiversity and carbon goals (Figure 8.9).

Carbon is also distributed unevenly across states, but several synergies between carbon and the RCN are apparent. New York for example, has conserved 27% of its estimated 2010 forest carbon stock, with 23% falling within the RCN. Another 27% is available for future conservation that would meet multiple objectives for biodiversity while safeguarding over 500 million metric tons of carbon (Figure 8.8). One characteristic of carbon is that its values are qualitative and interchangeable, whereas the distribution of biodiversity is qualitative with the species composition varying in response to the physical and ecological conditions of the land.

Table 8.1. Percent Conserved by Area, GAP status, RCN and Carbon.

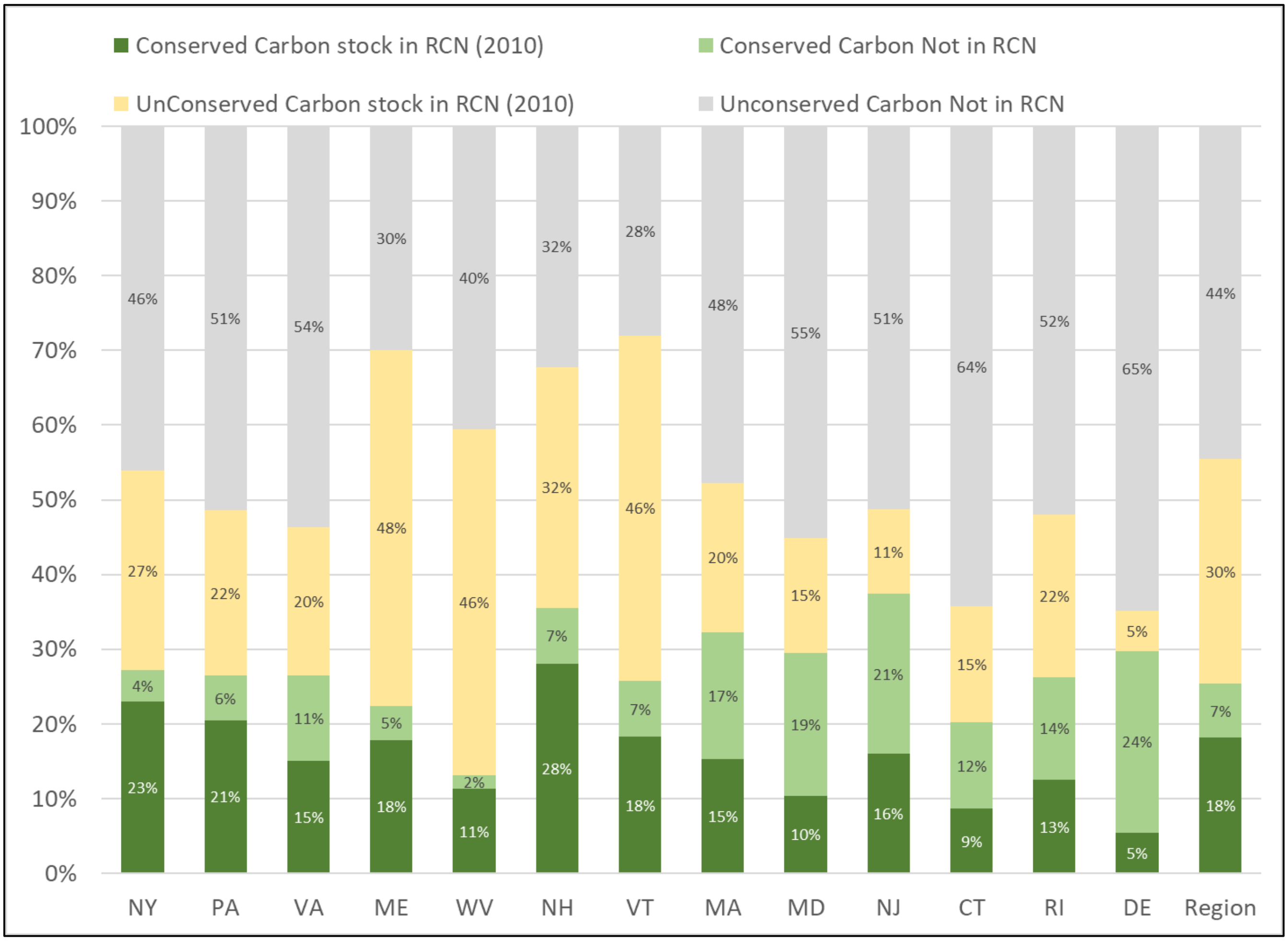
State	% Area GAP 1	% Area GAP 2	% Area GAP 3	% Area Conserved	% RCN Conserved	% Forest Carbon Conserved	Total Acres
CT	1%	4%	12%	17%	39%	20%	3,183,447
DC	0%	0%	20%	20%	100%	42%	39,988
DE	1%	4%	13%	18%	49%	30%	1,266,542
MA	3%	5%	16%	24%	46%	32%	5,200,573
MD	0%	2%	16%	18%	41%	30%	6,351,377
ME	2%	3%	16%	21%	28%	22%	20,824,982
NH	5%	8%	20%	33%	49%	36%	5,931,243
NJ	0%	13%	11%	24%	59%	37%	4,843,101
NY	9%	1%	9%	20%	46%	27%	31,055,902
PA	1%	1%	16%	18%	49%	26%	28,986,981
RI	1%	14%	5%	20%	38%	26%	697,220
VA	2%	3%	12%	17%	43%	26%	25,616,295
VT	3%	2%	16%	22%	36%	26%	6,153,095
WV	1%	2%	9%	11%	21%	13%	15,506,478
Region	3%	3%	13%	19%	38%	25%	**155,657,223**

Conserving America the Beautiful (30 by 30):

There is debate in the conservation community around what counts as "protected". In this report we count all conserved land (GAP 1-3) as contributing (Table 8.1). Scientific analysis has clearly indicated that we need land where the primary purpose is conservation for biodiversity (GAP 1-2) as these are the places where wildlife and plants can find quality breeding habitat and the resource they need to thrive. It also appears these lands improve in resilience and connectedness over time. This report has also shown the immense value of GAP 3 multiple use land in sustaining connectivity and services that benefit species at large scales beyond what has been achieved with GAP 1-2 conservation. Moreover, improved management practices have been shown to have a positive effect on biodiversity, and this is the essential land base for applying those practice. Ideally conservationists would plan collaboratively for a mix of wildlands and woodlands as has been promoted by Wildlands and Woodlands to amplify the benefits of both.

On way to look at achieving 30 by 30 is to assess how each state is doing towards conservation with respect to different footprints: acres, biodiversity as represented by the RCN, and carbon as represented by the total forest carbon stock (Table 8.1). In total, the region has conserved 19% of its area, 38% of the resilient and connected network and 25% of its forest carbon stock. For the most part these targets reinforce each other, but there is still a lot a conservation to be done in each state, particularly in unconserved carbon stock portion of the RCN (Figure 8.10).

Figure 8.10. Reaching 30 by 30: Conserving the Biodiversity and Carbon Footprint This table shows conservation as a percent of the estimated total forest carbon stock in each state. Green areas are already under conservation. The yellow-tan region is the place where conservation could make a difference to biodiversity and carbon.



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Appendix 8.1

List of Terrestrial Resilience Study Region Reports

TNC's Resilient and Connected Network (RCN) is a proposed conservation network of representative climate-resilient sites designed to sustain biodiversity and ecological functions into the future under a changing climate. The network was identified and mapped over a 10-year period by scientists in eleven geographic study regions. Methods and results for each region are described in an illustrated report reviewed by members of the steering committee.

All region's resilience reports can be accessed from the Interactive Reports and Resources Map found on http://nature.org/climateresilience or from the individual websites and direct links below.

Eastern U.S. Region: Website
https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/terrestrial/resilience/Pages/default.aspx

Resilient and Connected Landscapes: Report
Anderson, M.G., Barnett, A., Clark, M., Prince, J., Olivero Sheldon, A. and Vickery B. 2016. Resilient and Connected Landscapes for Terrestrial Conservation. The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA.
http://easterndivision.s3.amazonaws.com/Resilient_and_Connected_Landscapes_For_Terrestrial_Conservation.pdf

Resilient Sites: Report
Anderson, M.G., A. Barnett, M. Clark, C. Ferree, A. Olivero Sheldon, J. Prince. 2016. Resilient Sites for Terrestrial Conservation in Eastern North America. The Nature Conservancy, Eastern Conservation Science.
http://easterndivision.s3.amazonaws.com/Resilient_Sites_for_Terrestrial_Conservation.pdf

Webmap: https://omniscape.codefornature.org/#/analysis-tour.

Cameron, D. R., Schloss, C. A., Theobald, D. M., & Morrison, S. A. 2022. A framework to select strategies for conserving and restoring habitat connectivity in complex landscapes. Conservation Science and Practice, 4(6), e12698.
https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/csp2.12698

List of Coastal Resilience Study Region Reports

Coastal Northeast and Mid-Atlantic U.S.

Anderson, M.G. and Barnett, A. 2017. Resilient Coastal Sites for Conservation in the Northeast and Mid-Atlantic U.S.. The Nature Conservancy, Eastern Conservation Science. Boston, MA
View the interactive map, download the data, and read the report at:
https://www.nature.org/resilientcoasts

Published literature by TNC Authors on the Resilience Work.

Anderson, M.G., Clark, M., Olivero, A.P., Barnett, A.R., Hall, K.R., Cornett, M.W., Ahlering, M., Schinel, M., Unasch, B., Schoss, C., Cameron, D.R. (in press 2022). A resilient and connected network of sites to sustain biodiversity under a changing climate. PNAS

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