June 25, 2021

Mr. George Barrett
Chair
Town of Wareham
Planning Board
via Website and Email to kbuckland@wareham.ma.us and Sonia Raposo sraposo@wareham.ma.us

Re: Case No. 21-21 Site Plan Review

Wareham MA 3, LLC, Atlantic Design Engineers, Inc., 91 & 101 Fearing Hill Road,, Map 91, Lot 1000, and Map 74, Lot 1007

Dear Chairman Barrett and members of the Wareham Planning Board,

Thank you for the opportunity to submit comments on the application by Wareham MA 3, LLC for site plan review (Application). Community Land & Water Coalition (CLWC) is an alliance of groups and individuals working to preserve, protect and restore land and waters in Southeastern Massachusetts including those in Wareham. Our interests will be directly impacted by the proposal to clear-cut forests to install industrial solar energy generation and storage as proposed by Wareham MA3 LLC of Valhalla, NY (Applicant), the landowners Ninety Six Realty, LLC (Joseph Crespi), and Clean Energy Collective (CEC) of Colorado (lessee of the site).

The Application for the 44 acre Fearing Hill solar energy generating station and energy storage facility (the Project) should be rejected for the reasons stated below.

In addition, proceeding with a Public Hearing on Jun 28, 2021 without readvertising and providing new Abutter Notice will violate the Bylaw and G.L. c. 40A, Section 11.

Background

The purpose of Site Plan Review under the Wareham Zoning Bylaw is:

to ensure the design and layout of certain developments permitted as a matter of right or by Special Permit will constitute suitable development and **will not result in a detriment to the neighborhood or the environment**. (emphasis added)

The Board has an affirmative duty to, among other things, **protect "adjacent areas against detrimental or offensive uses** on the site by provisions of adequate surface water drainage, buffers against lighting, sight, sound, dust, vibration, and the allowance of sun, light, and air." (emphasis added)

The Planning Board has approved about 19 site plan review applications for ground mounted solar in the Town of Wareham -- about 330 acres -- the most of almost any town in Massachusetts. Your approvals have resulted in the destruction of pristine Pine Barrens forest, a globally rare ecosystem, obliteration of entire ecosystems, contributed to species extinction, caused massive and irreversible alteration of topography and surface water flows, increased pollution runoff into wetlands and waterways and threatened public safety and our drinking water.

In addition, you have consistently turned a blind eye to the commercial sand mining conducted by AD Makepeace (and possibly other site owners) to "prepare" solar sites for ground-mounted solar. AD Makepeace strip mining operations directly linked to your site plan review approvals include:

- Tihonet East Solar project (160 Tihonet Road, about 50 acres)
- Charlotte Furnace Solar Project (about 44 acres), and
- 77 Farm-to-Market (23 acres)

The total volume of earth removed from these and other sites exceeds 2 million cubic yards and has never been accounted for. Nor has the damage to the environment caused by stripping away forests and sand that filters our groundwater. While the Board of Selectmen issues Earth Removal Permits, the Planning Board has a legal duty under the Bylaw to ensure that Site Preparation Work does not occur until all necessary permits have been obtained. See, Section 1490.

To date, the Planning Board approvals for ground mounted solar have resulted in the creation of about 330 acres of land where nothing will ever grow again in human time because the land has been scraped bare. See, PFPI Report, May 2021, attached. These projects are undoubtedly depressing real estate values in Wareham -- a recent study shows that industrial solar lowers property values.

Against this backdrop, the Planning Board is being asked to accept subdivision plans for 1,400 acres of solar, against the will of the voters who rejected these projects at the June 12, 2021 Town Meeting. This includes the Fearing Hill solar project - another ill-conceived, dangerous and risky industrial utility operation in a residential district that will contribute to and exacerbate the irreversible harm and loss of real estate values caused to date.

1. **The developers are thumbing their noses at Wareham voters who unanimously passed a Bylaw on June 12, 2021 banning projects such as this.**

This project is banned under the Town's zoning amendment passed unanimously on June 12, 2021. This was the second time in three months Town voters resoundingly rejected inappropriate industrial and commercial development proposed by out-of-town speculators. In April, 2021, voters sent a loud and clear message to Town leaders voting by an 85% margin to reject the flawed NOTOS rezoning project. **Yet, these developers are seeking an exemption and to "freeze" the prior zoning to allow them to build this project.**

When will Town leaders listen to their voters and exercise the full range of their authority to implement the Bylaws in a manner that actually protects the health, safety and welfare of the community -- the key tenet of local zoning?

2. The Project is inconsistent with the Town's Master Plan

The Project site appears to be designed as low density homes and woodlands under the Town's Master Plan. The Planning Board must review and consider the Master Plan in its entirety including its goals for the community, before determining whether this Application is complete.

3. The Application does not address the Special Permit requirements of Bylaw Section 1460.

Because this project is over 30 acres, it is required to obtain a Special Permit in addition to Site Plan Review. This is stated explicitly in Section 1520 of the Bylaw:

> In addition, any development of any type on 30 acres or greater shall be subject to Section 1510. A Special Permit shall be granted only if the Special Permit Granting Authority finds that it is consistent with the purposes outlined in Section 1510 of this By-Law.

This provision means in addition to filling out an application for Site Plan Review, the Applicant must submit information to show that the Special Permit criteria of Section 1460 are met. The Application does not and therefore is incomplete and must be rejected.

4. Energy storage facilities such as batteries as proposed here are prohibited in an R130 district

The Project has two separate components:

- the collection of solar energy and conversion into electricity via 7,333 ground mounted solar panels and transformers and inverters, and
- an energy storage facility consisting of industrial-scale batteries (there are no specifications for the type, size or safety features of the batteries so the Application is incomplete in that regard).

The Wareham Zoning By-laws do not allow the second use---construction and operation of an energy storage facility that uses industrial batteries to store electricity, in a residential district.

The By-laws dedicate a portion of Article 5 to Solar Energy Generation Facilities or large ground mounted solar. As defined in Article 16, large ground mounted solar is,

> A solar photovoltaic system that is structurally mounted on the ground and is not roof-mounted, and has a minimum nameplate capacity of 250 kW DC. Included in this definition are canopy-mounted systems...

This does not include energy storage facilities in the form of industrial batteries therefore they are prohibited in the residential district.

This Project, which includes energy storage in the form of industrial batteries, cannot be built at this site. Therefore, the Planning Board has no jurisdiction to consider the Site Plan Review Application.

4. Waste issues are not adequately addressed, making the Application incomplete

This Project involves over seven-thousand solar panels that will end up in landfill by the end of their lifespan (20-25 years). This is one site out of nineteen existing and nine new solar sites in Wareham alone. In approving these prior projects, the Planning Board has not adequately taken into account the risk to the Town if the projects are abandoned at the end of their useful life. The Town faces the financial risk of remediating the sites. The decommissioning bonds and PILOT agreements are likely wholly inadequate based on current research. See attached *Harvard Business Review* article, June 2021, attached.

5. Even if battery storage is permissible under the Bylaw, the Application fails to adequately address the public safety risks.

Battery storage facilities propose a public safety risk of explosion, fire, leaching of toxic chemicals and metals, including but not limited to lithium and cadmium. The Application does not address these issues.

6. Solar company Clean Energy Collective (CEC) is bankrupt

The Application identifies CEC as the lessee of the Project site and as of this date it continues to be listed on the lease filed with the Registry of Deeds. This company is in bankruptcy.

Is the Planning Board going to put the future safety of Wareham residents in the hands of a bankrupt company?

Is this the type of developer that you can be sure will honestly and completely disclose the full impacts of the Project?

The financial risk to the Town could be substantial if it is left with a denuded landscape of industrial solar infrastructure or if there is a fire or other safety incident.

In summary, we respectfully urge you to reject this application. Thank you for your consideration.

Sincerely,

Margaret E. Sheehan

Meg Sheehan
Volunteer
Community Land & Water Coalition
environmentwatchsoutheasternma@gmail.com

Citations and Exhibits

1. Bankruptcy of Clean Energy Collective: *Inforuptcy*
2. Debt owed by Crespi & Ahearn to the Town of Wareham: source: conversation with Town officials
3. Harvard Business Review, 6/2021
4. The Nature Conservancy and Native Plant Society, 6/2021
5. Partnership for Policy Integrity, *Comments to MEPA on EENF 13940*, three ground mounted solar projects proposed by AD Makepeace and Borrego Solar, Wareham MA 2021
6. Letter from Trustees of Reservations to Board of Selectmen, Wareham
7. Letter from Trout Unlimited to Board of Selectmen, Wareham, June 3, 2021
8. Community Land & Water Coalition Fact Sheet: *Fearing Hill Solar Project*
9. University of Rhode Island study on real estate values

Exhibit One

inforuptcy Colorado Bankruptcy Court

Sign in Get Started

Case number: 1:20-bk-17543 - Clean Energy Collective, LLC - Colorado Bankruptcy Court

Case Information

Case title
Clean Energy Collective, LLC

Court
Colorado (cobke)

Chapter
11

Judge
Michael E. Romero

Filed
11/20/2020

Last Filing
06/21/2021

Asset
Yes

Docket Header

U.S. Bankruptcy Court
District of Colorado (Denver)
Bankruptcy Petition #: 20-17543-MER

Date filed: 11/20/2020
Deadline for filing claims: 02/19/2021
Deadline for filing claims (govt.): 07/06/2021

Assigned to: Michael E. Romero
Chapter 11
Voluntary
Asset

Debtor

Clean Energy Collective, LLC

PO Box 270927
Louisville, CO 80027
BOULDER-CO
Tax ID / EIN: 27-0408423

represented by **Lindsay Riley**

Wadsworth Garber Warner Conrardy, P.C.
2580 W Main Street, Suite 200
Suite 200
Littleton, CO 80120
303-296-1999
Email: lriley@wgwc-law.com

David Wadsworth

Docket Header

PO Box 270927
Louisville, CO 80027
BOULDER-CO
Tax ID / EIN: 27-0408423

Suite 200
Littleton, CO 80120
303-296-1999
Email: lriley@wgwc-law.com

David Wadsworth

Wadsworth Garber Warner Conrardy, P.C.
2580 West Main Street, Suite 200
Littleton, CO 80120
303-296-1999
Fax : 303-296-7600
Email: dwadsworth@wgwc-law.com

U.S. Trustee

US Trustee

Byron G. Rogers Federal Building
1961 Stout St.
Ste. 12-200
Denver, CO 80294
303-312-7230

represented by **Robert Samuel Boughner**

Byron G. Rogers Federal Building
1961 Stout St.
Ste. 12-200
Denver, CO 80294
303-312-7252
Fax : 303-312-7259
Email: Samuel.Boughner@usdoj.gov

Latest Dockets

Date Filed	#	Docket Text
06/21/2021	125	Report of Operations From May 1, 2021 To May 31, 2021 Filed by Lindsay Riley on behalf of Clean Energy Collective, LLC. (Riley, Lindsay)
06/11/2021	124	Certificate of Service Filed by Lindsay Riley on behalf of Clean Energy Collective, LLC (related document(s):[122] Motion to Reject, [123] 9013-1.1 Notice). (Riley, Lindsay)
06/11/2021	123	9013-1.1 Notice Filed by Lindsay Riley on behalf of Clean Energy Collective, LLC (related document(s):[122] Motion to Reject).. 9013 Objections due by 6/25/2021 for [122],. (Riley, Lindsay)
06/11/2021	122	Motion to Reject Executory Contract Filed by Lindsay Riley on behalf of Clean Energy Collective, LLC. (Attachments: # (1) Exhibit 1 # (2) Proposed/Unsigned Order) (Riley, Lindsay)
06/11/2021	121	Certificate of Service Filed by Lindsay Riley on behalf of Clean Energy Collective, LLC (related document(s):[16] Meeting of Creditors Chapter 11, [118] Declaration Under Penalty of Perjury for Individual/Non-Individual Debtor's, Summary of Assets and Liabilites, Schedule D And/Or Schedule E/F, [120] 1009-1.1 Notice of Amendment). (Riley, Lindsay)
06/11/2021	120	1009-1.1 Notice of Amendment to Voluntary Petition, Lists, Schedules, or Statements Filed by Lindsay Riley on behalf of Clean Energy Collective, LLC (related document(s):[118] Declaration Under Penalty of Perjury for Individual/Non-Individual Debtor's, Summary of Assets and Liabilites, Schedule D And/Or Schedule E/F)... (Riley, Lindsay)
06/11/2021	118	Amended Declaration Under Penalty of Perjury For Non-Individual Debtor's, Amended Summary of Assets and Liabilities Schedules For Non-Individual, Amended Schedule D: Creditors having Claims Secured by Property And/Or Schedule E/F: Creditors Who Have Unsecured Claims For Non-Individual Total Number of Creditors Added or Uploaded: 1 Filed by Lindsay Riley on behalf of Clean Energy Collective, LLC (related document(s):[1] Voluntary Petition - Chapter 11, [59] Statement of Financial Affairs, Summary of Assets and Liabilites, Schedule A/B, Schedule D And/Or Schedule E/F, Declaration Under Penalty of Perjury for Individual/Non-Individual Debtor's). (Riley, Lindsay)
06/03/2021	117	Disregard this entry, entered in error see case 21-13012 CDP Entry of Appearance and Request for Notice Filed by Michael C. Payne on behalf of Great Western Bank... (Payne, Michael) Modified on 6/3/2021 per e-filer request (rjr).
05/21/2021	116	Report of Operations From 4/1/2021 To 4/30/2021 Filed by David Wadsworth on behalf of Clean Energy Collective, LLC. (Wadsworth, David)
04/21/2021	115	Courts Notice or Order and BNC Certificate of Mailing (related document(s)[112] Order on Application to Employ). No. of Notices: 20. Notice Date 04/21/2021. (Admin.)

Exhibit Two

“The land speculators owe Wareham $217,370.00 from a tax fight with the Town & bankrupt solar developer CEC has sales that plummeted 97% in 2020” (source: conversation with Town officials).

Exhibit Three

Sustainability

The Dark Side of Solar Power

by Atalay Atasu, Serasu Duran, and Luk N. Van Wassenhove

June 18, 2021

It's sunny times for solar power. In the U.S., home installations of solar panels have fully rebounded from the Covid slump, with analysts predicting more than 19 gigawatts of total capacity installed, compared to 13 gigawatts at the close of 2019. Over the next 10 years, that number may quadruple, according to industry research data. And that's not even taking into consideration the further impact of possible new regulations and incentives launched by the green-friendly Biden administration.

Solar's pandemic-proof performance is due in large part to the Solar Investment Tax Credit, which defrays 26% of solar-related expenses for all residential and commercial customers (just down from 30% during 2006-2019). After 2023, the tax credit will step down to a permanent 10% for commercial installers and will disappear entirely for home buyers.

Therefore, sales of solar will probably burn even hotter in the coming months, as buyers race to cash in while they still can.

Tax subsidies are not the only reason for the solar explosion. The conversion efficiency of panels has improved by as much as 0.5% each year for the last 10 years, even as production costs (and thus prices) have sharply declined, thanks to several waves of manufacturing innovation mostly driven by industry-dominant Chinese panel producers. For the end consumer, this amounts to far lower up-front costs per kilowatt of energy generated.

This is all great news, not just for the industry but also for anyone who acknowledges the need to transition from fossil fuels to renewable energy for the sake of our planet's future. But there's a massive caveat that very few are talking about.

Panels, Panels Everywhere

Economic incentives are rapidly aligning to encourage customers to trade their existing panels for newer, cheaper, more efficient models. In an industry where circularity solutions such as recycling remain woefully inadequate, the sheer volume of discarded panels will soon pose a risk of existentially damaging proportions.

To be sure, this is not the story one gets from official industry and government sources. The International Renewable Energy Agency (IRENA)'s official projections assert that "large amounts of annual waste are anticipated by the early 2030s" and could total 78 million tonnes by the year 2050. That's a staggering amount, undoubtedly. But with so many years to prepare, it describes a billion-dollar opportunity for recapture of valuable materials rather than a dire threat. The threat is hidden by the fact that IRENA's predictions are premised upon customers keeping their panels in place for the entirety of their 30-year lifecycle. They do not account for the possibility of widespread early replacement.

Our research does. Using real U.S. data, we modeled the incentives affecting consumers' decisions whether to replace under various scenarios. We surmised that three variables were particularly salient in determining replacement decisions: installation price, compensation rate (i.e., the going rate for solar energy sold to the grid), and module efficiency. If the cost of trading up is low enough, and the efficiency and compensation rate are high enough, we posit that rational consumers will make the switch, regardless of whether their existing panels have lived out a full 30 years.

As an example, consider a hypothetical consumer (call her "Ms. Brown") living in California who installed solar panels on her home in 2011.
Theoretically, she could keep the panels in place for 30 years, i.e., until 2041. At the time of

installation, the total cost was $40,800, 30% of which was tax deductible thanks to the Solar Investment Tax Credit. In 2011, Ms. Brown could expect to generate 12,000 kilowatts of energy through her solar panels, or roughly $2,100 worth of electricity. In each following year, the efficiency of her panel decreases by approximately one percent due to module degradation.

Now imagine that in the year 2026, halfway through the lifecycle of her equipment, Ms. Brown starts to look at her solar options again. She's heard the latest generation of panels are cheaper and more efficient — and when she does her homework, she finds that that is very much the case. Going by actual current projections, the Ms. Brown of 2026 will find that costs

associated with buying and installing solar panels have fallen by 70% from where they were in 2011. Moreover, the new-generation panels will yield $2,800 in annual revenue, $700 more than her existing set-up when it was new. All told, upgrading her panels now rather than waiting another 15 years will increase the (net present value) NPV of her solar rig by more than $3,000 in 2011 dollars. If Ms. Brown is a rational actor, she will opt for early replacement. And if she were especially shrewd in money matters, she would have come to that decision even sooner — our calculations for the Ms. Brown scenario show the replacement NPV overtaking that of panel retention starting in 2021.

If early replacements occur as predicted by our statistical model, they can produce 50 times more waste in just four years than IRENA anticipates. That figure translates to around 315,000 metric tonnes of waste, based on an estimate of 90 tonnes per MW weight-to-power ratio.

Alarming as they are, these stats may not do full justice to the crisis, as our analysis is restricted to residential installations. With commercial and industrial panels added to the picture, the scale of replacements could be much, much larger.

The High Cost of Solar Trash

The industry's current circular capacity is woefully unprepared for the deluge of waste that is likely to come. The financial incentive to invest in recycling has never been very strong in solar. While panels contain small amounts of valuable materials such as silver, they are mostly made of glass, an extremely low-value material. The long lifespan of solar panels also serves to disincentivize innovation in this area.

As a result, solar's production boom has left its recycling infrastructure in the dust. To give you some indication, First Solar is the sole U.S. panel manufacturer we know of with an up-and-running recycling initiative, which only applies to the company's own products at a global capacity of two million panels per year. With the current capacity, it costs an estimated $20-30 to recycle one panel. Sending that same panel to a landfill would cost a mere $1-2.

The direct cost of recycling is only part of the end-of-life burden, however. Panels are delicate, bulky pieces of equipment usually installed on rooftops in the residential context. Specialized labor is required to detach and remove them, lest they shatter to smithereens before they make it onto the truck. In addition, some governments may classify solar panels as hazardous waste, due to the small amounts of heavy metals (cadmium, lead, etc.) they contain. This classification carries with it a string of expensive restrictions — hazardous waste can only be transported at designated times and via select routes, etc.

The totality of these unforeseen costs could crush industry competitiveness. If we plot future installations according to a logistic growth curve capped at 700 GW by 2050 (NREL's estimated ceiling for the U.S. residential market) alongside the early replacement curve, we see the volume of waste surpassing that of new installations by the year 2031. By 2035, discarded panels would outweigh new units sold by 2.56 times. In turn, this would catapult the LCOE (levelized cost of energy, a measure of the overall cost of an energy-producing asset over its lifetime) to four times the current projection. The economics of solar — so bright-seeming from the vantage point of 2021 — would darken quickly as the industry sinks under the weight of its own trash.

Who Pays the Bill?

It will almost certainly fall to regulators to decide who will bear the cleanup costs. As waste from the first wave of early replacements piles up in the next few years, the U.S. government — starting with the states, but surely escalating to the federal level — will introduce solar panel recycling legislation. Conceivably, future regulations in the U.S. will follow the model of the European Union's WEEE Directive, a legal framework for the recycling and disposal of electronic waste throughout EU member states. The U.S. states that have enacted electronics-recycling legislation have mostly cleaved to the WEEE model. (The Directive was amended in 2014 to include solar panels.) In the EU, recycling responsibilities for past (historic) waste have been apportioned to manufacturers based on current market share.

A first step to forestalling disaster may be for solar panel producers to start lobbying for similar legislation in the United States immediately, instead of waiting for solar panels to start clogging landfills. In our experience drafting and implementing the revision of the original WEEE Directive in the late 2000s, we found one of the biggest challenges in those early years was assigning responsibility for the vast amount of accumulated waste generated by companies no longer in the electronics business (so called orphan-waste).

In the case of solar, the problem is made even thornier by new rules out of Beijing that shave subsidies for solar panel producers, while increasing mandatory competitive bidding for new solar projects. In an industry dominated by Chinese players, this ramps up the uncertainty factor. With reduced support from the central government, it's possible that some Chinese producers may fall out of the market. One of the reasons to push legislation now rather than later is to ensure that the responsibility for recycling the imminent first wave of waste is shared fairly by makers of the equipment concerned. If legislation comes too late, the remaining players may be forced to deal with the expensive mess that erstwhile Chinese producers left behind.

But first and foremost, the required solar panel recycling capacity has to be built, as part of a comprehensive end-of-life infrastructure also encompassing uninstallation, transportation, and (in the meantime) adequate storage facilities for solar waste. If even the most optimistic of our early-replacement forecasts are accurate, there may not be enough time for companies to accomplish this alone. Government subsidies are probably the only way to quickly develop capacity commensurate to the magnitude of the looming waste problem. Corporate lobbyists can make a convincing case for government intervention, centered on the idea that waste is a negative externality of the rapid innovation necessary for widespread adoption of new energy technologies such as solar. The cost of creating end-of-life infrastructure for solar, therefore, is an inescapable part of the R&D package that goes along with supporting green energy.

It's Not Just Solar

The same problem is looming for other renewable-energy technologies. For example, barring a major increase in processing capability, experts expect that more than 720,000 tons worth of gargantuan wind turbine blades will end up in U.S. landfills over the next 20 years. According to prevailing estimates, only five percent of electric-vehicle batteries are currently recycled – a lag that automakers are racing to rectify as sales figures for electric cars continue to rise as much as 40% year-on-year. The only essential difference between these green technologies and solar panels is that the latter doubles as a revenue-generating engine for the consumer. Two separate profit-seeking actors — panel producers and the end consumer — thus must be satisfied in order for adoption to occur at scale.

***

None of this should raise serious doubts about the future or necessity of renewables. The science is indisputable: Continuing to rely on fossil fuels to the extent we currently do will bequeath a damaged if not dying planet to future generations. Compared with all we stand to gain or lose, the four decades or so it will likely take for the economics of solar to stabilize to the point that consumers won't feel compelled to cut short the lifecycle of their panels seems decidedly small. But that lofty purpose doesn't make the shift to renewable energy any easier in reality. Of all sectors, sustainable technology can least afford to be short-sighted about the waste it creates. A strategy for entering the circular economy is absolutely essential — and the sooner, the better.

Atalay Atasu is a professor of technology and operations management and the Bianca and James Pitt Chair in Environmental Sustainability at INSEAD.

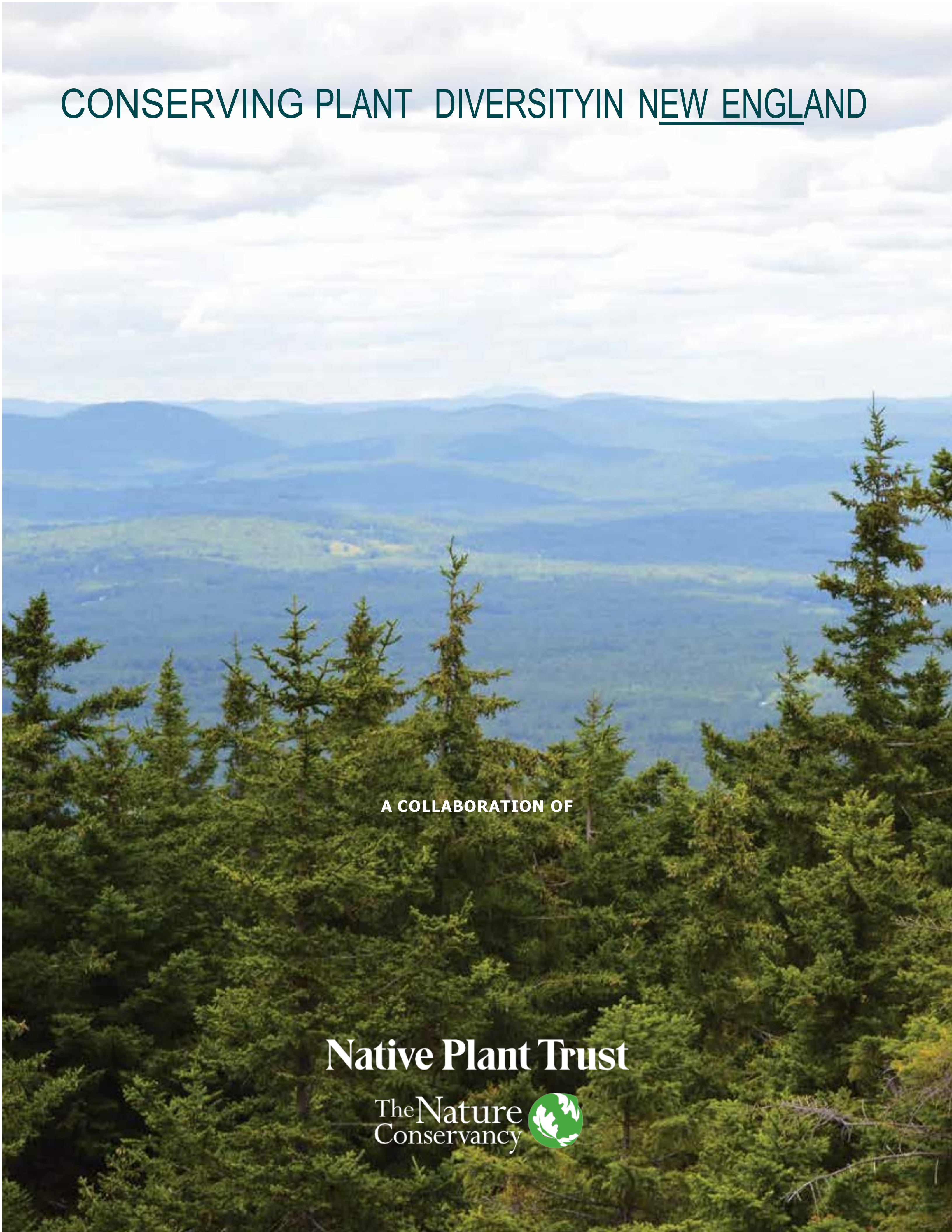
Serasu Duran is a professor at the University of Calgary's Haskayne School of Business in Calgary, Alberta.

Luk N. Van Wassenhove is the Henry Ford Chaired Professor of Manufacturing, Emeritus, at INSEAD and leads its Humanitarian Research Group and its Sustainable Operations Initiative.

Read more on **Sustainability**

Exhibit Four

CONSERVING PLANT DIVERSITYIN NEW ENGLAND



A COLLABORATION OF

Native Plant Trust

The Nature Conservancy

CONSERVING PLANT DIVERSITY IN NEW ENGLAND

A COLLABORATION OF

Native Plant Trust

The Nature Conservancy

AUTHORS

MarkAnderson

Director of Conservation Science, Eastern United States, The Nature Conservancy

Michael Piantedosi

Director of Conservation, Native Plant Trust

William Brumback

Director of Conservation Emeritus, Native Plant Trust

MAP PRODUCTION

Arlene Olivero

WEB TOOL

Melissa Clark

DESIGN

Rachel Wolff-Lander KateWollensakFreeborn

The authors wish to thank the six state Natural Heritage programs for sharing their data and for their support.

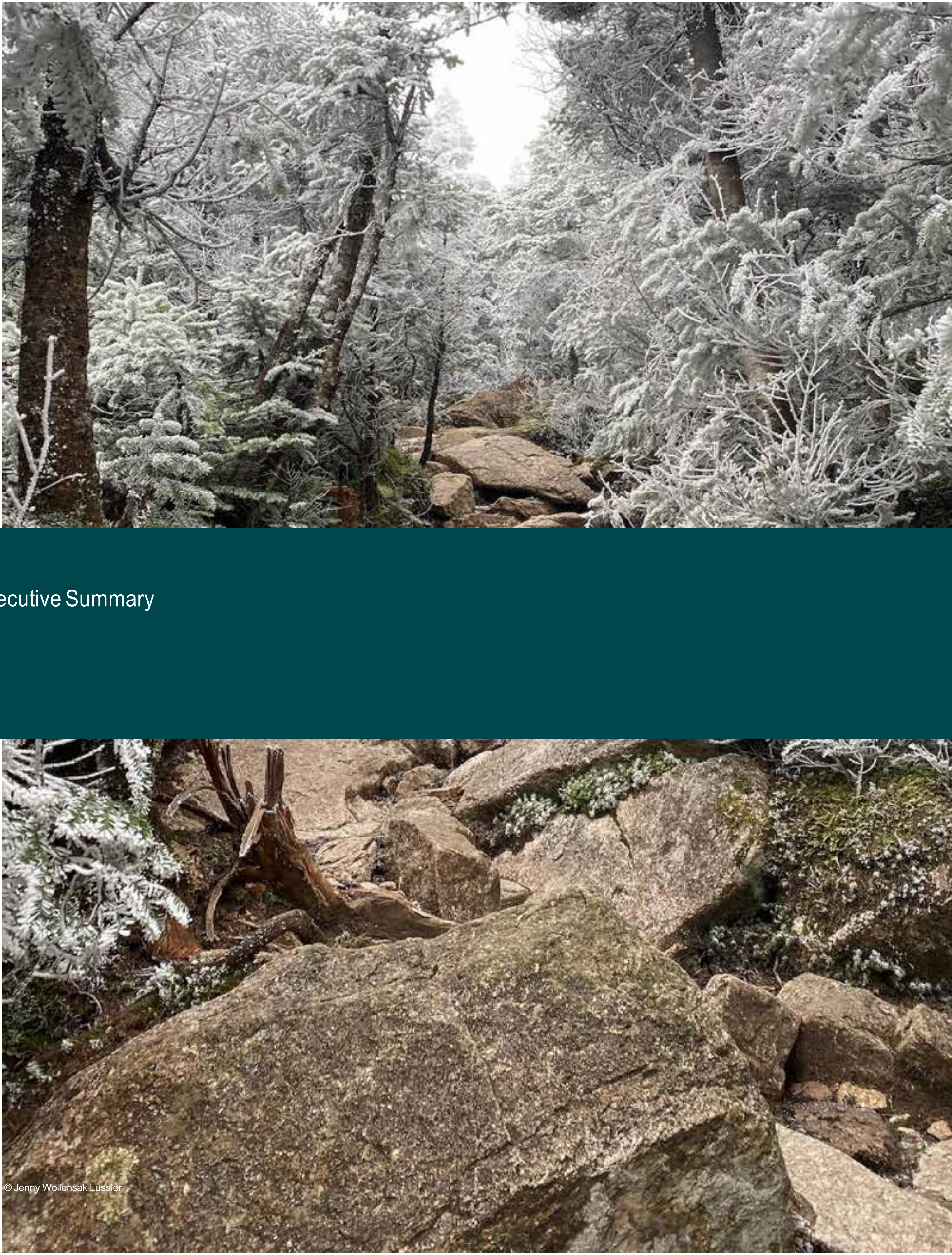
Published June 2021


© Peter James

CONTENTS

CONTENTS
continued

xecutive Summary



© Jenny Wollensak Lussier

EXECUTIVE SUMMARY

Overview

Conserving Plant Diversity in New England is a groundbreaking new report resulting from a two-year collaboration between Native Plant Trust and The Nature Conservancy. The report provides a scientific framework and detailed roadmap for conservation action and land protection at the species, habitat, and parcel scales that will effectively save plant diversity—and thus overall biodiversity—in New England

Michael Piantedosi © Native Plant Trust

The genesis of the study was a desire to know whether a century or more of land conservation has protected enough land in the right places to save the region's plant diversity. Our goal was to assess the region's status in meeting targets in the Global Strategy for Plant Conservation, which is part of the United Nations' Convention on Biological Diversity (CBD). The CBD partners recently extended their targets to encompass goals recommended by the Global Deal for Nature (Dinerstein et al. 2019), and thus the 2021 update calls for protecting 30% of the world's ecosystems by 2030. To determine progress toward both the original and expanded goals, the team:

- delineated the regional distribution of 43 unique habitats
- identified 234 Important Plant Areas (IPAs)—climate-resilient areas with a relative abundance of rare and endangered plant species, containing 212 of our rarest species
- assessed the current protection status of those habitats and IPAs and likely losses to development by 2050
- evaluated their ability to effectively adapt to a changing climate.

Recently, the Biden administration announced its "Conserving and Restoring America the Beautiful" initiative, which calls for locally led campaigns to conserve and restore 30% of the nation's lands and waters by 2030 (Executive Order 14008). **This report and the accompanying interactive mapping tool give policy makers, federal and state agencies, and land trusts in each state the detailed information needed to most effectively spend conservation dollars** to achieve that goal by protecting resilient, biologically diverse landscapes across New England.

Finally, we want to acknowledge other important reports assessing habitat conservation in New England, including "Wildlands and Woodlands" (Foster 2012), "Losing Ground" (Lautzenheiser et al. 2014), "Resilient Sites for Terrestrial Conservation in the Northeast and Mid-Atlantic Region" (Anderson et al. 2012), and "The vulnerabilities of fish and wildlife habitats in the Northeast to climate change" (Manomet 2012). To our knowledge, however, this is the first analysis to identify the specific sites throughout New England to protect to ensure the survival of plant assemblages and their inherent diversity.

Targets and Approach

Plants are the basis for life on Earth. Plant communities translate the geophysical variation of the land, such as soil and topography, into the living habitats that sustain life.

Conserving multiple intact examples of every habitat is a strategy for sustaining the natural benefits plants provide and maintaining the full diversity of species that depend on them (Beier et al. 2010). This report is thus the first to focus on regional plant diversity and resilience as the foundation for conservation policy and action.

northern blazing star (Liatris novae-angliae)
Liza Green © Native Plant Trust

Plants and plant communities face a host of immediate threats, from development to invasive species, as discussed in this report and more thoroughly in Native Plant Trust's "State of the Plants: Challenges and Opportunities for Conserving New England's Native Flora" (Farnsworth 2015).
The altered temperature and precipitation patterns brought by a changing climate pose long-term challenges for ecosystems, as the composition and location of plants and plant communities shift in response. Thus, the research team took as a fundamental premise that the conservation targets must be grounded in an analysis of **resilience**—places where the land provides many microclimates or natural strongholds for current plant populations that will enable them to endure under different climate scenarios. Thus, for each habitat and Important Plant Area (IPA), we mapped the location of its most resilient land and measured the achievements of a century of collaborative conservation efforts toward permanently protecting those sites from conversion.

Our classification of conservation lands follows the U.S. Fish and Wildlife Service GAP program terminology (Crist et al. 1998), in which:

- "**Secured**" refers to land that is permanently secured against conversion to development through public or private fee ownership, easement, or other legal means.
- "**Protected**" refers to the subset of secured land explicitly dedicated to conserving nature and natural processes (GAP 1) or managed for a primarily natural state (GAP 2)
- "**Multiple Use**" refers to the subset of secured land that is open to many types of uses including recreation, resource extraction, and management (GAP 3)
- "**Unsecured**" refers to privately owned land or public land with no conservation restrictions.

With that data, we then determined how much of each resilient habitat or IPA needs protection to meet the goals of the two international benchmarks.

The Global Strategy for Plant Conservation (GSPC) has three targets relevant to this analysis:

- Target 4: At least 15% of each vegetation type secured through effective management or restoration (i.e., "protected")
- Target 5: At least 75% of the most important areas for plant diversity (IPAs) of each ecological region protected with effective management in place for conserving plants and their genetic diversity
- Target 7: At least 75% of known threatened plant species conserved in their natural place in the wild.

We tailored the area-based goals of the Global Deal for Nature (incorporated into Biden's "America the Beautiful" initiative) to the character of the New England landscape, the varieties of legal protec-tion available here, and the impact of climate change. Thus, we set New England targets to parallel the GSPC targets, both with a timeframe of 2030:

- NE Target: At least 5-15% of each habitat protected and at least 30% secured against conversion. At least 75% of the securement on climate resilient land.
- NE Target: At least 30% of each climate-resilient area with the highest rare plant diversity (IPA) protected and at least 75% of each IPA secured against conversion across habitats and states.

The first NE target sets the protected level (conserved to protect nature and natural processes) needed based on habitat scale: dominant matrix forests 5%, wetlands 10%, patch-forming habitats 15%. Similarly, the resilience criterion is adjusted downward to 50% for wetlands to include some vulnerable but already protected examples of these critical habitats.

While this report focuses on protecting resilient and representative land, that approach is not always sufficient to sustain diversity. Protection of resilient land is most effective where the threat is habitat loss, conversion, or climate change; but other threats—like altered processes, trampling, overharvesting, and invasive species—need monitoring and management. Land protection also needs to go hand-in-hand with conservation strategies like seed banking, reintroduction, and assisted migration that ensure sources of biotic renewal are available and viable. The GSPC has a goal (Target 8 below) specifically related to ensuring that 75% of threatened plant species are in *ex situ* collections (seed banks and living collections at botanic gardens).

Eastern red cedar
(*Juniperus virginiana* var. *virginiana*)
Dan Jaffe © Native Plant Trust

Results

Conservation of New England's plant diversity under a changing climate is an achievable goal, butit requires significant increases in the securement and protection of resilient habitat. This will requiresecuring large, multiple-use areas against conversion and managing them to retain essential functions, as well as protecting smaller areas for natural processes that ensure plant populations andcommunities thrive. As much as possible, securement should be focused on climate-resilient land. **To achieve the NE target of 30% secured will require the protection of 2.3 million acres of additional resilient land in specific habitats.** In addition, we must ensure the effective manage- ment of the existing 5.3 million acres of multiple-use forest land that is central to wildlife habitat and carbon storage but open to logging and mineral extraction.

- **Forests cover 86% of the natural landscape, but only one of New England's ten dominant forest types meets GSPC target 4 and only two meet the NE target.** Reaching the NE target will require securing an additional 2 million acres of climate-resilient forest. To reach the GSPC goal of 15% protection across all forest habitats requires investing in 3 million acres, including increasing the GAP level on land that is already secured. Urgently in need of conservation are resilient examples of oak-pine and coastal hardwood forests of southern New England that are already challenged by fragmentation and predicted to lose up to 18% of their current distribution to development by 2050.

- **Wetlands cover 12% of the region and are critical to sustaining almost half our plants, birds, and other wildlife, but are less conserved than we expected.** Of New England's eighteen types of bogs, swamps, floodplains, and marshes, only six meet the GSPC and three the NE targets, and these are predominantly small, unique bogs and peatlands. None of our five most common wetland types meet either target, although many unprotected examples occur on resilient land, and at least 20% of each habitat is secured against conversion. Reaching the NE target will require conservation of an additional 253,902 acres of resilient wetland and for the GSPC target 405,083 acres protected for nature.

- **Patch-forming terrestrial habitats are hotspots of plant diversity and often critical habitat for rare and endangered plant species.** Covering only 2% of New England's landscape, these summits, cliffs, barrens, and dunes sustain densities of rare species ten times higher than wetlands and forty times higher than upland forests. These unusual habitats are more often on secured land than their widespread counterparts, and seven out of fourteen types meet the GSPC target. However, only four meet the NE target because sites supporting sand-based habitats like pine barrens and coastal grasslands occur on flat and fragmented land that is vulnerable to climate change. Many of these habitats are also under high threat of conversion, with 15-18% oftheir current extent predicted to be lost by 2050. Meeting the 30% NE target requires securing only 17,726 acres, but it will take 88,620 acres of targeted resilient land to bring the silt- and sand- based systems to the standard for climate resilience.

- **Important Plant Areas (IPAs) are patches of resilient land that contain an exceptionally high density of rare plant species.** We identified 234 IPAs for New England that in aggregate cover 2.6 million acres and contain multiple examples of 212 rare plant species and resilient examples of 92% of the habitats. Each IPA's rare plant diversity ranges from 2 to 26 taxa depending on the site's size and location. By acreage, the IPAs are 29% protected, with another 23% secured on multiple-use lands. By site, 10 IPAs (4%) are more than 75% protected (GSPC target) and 32 (14%) have more than 75% securement in a combination of protected and multiple-use land. Conserving the unsecured IPAs (1.3 million acres) would go a long way toward sustaining the region's floristic and habitat diversity.

© Nathan Anderson

Elizabeth Farnsworth © Native Plant Trust

- **New England has 388 globally and regionally rare taxa in need of conservation, as documented in Native Plant Trust's "Flora Conservanda: New England" (Brumback and Gerke 2013).** State Natural Heritage program inventories provide high-quality spatial records on 245 of them. Of those, 226 (92%) have occurrences on secured land (GAP 1-3), and of those 42% have more than 50% of their known locations are on secured land. However, only 16% of these occurrences are on protected land (GAP 1-2). The majority of the mapped locations are on resilient lands, although many taxa occur on a mix of resilient and vulnerable sites. Of the 245 well-mapped taxa, 19 have no permanent protection.

- **Conserving rare plants also requires ex situ strategies, as captured by GSPC Target 8**: "At least 75% of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs." In New England, Native Plant Trust manages the primary seed bank of rare and endangered species. Currently the seed bank holds collections of 43% of globally and regionally rare plant species. However, the collections are from only 7% of the populations.

Recommendations

We recommend an approach to land conservation that focuses **on more proportional representation of the region's habitats across their ranges**, rather than on securing more acres of habitat types that are abundantly conserved already. While securing 30% of each habitat from conversion to another land use is important for maintaining resiliency and biodiversity in a changing climate, we also recommend each state aim for 15% of each habitat protected (conserved for nature and natural processes), with a minimum of 5% for dominant forest types.
Prioritizing the IPAs will ensure that habitat protection also captures rare plant species.


sugar maple
(Acer saccharum var. *saccharum)*
Uli Lorimer © Native Plant Trust

The report's interactive maps and state-specific data will enable policy makers, federal and state agencies, and the land trusts in each state to effectively target the most significant areas for protecting New England's plant diversity and the biodiversity it supports. Examples include:

- Habitats that are rare within New England, such as coastal plain habitat primarily in Massachusetts and Rhode Island, warrant greater protection efforts, with a higher proportion secured for nature within the states where they occur.
- States with relatively large areas of a common habitat lacking conservation protection should also increase the amount of that habitat secured. For example, 90% of the regional habitat area of *Laurentian-Acadian Alkaline Conifer-Hardwood Swamp* is found in Maine, yet 84% of this habitat is unsecured in the state.
- Habitats facing significant losses to development by 2050, such as the coastal hardwood forests of southern New England, are also high priority.

A recommended starting point is **conserving the IPAs in each state**, which saves rare species across multiple habitats. The two primary strategies are focusing on IPAs that are unsecured and increasing the amount of protection within IPAs that are partially secured, either by conserving more acres or raising the level of securement to GAP 1 or GAP 2, depending upon the density of rare species.

While most of the 43 habitats need additional securement, we highlight several, and their IPAs, that need urgent conservation action.

Matrix Forests

- Mid-elevation *Laurentian-Acadian Pine-Hemlock-Hardwood Forest* in Maine and Vermont has relatively high resilience but the lowest protection (2%) and securement (14%) of any forest type.
  - In Maine, there are eight unsecured IPAs within this habitat, totaling 22,980 acres.
  - New Hampshire has a single unsecured IPA of 5,537 acres.
  - Vermont has two unsecured IPAs totaling 3,515 acres.

- *North Atlantic Coastal Plain Hardwood Forest* (in all states but Vermont) meets the NE target of 5% protected, but less than half of that is on resilient land; it is also only 19% secured and highly threatened by development. All states should focus on this habitat, but Connecticut, Maine, and Rhode Island have the least securement.
  - In this habitat, there are twelve IPAs needing protection: six in Connecticut (6,402 acres), three in Massachusetts (2,085 acres), and three in Rhode Island (3,175 acres).
- *Northeastern Interior Dry-Mesic-Forest* and *Northeastern Coastal & Interior Pine-Oak Forest* have low securement, low resilience, fall short of the GSPC and NE targets, and are moderately threatened by development. The former needs securement in Connecticut, Massachusetts, and Rhode Island, and the latter is especially unsecured in southern Maine. The small IPAs will likely need to be embedded in a larger matrix of protected lands to remain viable.
  - In *Northeastern Interior Dry-Mesic Forest*, Connecticut has ten IPAs on a total of 7,754 acres, nine of which are unsecured. Massachusetts has two IPAs on 2,441 acres needing protection.
  - In *Northeastern Coastal & Interior Pine-Oak Forest*, Maine (9 acres), Massachusetts (468 acres), and New Hampshire (2,612 acres) each have a single IPA needing protection.

Wetland Habitats

- *Laurentian-Acadian Alkaline Conifer-Hardwood Swamp* is well-secured in the southern part of its range, but it is predominantly in Maine, where it is largely unsecured. The habitat also needs conservation in Vermont, where only 14% of total acres and 21% of resilient acres are secured.
- *North-Central Interior Wet Flatwoods* is a rare habitat with only 25,306 acres across five states (all but Rhode Island), very little of which is protected, and most of the 16% total securement is not on resilient land. The habitat is also threatened by development. A single unsecured IPA in Massachusetts of only 67 acres should be a high priority for investigation.
- The 14,032 acres of *Glacial Marine & Wet Clayplain Forest* occur only in Vermont and are a high priority for conservation. Only 3% of total acreage is protected and 12% secured; only 14% of resilient acres are secured.
- *Laurentian-Acadian Large River Floodplain* is home to an exceptionally high density of regionally or globally rare plant species, with more than 30 rare taxa, many of which occur primarily in this habitat type. While 29% of the resilient acreage of this habitat (212,136 acres) is secured regionally, only 7% is protected (GAP 1-2). This habitat is predominantly found in Maine, where 71% of the 186,857 resilient acres are unsecured.

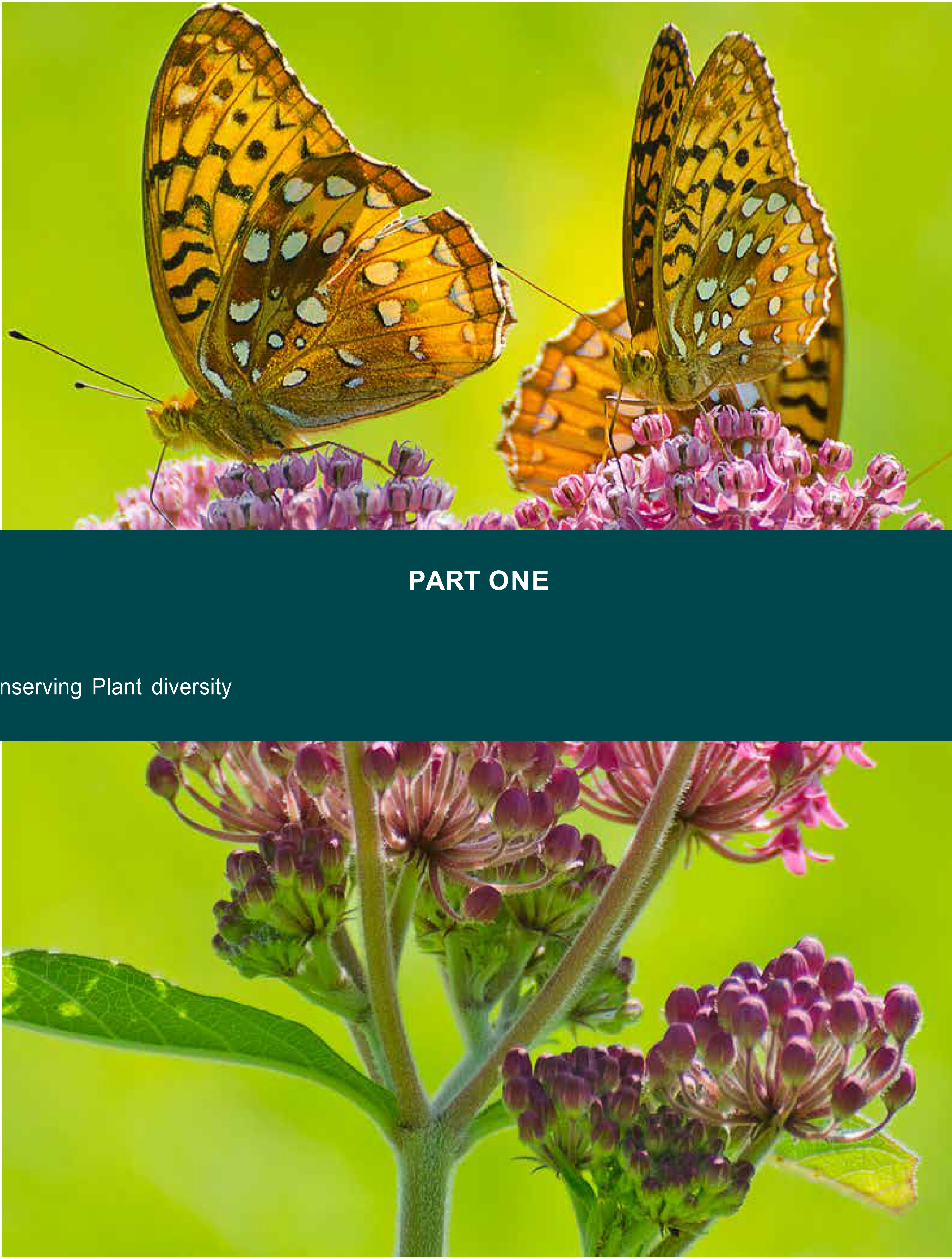
Patch-forming Habitats

- Four forest habitats are so restricted that they are included in the patch-forming habitat analysis, and two are high priority for conservation. The *North Atlantic Coastal Plain Maritime Forest* is only 15% secured in Maine, and only 18% of resilient acres are secured. Vermont's *Glacial Marine & Lake Mesic Clayplain Forest*, encompassing 32,066 acres, is only 7% secured.
  - Of the two IPAs in the maritime forest, a 500-acre site in Massachusetts needs protection.
- The coastal plain sand- and silt-based habitats are especially vulnerable to climate change. While the number of acres needed to reach targets is relatively small, it may be difficult to sustain these habitats over time. A clear focus should be saving the 36 rare plant species in the beach and dune habitats and the 8 in the coastal grassland.
  - Three *North Atlantic Coastal Plain Heathland & Grassland* IPAs in Massachusetts, encompassing 2,657 acres, are priorities; only one is protected.

Michael Piantedosi © Native Plant Trust

While this report focuses primarily on land conservation, we also examine and recommend addi- tional conservation strategies, such as assisted migration, restoration and augmentation of sites and populations, and seed banking to preserve genetic diversity. What is certain in a changing climate is that we need multi-layered, science-based approaches to saving plant diversity and the life it sustains. We know that a rapidly changing climate will stress the ability of individual species and entire habitats to adapt, and thus recognize that some will migrate, some will die, and some will form new assemblages. With this report and its mapping tool, we aim to ensure that New England's native plants—the green foundation for functioning ecosystems—are at the forefront of conservation policy and action as climate plans develop.

American chaffseed
(Schwalbea americana)
Uli Lorimer © Native Plant Trust



PART ONE

Conserving Plant diversity

PART ONE

CONSERVING PLANT DIVERSITY

Background

PLANT DIVERSITY AND RESILIENCE

In this report, we focus on the diversity and resilience of habitats rather than on plant diversity as the number of species. Plant communities translate the land's geophysical variation into living habitats that support many types of species. Conserving multiple intact examples of every habitat is a strategy for sustaining the natural benefits plants provide and for maintaining the full diversity of species that depend on them. In this section, we review the importance of habitat diversity, while in later sections we describe the habitats and rare species of the region. To account for the overarching effect of climate change on the distribution of plant species, we present an approach for identifying occurrences of each habitat that have the greatest resilience to climate change.
Using The Nature Conservancy's map of site resilience and fine-scale maps of land securement, we assess the status of each habitat with respect to protection and resilience, and we set goals for conserving a resilient network of representative habitats.

For many conservation activities, plants are considered background, yet they furnish and cleanse the air we breathe and provide the basis for our medicines and food (Grifo and Rosenthal 1997). They are the basis for all life on planet Earth, and their role in forming and maintaining the ecosystems of the world has been valued at $125 trillion per year in tangible ecological services that benefit humans (Costanza et al. 2014). Plants also remove carbon dioxide from the atmosphere and store it as wood, leaves, roots, and soil. Plants process 123 billion metric tons of carbon each year across the globe (Beer et al. 2010), thus stemming the buildup of greenhouse gases. Half the weight of a tree consists of stored carbon, and since 80% of New England is forested, forests can help reduce the impact of climate change (Catanzaro and D'Amato 2019).

Gray's flatsedge
(Cyperus grayi)

Michael Piantedosi © Native Plant Trust

For many conservation activities, plants are considered background, yet they furnish and cleanse the air we breathe and provide the basis for our medicines

Species Diversity

Plant diversity is often measured as "richness," the number of species within a given area or the average number of species within a habitat. Diversity may also be represented as taxonomic diversity (the genetic relationships between different groups of species) and be quantified by the relative abundances of the species present. Further, plant diversity may be described in terms of functional diversity—those traits of the species present in an ecosystem that influence how an ecosystem operates or functions. The structure of a plant community (trees, shrubs, herbaceous plants) is part of the functional diversity of the community.

Ecologists have long held that a more diverse community tends to be more stable, and there is some evidence to support this. A classic study in the 1990s demonstrated that grassland plots with the most species, that is, those with greater diversity, were most resistant to the effects of drought and were most likely to have a growth rebound after the drought ended (Tilman 1999). A more recent study shows that vegetation, such as a patch of prairie or forest stand, is more productive in the long run when more plant species are present (Reich et al. 2012). Moreover, when biodiversity in the landscape is reduced, as in a cornfield, pine plantation, or suburban lawn, we fail to capitalize on the natural services that biodiversity provides (Reich et al. 2012). Some studies show that high local and regional diversity enhances multiple ecosystem services over time in a changing world (Duffy 2008). Of course, many habitats (e.g., alpine areas, peat bogs) have been stable for millennia despite having relatively few species in the assemblage, suggesting that species counts are most meaningful within the context of a given region and the communities and habitats that characterize it.

Habitat Diversity

“What better expresses the land than the plants that originally grew on it?” (Leopold 1949).

Habitat diversity refers to the extent and distribution of vegetated habitats within a region. Plants have evolved to exploit almost every terrestrial situation on Earth, and in each they must negotiate the challenges and limitations of the local conditions. Thus, habitat diversity conveys information about representation of the physical landscape and sets the context for a more nuanced under- standing of richness and productivity. For example, tropical forests, with their ample warmth, moisture, and nutrients, represent almost the ideal condition for plants; as a result, they are rich in diversity. In contrast, a New England salt marsh is low in plant diversity because few species have the complex adaptations needed to tolerate cyclic exposure to air, freshwater, and saltwater, but those that do can utilize the rich sources of available nutrients. As a result, salt marshes are extraordinarily productive. These two habitats have evolved to fit different sets of physical con- ditions, and one cannot substitute for the other. Both habitats are necessary for sustaining the Earth’s diversity; thus, the principle of representation—conserving examples of every habitat—is fundamental to maintaining the diversity of life.

The New England landscape is a study in variation. Set over a complicated layering of bedrock and stamped with thousands of wetlands and waterbodies during glaciation, the region’s rocky terrain can stretch from coastal marsh to alpine tundra in a single state. As plants transform the abiotic variation into living biotic habitats, their forms and composition become the recognizable habitats that characterize the region. Gnarled wind-buffeted firs among compact cushions of tiny-flowered herbs immediately convey the underlying alpine conditions, where plants are designed to minimize exposure, conserve water, and trap heat. Wet depressions filled with huge-leaved herbs like skunkcabbage and false hellebore convey early spring near the coast and anticipate the deep shady oak-pine canopy to come. As the climate changes, we expect the compositional details of each habitat to adjust in response, but the underlying geophysical settings and terrain-driven processes to remain stable.

Habitats, as described by their characteristic plants and physical setting, are used in conservation as a coarse filter, or shorthand, for the full biotic communities they represent. Alpine habitats, for example, harbor more than 200 plant species, but the habitat’s full diversity includes the 3,000 invertebrate species supported by those plants, as well as the 30+ birds, mammals, and herptiles that depend on them both as a food base (Jones et al. 2018). Interspecies relationships may be loose or highly intertwined, such as the blooming cycle of alpine flowers, which is tuned to the seasonal availability of pollinators. Relationships can get very specific; for example, the larva of the endangered White Mountain arctic butterfly (*Oeneis melissa semidea*) feeds on only two alpine sedges, including the rare Bigelow’s sedge (*Carex bigelowii*). Evidence suggests that protecting enough habitat also conserves the associated species and relationships.

> *“What better expresses the land than the plants that originally grew on it?”* ALDO LEOPOLD 1949

Habitat diversity goes beyond a count of associated organisms. It also includes the functional differences among a diversity of traits and the fulfillment of niche roles in an ecosystem.Adiversityof functional traits is often correlated with a diversity of species in everything from phenological variation to biomass accumulation to root establishment. A study in a freshwater stream habitat found that variation in the role of plant functional diversity between seasons highlighted the importanceoffluctuationsintherelativeabundancesofleafbiomassoninsectdetritivorediversityand for ecosystem processes at various trophic levels (Frainer et al. 2014). Functional diversity canconveyresiliencebyincreasingtheoptionsavailableforrecovery,aswasfoundinastudyon short- ened intervals of climate-related wildfire, which showed that plants reliant on both soil seed banks and vegetative spread for growth were more resilient than those dependent on one strategy alone (Enright 2014). The associations between plant species richness and arthropod species richness has also been tied to the functional and structural diversity of plants in both grasslands and forests (Schuldt et al. 2019). In this study, there was a direct relationship between forest herbivores and plant species richness, a pattern that held for overall arthropod species richness because of the large proportion of herbivores.

To correctly use habitat diversity as a target for conservation, it is necessary to understand the different scales at which habitats occur and the intricate ways in which they nest. Matrix-forming forests reflect a region's dominant climate and soils, while wetland habitats respond to smaller scale hydrologic settings. Patch-forming habitats reflect very specific edaphic or disturbance factors (Poiani et al. 2000). Matrix forests define the character and fauna of the region, so in order to retain the full suite of services derived from them, they must be conserved at much larger scalesthan wetland or patch habitats (Anderson, 2008). One approach used by The Nature Conservancy(TNC) to identify areas for matrix forest conservation was to identify large 5,000- to 25,000-acre blocks of relatively unfragmented forest and then prioritize them for conservation action based on the number of embedded wetland and patch habitats (Anderson et al. 2006). Colloquially, this
was referred to as prioritizing the chocolate chip cookie with the most chips. Similarly, the IPAsidentified in this study are characterized by their dominant habitat but can be evaluated by thenumber of other habitats and the number of rare species contained within.

In summary, habitats make informative conservation targets because they reflect the region's geophysical variation, support thousands of associated species, convey resilience through func- tional diversity, and can form the basis of a representative conservation network appropriately configured and scaled to sustain diversity and services. We acknowledge, however, that habitats are messy entities. On the ground, distinctions between similar types can be subtle, and their boundaries are subject to interpretation. For this report, we use NatureServe's ecological system classification and TNC's terrestrial habitat map (Ferree and Anderson 2018). Although these are widely used tools, there is no agreed-upon scale of classification for habitats comparable to that forgenus-species. Further, like all living systems, habitats are not static entities, and their compositionis dynamic in both time and space. This makes it even more critical that we identify and conserve the most resilient examples of each habitat to ensure that the sites protected will continue to support diversity and ecological function into the future.

Climate Resilience

Climate change is expected to alter species distributions, modify ecological processes, and exacer-bate environmental degradation (Pachauri and Reisinger 2007). Assessments of past and projectedfuture climates indicate that New England is already experiencing increased temperatures and altered precipitation patterns (Dupigny-Giroux 2018). In response, trees are shifting their ranges,creating potentially new species combinations (Fei et al. 2017). Although, conservationists have long prioritized land acquisitions based on habitats (Groves 2003), nowthey need a way to ensure

that sites targeted for a specific habitat will continue to conserve biological diversity into the future,despite climate-driven changes in community composition. To address this issue, The Nature Conservancy has devised an approach for identifying climate-resilient areas based on enduring geophysical characteristics of the land (Anderson et al. 2014).

A climate resilient site is one that maintains species diversity and ecological function even as it changes in response to a changing climate (Anderson et al. 2014). Identifying resilient sites requires that we look beyond the composition and structure of the vegetation and assess the characteristics ofthe land itself. Plants experience climate at a very fine scale (inches to yards), such that a site with ample topographic and hydrologic variation is experienced by plants as a mix of microclimates. If well connected, areas of high topoclimate variation have the potential to buffer climate-change impacts by enabling local dispersal to more favorable microclimates and may also provide stepping- stones to facilitate longer distance range shifts (Suggitt et al. 2018). This "microclimatic buffering"(Willis and Bhagwat 2009) enables species to persist, even where the average background climate appears unsuitable.

Microclimate buffering was first reported in California's serpentine grasslands, where microtopo-graphic thermal climates showed a 34 °F difference between maximum values on different slopes (Dobkin et al. 1987).Another study found areas of high local landscape diversity were important for long-term population persistence of butterfly species and their host plants under variable climatic conditions (Weiss et al. 1988). Many more studies of landscape-based climate variation have now shown how local climatic variation strongly influences species persistence, leading some scientists to suggest that microclimates not only slow the rate of transition, but also may act as long-term refugia (Morelli et al. 2018; Reside et al. 2013; Ashcroft 2010; DeFrenne et al. 2013; Dobrowski 2011). In the largest and most definitive study, Suggitt et al. (2018) examined five million distribution records for 316 plant species over 30+ years across England and found that microclimatic heterogeneity strongly buffered them against regional extirpations linked to recent climate change, reducing extirpation risk by 22%.

This is all good news for New England, where topography, aspect, moisture, and elevation modify local conditions and create microclimatic patterns that are relatively predictable at the site scale.TNC staff in Vermont measured the soil temperature at six points along Rattlesnake Ridge (a site mapped as having high resilience) and found differences up to 10 °F depending on aspect, eleva- tion, and slope. Combined with moisture and bedrock differences, the small area supported sevendistinct natural community types (Goodwin, personal communication, 2019). Even at finer scales there can be considerable climatic variation. A study of ten bogs in the Adirondacks (Langdon et al. 2018) found that while coarse-scale climate models predicted they would have a relatively long growing season averaging 128 days, temperature loggers at each bog found them to be much cooler and more variable, with an average growing season of only 73 days and a range from 22 to 128 days.

Moisture and hydrologic microrefugia are likely to prove essential for species persistence, espe- cially plants (McLaughlin et al. 2017). At the site level, moisture is correlated with topography and aspect and can explain 40-72% of soil moisture variation (Yeakley et al. 1998). Mesic microenvi- ronments are generated by a wide array of hydrologic processes and may be only loosely coupledto the regional climate. Thus, the presence of wetlands, riparian habitats, and groundwater-fed springs and seeps can be used to indicate relative differences in site resilience for areas with flatter topography. The extent and variety of wetlands can be a good indicator of microclimatic variationderived from subtle differences in topography and soils that are challenging to model.

saltmarsh hay (Spartina patens)
Michael Piantedosi © Native Plant Trust

TNC's spatially explicit model of **site resilience** is based on observations that intact sites with little fragmentation and a large variety of microclimates and wetlands enable species to persist longer under a changing climate (Anderson et al. 2014). In the model, every patch of land within an ecoregion is compared, and areas with more microclimates and less fragmentation are scored as having greater resilience than flatter and more fragmented areas of the same geophysical setting. The two measured factors used by TNC to map site resilience are: 1) landscape diversity, defined as microclimatic variation derived from topography and hydrology, and 2) local connectedness, derived from local fragmentation patterns. These factors underlie the map of climate resilience that forms the base data layer used in this report.

Landscape diversity refers to landscape-based climate variation defined as the variety of temperature and moisture environments created by an area's topography, wetlands, and elevationrange. Landscape diversity is quantified by summarizing the variety of landforms, the elevation range, and the density of wetlands in a 0.4 sq km (100 acre) search area around every 30 m patch of land in the region.

Local connectedness is the degree to which a given landscape is conducive to the movement of organisms and the natural flow of ecological processes such as local dispersal (Meiklejohn et al. 2010). TNC's model of local connectedness uses 30 m data on land cover, roads, railroads, pipelines, energy infrastructure, and industrial forestry; and each element is assigned a "resistanceweight" based on its theoretical resistance to population movements. The analysis measures the connectivity of a focal cell to its surrounding neighborhood when the cell is viewed as a source of movement radiating out in all directions to simulate dispersal through a medium of mixedresistance (Compton et al. 2007).

The **site resilience score** is an equally weighted combination of landscape diversity and local connectedness applied and scored for every cell in the region relative to the cell's geophysical setting and ecoregion (e.g., low-elevation sand in the North Atlantic Coast is compared to other low-elevation sand in the North Atlantic Coast, etc.). Full methods can be found in the publishedliterature (Anderson et al. 2014; Anderson et al. 2012; Anderson et al. 2018). TNC uses the information to incorporate microclimate variation, local connectedness, and site resilience into conservation planning (see http://maps.tnc.org/resilientland/).

GLOBAL STRATEGY FOR PLANT CONSERVATION AND GLOBAL DEAL FOR NATURE

The genesis of this report was an interest in assessing how well a century or more of conservation action is protecting plant diversity in New England, as measured against the Global Strategy for Plant Conservation, which is part of the United Nations' Convention on Biological Diversity (CBD). We extended the analysis to encompass goals of the Global Deal for Nature (Dinerstein et al. 2019), which calls for protecting 30% of the world's ecosystems by 2030. The 30 by 30 goals are being incor- porated into the 2021 update to the CBD and were recently adopted by the current administration as part of its "Conserve and Restore America the Beautiful" initiative (Executive Order 14008).

Global Strategy for Plant Conservation

The Global Strategy for Plant Conservation (GSPC) was first adopted by the Conference of the Parties to the Convention on Biological Diversity (CBD) in 2002. The GSPC considers plants in the terrestrial, inland water, and marine environments. Further, it applies to the three primary levels of biological diversity as recognized by the Convention, hence plant genetic diversity, plant species and communities, and their associated habitats and ecosystems. The GSPC originally included sixteen targets to be achieved by 2010. The targets were revised for a 2020 timeline and are being updated again in 2021 with a 2030 deadline.

The GSPC emphasizes that the outcome-oriented global targets are a flexible framework within which national and/or regional targets may be developed, according to national priorities and capacities, and taking into account differences in plant diversity between countries (Convention on Biological Diversity 2012).

For this study, we primarily focus on three targets for assessing the conservation of plant diversity in New England:

- Target 4: At least 15% of each vegetation type secured through effective management or restoration
- Target 5: At least 75% of the most important areas for plant diversity of each ecological region protected with effective management in place for conserving plants and their genetic diversity
- Target 7: At least 75% of known threatened plant species conserved *in situ.*

The GSPC has a goal (Target 8) specifically related to ensuring that 75% of threatened plant species are in *ex situ* collections (seed banks and living collections at botanic gardens), which we address later in this report. In addition, prior work by Native Plant Trust achieved the first two targets: Go Botany satisfies Target 1, which is "an online flora of all known plants"; and "*Flora Conservanda:* New England" (Brumback and Gerke 2013) fulfills Target 2, "an assessment of the conservation status of all known plant species, as far as possible, to guide conservation action."

© Jenny Wollensak Lussier

Global Deal for Nature

The Global Deal for Nature (Dinerstein et al. 2019) is a landmark paper authored by nineteen prominent scientists that advances a science-driven plan to save the diversity and abundance of life on Earth. 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. The 30 by 30 target isderived from five fundamental goals of conservation science: (1) represent all native ecosystem types or "representation"; (2) maintain viable populations of all native species in natural patterns of abundance and distribution; (3) maintain ecological function and ecosystem services; (4) maximize carbon sequestration by natural ecosystems; and (5) address environmental change to maintain evolutionary processes and adapt to the impacts of climate change (Noss andCooperrider 1994). Based on these axioms, and the area needed to fulfill them, the GDN argues for 30% of each of the Earth's ecoregions to be protected by 2030.

In this report, we give more detail in the form of a 2030 New England Target (NET), demonstratinghow protection should be defined and distributed within ecoregions by translating the goal from 30% of the ecoregion to 30% of each habitat within ecoregions.

SECURED LANDS AND GAP STATUS

Land and water permanently maintained in a natural state remains the most effective, long lasting,and essential tool for conserving species and habitats (Dudley 2008). Through land securement, conservationists aim to maintain the quality of land and water by regulating its use in specific places. In New England, conservation lands are far from uniform entities; instead, they have a wide range of management intents, are governed by a variety of public and private stakeholders, and represent an array of restrictions, designations, tenures, easements, interest holders, and ownership types.

The evolution of land and water protection to encompass a broader palette of securement is oneofthe important advances in conservation, because it offers a realistic chance to create conserva-tion infrastructure at a larger scale and with a more diverse set of players. Protected reserves are still critical, but other strategies can inform responses to the increasingly complex nature of the environmental crisis.

Secured Lands: The Nature Conservancy's secured lands dataset (Prince et al. 2018) shows publicand private lands that are permanently secured against conversion to development through fee ownership, easements, or permanent conservation restrictions. Each land parcel is tagged with acreage, ownership type, and GAP status.

GAP Status: GAP status was developed by the U.S. Fish and Wildlife Service (Crist et al. 1998) as away of classifying all public and private conservation lands relative to the intent of the landowneror easement holder. It is widely used in the U.S. by public agencies, and it is included as part of the Protected Area Database maintained by the U.S. Geological Service.

GAP 1 and 2 lands are considered **protected**, and we adopt that language in this report.

- **GAP Status 1: 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 within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management. *Examples: nature reserves, Forever Wild easements, wilderness areas.*

- **GAP Status 2: Secured for Nature with Management**
  An area having permanent protection from conversion of natural land cover anda mandated management plan in operation to maintain a primarily natural state,but which may receive uses or management practices that degrade the quality ofexisting natural communities, including suppression of natural disturbance.
  Examples: national wildlife refuges, national parks.

GAP 3 lands are considered multiple use. They are secured against conversion to development butopen to many uses, including extraction and recreation.

- **GAP Status 3: Secured for Multiple Uses**
  An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type(e.g., logging) or localized intense type (e.g., mining), or motorized recreation.
  It also confers protection on federally listed endangered and threatened species throughout the area. *Examples: state forests, forest management easements, conservation restrictions on working forest.*

Unsecured lands are not permanently secured against conversion; this includes most private land.

Using GAP Status to Assess Progress: In this report, we consider land in GAP status 1-3 to be "secured against conversion" but only land in GAP status 1 and 2 to be "protected." We consider GSPC target 4 ("secured through effective management and/or restoration") and GSPC target 5 ("secured with effective management in place for conserving plants and their genetic diversity") to be equivalent to GAP 1-2 protection, as multiple-use lands do not have a mandate for sustainingthe habitats or natural features. In New England, there is an important conservation role for multiple-use lands (GAP 3) that enables us to maintain forest cover at large regional scales.
Thus, for the primary (not IPA) NE target we explicitly aim for a mix of protected land (GAP 1-2)nested within a larger matrix of multiple-use land secured against conversion (GAP 3).

The secured land dataset (Prince et al. 2018) used for this study is compiled biannually by TNC from over sixty sources. For the most part, it is a combination of public land information main- tained by each state and private conservation land information compiled by TNC's state field offices from land trusts and individuals. Staff in each state office compile the dataset for their state, assign the GAP status to each tract, and fill out the other standard fields. The completed state datasets are then compiled by the regional science office and quality checked for consistencyand discrepancies.

For this study, we overlaid the secured land dataset on the habitat and climate resilience maps to identify the proportion of each that fall within each GAP status. Only parcels where the ownership duration is permanent are included in the mapped dataset. Although many volunteer, temporary, ornon-permanent agreements may contribute to conservation, it is beyond our capacity to track andmaintain information on non-permanent ownerships or activities at a regional scale.

Michael Piantedosi © Native Plant Trust

NEW ENGLAND FLORA AND RARE TAXA

As one of the earliest colonized areas of the United States, the New England region has a long history of botanical interest and published science. Native Plant Trust's comprehensive flora of the native and naturalized higher vascular plants, *Flora Novae Angliae* (Haines 2011), is the primary reference for the region's plants. This manual has been converted into an interactive, online flora, Go Botany (Native Plant Trust 2012), that can be continuously updated to reflect taxonomic and nomenclatural changes to the flora, as well as actual changes in plant taxa of the region. This online flora for the region meets the criteria for Target 1 of the GSPC, "an online flora of all known plants" (Convention on Biological Diversity 2012).

The six states that make up New England cover more than 186,443 km^2, roughly the size of Washington State, with a comparable number of plant taxa (Farnsworth 2015). More than 3,500 species occur in the region, but almost a third of these are introduced (not native) (Haines 2011; Mehrhof 2000). Maine is the largest state in New England, covering almost half the region.
Massachusetts has the most native taxa and also the most introduced taxa. table 1 shows the breakout by state. An excellent summation of the history and development of the region's flora can be found in Native Plant Trust's "State of the Plants" (Farnsworth 2015).

TABLE 1. Number of Taxa per New England State

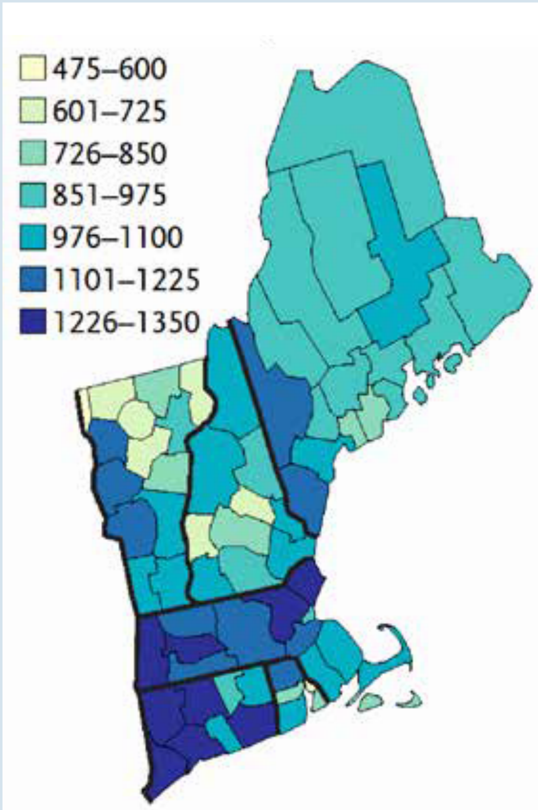
"Taxa" includes all species, varieties, and subspecies. Data also include taxa that are considered either native or naturalized but are no longer present in New England (historic). Source: Native Plant Trust's Go Botany database.

STATE	NATIVE	NON-NATIVE	SUM*	TOTAL INDIVIDUAL TAXA**
MA	1816	1487	3303	3275
CT	1731	1100	2831	2816
ME	1603	867	2470	2453
VT	1622	799	2451	2407
NH	1592	683	2275	2267
RI	1352	654	2006	1997

** Total individual taxa counted only once per state, whether native or non-native.

FIGURE 1. Native Plant Taxa in New England by County Source: Go Botany.

NUMBER OF NATIVE PLANT TAXA



Habitat and Plant Diversity

The varied physical features of New England's landscape—low coastal plains, rocky coasts, riverfloodplains, alluvial valleys, glacial lakes, forested mountains, and alpine peaks—in part accountfor the diversity of the region's flora. This following summary of the region's flora is based on Haines (2011) and Seymour (1969).

The region is home to part of the Appalachian Mountain chain, which is especially prominent in the northern states of ME, NH, and VT. Alpine habitats are also present in these states, and the highest peak in the region is Mt. Washington in NH at 1917 meters. The underlying bedrock of the region is primarily acidic (granite schist), but rock that is basic in nature (limestone, marble) is found mainly along the western border in CT, MA, and VT. Glaciers covered all but a tiny fraction of the region (part of the island of Martha's Vineyard), and before European settlement the region was primarily forests with a wide variety of coniferous and deciduous trees. New England is knownfor the extensive spruce fir-forests of NH and ME as well as several types of hardwood forest, the most renowned being the sugar maple hardwood forest, famous for its maple syrup and fall color.

All states in New England except VT border the Atlantic Ocean, and the seacoast has salt marshes and salt water species typical of eastern North America. Southeast MA and RI harbor numerous coastal plain species, many of which are typical of the mid-Atlantic states. The coastal plain pond shores of MA and RI, connected to and maintained by groundwater, are a globally rare habitat witha unique flora.

The Connecticut River, the largest in New England, flows the entire length of the region, from a small lake in NH near the Canadian border to Long Island Sound in CT. Several other large riversin the region hold recognizable plant assemblage due to their underlying bedrock and climate. These include the St. John and Aroostook rivers in ME (ice-scoured Laurentian shorelines), the Housatonic River in western MA and CT (limestone and marble bedrock), and the lower Connecticut River, Merrimack River (MA), and Kennebec River (ME), which all contain freshtidal and brackish tidal habitat.

There are several notable hotspots of rare plant diversity in New England; these are sites in which clusters of specialized plants co-occur on unusual substrates or in uncommon ecologicalcommunity types. These hotspots include the marble valleys of western New England (CT, MA, VT), Connecticut River Valley (CT, MA, NH, VT), Cape Cod and the Islands (MA), southern RI, St. John River Valley (ME), and the Presidential Range (NH) (Farnsworth 2015).

© Wikimedia / Connecticut River

Plant Rarity

From 1993 to 1996, Native Plant Trust (at that time New England Wild Flower Society) and its partners compiled data on the status of rare plants in the six New England states to formulate "*Flora Conservanda:* New England," a list of higher tracheophyte plant taxa to be prioritized for regional conservation" (Brumback and Mehrhoff et al. 1996). To account for nomenclatural and taxonomic changes since 1996 and to suggest updated priorities for protection at both the species and population level, *Flora Conservanda* was updated in 2012 by Native Plant Trust and its New England Flora Committee, which consists of representatives of each of the six New England state'sNatural Heritage programs, or their equivalents, and other botanists familiar with the regional flora. Determination for listing was based on the global rank (per NatureServe 2013) of the species and the number of Element Occurrences (EOs *sensu* NatureServe 2013) known in New England.

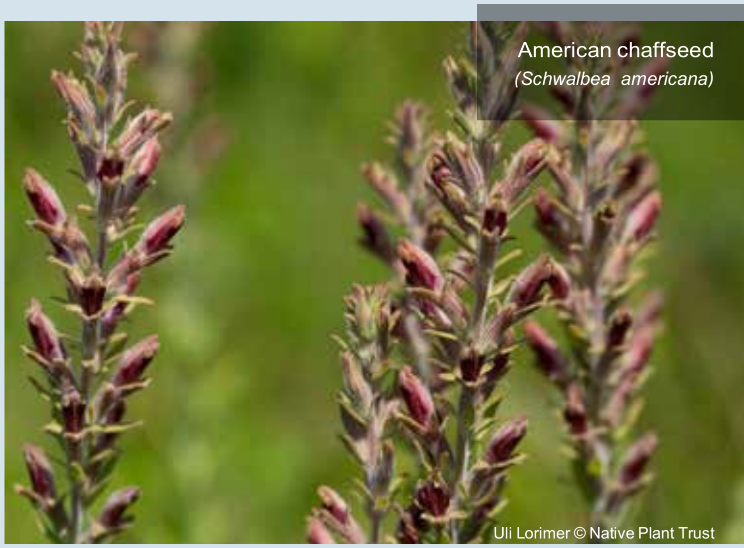
By applying strict definitions for the inclusion of a taxon within one of the five divisions, the groupidentified 593 taxa of high regional concern out of a total of approximately 2300 species indigenousto New England (Brumback and Gerke 2013).

Flora Conservanda focuses on taxa that are globally and regionally rare (Divisions 1 and 2). It also identifies taxa that may be declining throughout a significant portion of the region or that have occurrences of conservation importance owing to their biological, ecological, or (potential) genetic significance (Division 3). It further identifies taxa that are considered historic in the region(Division 4) as well as those that may be rare throughout New England, but for which taxonomic or distributional information is insufficient to determine status (Division IND). *Flora Conservanda* meets Target 2 of the GSPC, which calls for "an assessment of the conservation status of all known plant species, as far as possible, to guide conservation action" (Convention on Biological Diversity 2012).

Flora Conservanda indicates that 22% of the region's native plants are now considered rare orhave populations in need of conservation (table 2). Among them are 62 globally rare taxa and10 endemic taxa, three of which are now considered extinct. An additional 96 taxa have been extirpated from their New England range and, in many cases, are imperiled in the remainder oftheir range (Farnsworth 2015). Since publication of *Flora Conservanda*, another globally rare species, American chaffseed (*Schwalbea americana*), has been rediscovered in Massachusetts, after last being seen in the 1960s.

DIVISION	1996	2021
1 – Globally Rare	57	62
2 & 2(a) – Regionally Rare	272	326
3 – Locally Rare	76	57
4 – Historic in New England	56	95
IND – Status Indeterminate	114	53
TOTAL	**575**	**593**

See Appendix 1 ''Divisions of the List'' for definitions of these divisions and Appendix 2 for definitions of global status.



American chaffseed
(Schwalbea americana)

Uli Lorimer © Native Plant Trust

THREATS TO PLANT DIVERSITY IN NEW ENGLAND

As outlined in the "State of New England's Native Plants" (Farnsworth 2015), plant diversity in New England faces a variety of anthropogenic stressors. These include air pollution and trampling in the alpine zone; thousands of acres of forest cleared each year; more than 10,250 dams altering hydrology along rivers; fire suppression leading to succession of grassland habitats to forests; and a combination of ditching, draining, and overfishing, resulting in severe die-back of vegetation and erosion of substrate in estuarine marshes. Further, anthropogenic threats include those indirect- ly influenced by human activity, such as an overabundance of deer from having eliminated their predators. These threats have been exacerbated by the introduction of invasive plants, insects, and pathogens, which readily colonize habitats with significantly disturbed ecological processes. Each of these threats is altered or compounded by the effects of a changing climate, further pushing ecological systems out of balance.

Habitat Loss and Fragmentation

Loss of habitat is the most significant driver of declines in plant diversity. Habitat loss in a land-scape can fragment and isolate patches of suitable habitat for plant species, thereby reducing the potential for many organisms to move within a contiguous area.

Fragmentation of habitat as a result of road construction, residential and commercial development, altered hydrology (damming, locks, channeling), and associated infrastructure modifications has isolated blocks of forests, rivers, and wetlands, leading to isolated plant communities, disconnection of animal migration routes, and the breaking of intricate relationships based on connectivity that are critical to the survival of both.

With increased habitat fragmentation comes a compounding of associated threats to plant diversity through increased edge-effects. These include increased invasive species instances in native plant habitats, increased predation of interior forest birds and amphibians by edge-dwelling wildlife (and feral housecats), and alteration of microclimates by increased sunlight, wind, and soil erosion (Woolsey 2010).

Implications of fragmented habitats for plant life include a reduction of dispersal rates by seed or spore and reduced pollinator-visitation frequency, leading to declines in seed set. With habitat loss comes changes in abundance of species, affecting the network of interspecific interactions in a community. Syntheses published on plant-pollinator networks have found that many mutual- istic networks, like plant-pollinator interactions, exhibit a relatively high degree of connectivity,
especially when compared with networks of antagonistic interactions, such as food webs at various trophic levels. Literature suggests these general attributes of mutualistic networks are not only correlated with declines in habitat, but also that when maintained, impart significant stability and enable more species to persist in a community (Okuyama and Holland 2008; Bastolla et al. 2009; Thebault and Fontaine 2010).

In addition, residential, commercial, and industrial development has resulted in 1.1 million acres (21% of total land area) in Massachusetts alone being developed (Woolsey 2010), with adjacent habitats and plant communities degraded or disturbed by invasive species encroachment; light, air, and water pollution; excessive noise; and the compounded effects of each on shifting lands from carbon sinks to carbon sources.

downy rattlesnake-plaintain
(Goodyera pubescens)
Dan Jaffe © Native Plant Trust

Invasive Species

Among the many threats to global biodiversity, the movement of species across historically distinct biogeographic borders remains one of the most intractable (Facon et al. 2006; Barney and Whitlow 2008; Moles et al. 2008). Introduction of invasive organisms, largely a result of human actions, has caused plant, animal, and pathogenic pests to transform many habitats in New England. While threats of invasive species on native habitats are well documented, they vary in level of severity depending on the habitat and the invasive species in question, and they tend to dominate in areas where disturbance events are consistent. Invasive species should generally be regarded as both a direct threat and a symptom of other, broader threats (e.g., climate change, development, fire suppression, etc.) to native plant communities.

In New England, the Invasive Plant Atlas of New England (IPANE) improved our understanding of the effects and distribution of invasive plant species in the region. At the time of IPANE's inception in 2001, 30-35% of the plant species known to New England were thought to be non-native and of those 3-5% were considered aggressive invaders. Since then, the number of non-native and invasive species in New England appears to have increased slightly, as the "State of the Plants" report notes that "31% of the 3,514 documented plants are not native, and 10% of those are invasive" (Farnsworth 2015).

Introduction of invasive organisms, largely a result of human actions, has caused plant, animal, and pathogenic pests to transform many habitats in New England.

Plant communities already stressed by the effects of habitat loss and fragmentation are more susceptible to invasion from pests and pathogens. An example is the impact on plant diversity as a result of invasive earthworms. Research has shown that exotic earthworms in northern hardwood forests cause remarkable changes in soil structure, nutrient cycling, and plant communities. The most arresting of these findings is earthworm invasions turning these ecosystems from important global carbon sinks into carbon sources (Alban and Berry 1994; Bohlen et al. 2004a) through increased heterotrophic respiration (Li et al. 2002). In addition, earthworms shift the soil system from fungal dominated to bacteria dominated, resulting in a loss of important mycorrhizal-plant root relationships (Wardle 2002). Loss of mycorrhizae can lead to negative effects on plant root function (Lawrence et al. 2003), plant growth (Gundale 2002), and plant community assemblages (Holdsworth et al. 2007), ultimately affecting plant community diversity and every trophic level reliant on such diversity. In addition, an increase in earthworm diversity may cause a decrease in plant species diversity due to different earthworm species occupying multiple soil niches, such as those which live in the organic soil horizons and below in the organic-mineral horizons (Hopfensperger et al. 2011).

Altered Hydrology (anthropogenic)

Throughout New England altered hydrology, most often a result of damming and channeling rivers, drastically affects both terrestrial and aquatic plant communities. The manmade modifications shift the seasonality, level, flow rate, and regularity of river flow. The result is decreased water and ice scour, altered patterns of sediment deposition, and reduced migration of plant propagules such as seeds and rhizomes along river shores, all of which affect the composition and viability of plant communities.

Further, as modifications to lands adjacent to coastal areas and wetlands increases (impervious surfaces, storm-wall construction, development, etc.) plant diversity in these hydric systems will likely decline. A 2014 study showed the influence of elevation and salinity on vegetation structure in tidal wetlands (when compared to estuarine hydrology and other variables) and found that global climate change may lead to changes in species distributions, altered floristic composition, and reduced plant species richness in estuarine wetlands. This conclusion largely shows the likelihood of near-term changes to plant diversity as coastal plant communities face several compounding threats, including sea-level rise, increased flood intensity, and exposure of freshwater wetland plant communities to salt water (Noto 2017, Janousek and Folger 2014).

Fire Suppression

Fire suppression has removed an important disturbance event from the landscape and significantly altered New England's plant communities. Reduction of fire, primarily as a result of dense human habitation and the immediate threat of fire to infrastructure, has caused declines in fire-adapted plant communities, such as early-successional sandplains. In habitats such as sandplain grasslands and heathlands, a history of lightning-caused wildfires resulted in plant communities adapted to fire events. Without fire, much of New England's grassland habitats will over time become new-growth forests. In addition, with shortened fire intervals, species dependent on seedling recruitment (such as annuals) are more vulnerable to local extinction than are species that spread vegetatively (Enright 2014). In a changing climate, a projected reduction in post-fire rainfall in certain areas is likely to impact seedling recruitment, further altering plant diversity.

Trampling

In plant communities less adapted to regular disturbance, such as in alpine, subalpine, and bog habitats, trampling by humans can have significant negative impact. Studies have shown varied impacts of trampling in alpine and subalpine plant communities (Chardon et al. 2018; Gremmen et al. 2003), as well as the degradation of bog systems as a result of deer trampling (Pettorelli 2006)

– which will likely continue to increase as forest-edge habitat increases and with the absence of predatory megafauna (both anthropogenic impacts) keeping deer populations in control.

In incline- and elevation-driven habitats, some studies have shown that light to moderate disturbances can maintain high species diversity, while others emphasize that heavier disturbance reduces plant species richness and plant diversity. Highly disturbed and trampled alpine and subalpine systems could therefore be at greater risk for upward encroachment of lower-elevation species in a changing climate (Chardon et al. 2018).

© Clay Kaufmann

CONSERVATION ACTIONS TO COUNTER THREATS TO PLANT DIVERSITY

Protect as Much Intact, Diverse, Complex Habitat as Possible

The focus of this report is land securement—whether through purchase or conservation ease- ments—as the primary tool for sustaining plant diversity and the range of plant communities on the New England landscape. We argue that the goal is securing a proportional representation of habitats across the landscape and ensuring the sites conserved are resilient to climate change, as defined above.

There are other important conservation actions that have a prominent role in countering or mitigating threats to plant diversity.

Monitor Plant Populations for Health and Threats

Monitoring of individual taxa and entire habitats to record baseline data is crucial for effective management of species, communities, and ecological systems. This baseline of what is "normal" for a species or a habitat is often a result of both biological and historical data gathered through consistent intervals of monitoring floristic health and changes to the system.

In New England, we are fortunate to have state-level Natural Heritage programs (or their equivalent), land trusts monitoring conservation lands they own or manage, and regional community-science monitoring programs, such as Native Plant Trust's New England Plant Conservation Program (NEPCoP) and Plant Conservation Volunteer (PCV) program. NEPCoP's primary goal is to address the questions of plant rarity at the population level, taking a regional perspective on endangerment, availability of resources, and likely benefits of species and habitat management (Parks 1993). For nearly thirty years, monitoring efforts through NEPCoP and the PCV program have gathered data on imperiled plant populations throughout New England to inform applied conservation actions. Data collected through regular monitoring of imperiled plant populations are fundamental to understanding trends occurring in an ecological system over time. For example, monitoring data can reveal the disproportionate decline of insect-pollinated plant species (Farnsworth and Ogurcak 2006; Farnsworth 2015), or the regional loss of dominant forests trees in the Northeast as a result of climate change (Clark 2014). Measuring and monitoring the results of management actions such as habitat restoration or species augmentation are critical to understanding the potential for species or ecosystems to adapt to the changes brought by climate change.

Collect and Bank Seeds to Preserve the Genetic Diversity of Species and Habitats

Seed banking of wild species, one facet of *ex situ* conservation, is critical to integrated conservation measures seeking to protect plants in their native habitats (*in situ*), as seed banks provide a safety net against extinction in the wild and a source of local genotype seed for restoration projects (Havens et al. 1999). Unfortunately, there is a well-documented scarcity of seed for restoration; insufficient research in such areas as seed transfer zones, seed physiology, and longevity; and inefficient supply chains without clear documentation of seed origin and quality (Bischoff et al. 2010).

Effective seed banking collects from a range of geographically isolated species and populations andensures intraspecific genetic diversity within each collection, often achieved through randomized sampling of a population. This approach has implications not only for individual taxa, but also for successful restoration of habitats. Several studies have shown genotypic diversity among plants may play a larger role in community and ecosystem processes than previously realized (Cook-Patton 2011; Kotowska 2009). In addition, a sufficient genotypic diversity of plants sown in habitat restorations may be "biological insurance" against fluctuations in ecosystemprocesses, thus increasing the reliability of restoration measures (Bischoff 2010).

In New England, Native Plant Trust banks the seeds of imperiled taxa at highest risk of extirpationfrom the wild, has engaged in a multi-year effort to collect and bank seeds of coastal habitats for restoration of public lands, many damaged by Hurricane Sandy in 2012, and participates in the collection of tissue of common orchids for long-term banking. Further, programs such as Seeds of Success, a partnership between the federal Bureau of Land Management and botanic gardens, zoos, and municipalities, aim to collect and bank seeds from common native taxa whose presenceon the landscape are invaluable to maintaining habitat-scale function in ecosystems.

Manage Habitats for Plant Diversity Where Necessary and Feasible

Ecological management of habitat is a complex and often challenging approach to maintaining plant diversity at the ecosystem scale. Its goal is sustaining or restoring composition, structure, and function (of individual taxa or entire habitats) and enhancing resistance and resilience underclimate change. Highest priority for action is preserving exemplary, biodiverse habitats and areas important to their function and resiliency.

In New England, stewardship of terrestrial and aquatic ecosystems often requires controlling invasive species, using adaptive management techniques for species lost through succession (oftena result of fire suppression, altered hydrology, or development of wild lands), and implementing species- or habitat-specific management practices. For example, prescribed burning is commonly used for managing successional growth of trees or some invasive species, which may compete with fire-adapted herbaceous plants in habitats traditionally kept open through wildfires. Simi- larly, tree-canopy thinning enables light to reach the forest floor for spring ephemerals or certain orchids requiring increased light levels to germinate and flourish. The common thread of these different approaches is a balanced interval and intensity of disturbance events (relative to each particular habitat and plant community) to support the greatest diversity of plant species. Habitatmanagement may entail augmenting populations (see below) with plugs or small plants grown from locally-adapted, genotypic seed. Measuring success through consistent monitoring and data collection is critical to ensuring that information about techniques for preserving plant diversity can be shared with colleagues engaged in conservation and land management.

Augment and Introduce Plants

As plant communities are progressively degraded, invaded, or highly fragmented, ecological restoration becomes essential for maintaining imperiled taxa and overall plant diversity. Either augmentation (introducing plants or seeds to an extant site) or introduction (introducing plants or seeds at a new location within a species' known, historic range) of species is most effective when areas of appropriate habitat already exist. At both the species and habitat scales, augmentation or introduction with seed is typically undertaken only when other strategies to counter impacts to plant diversity have been deemed ineffective. Best practices include: establishing baseline data on species' populations, plant communities, and entire habitats (including historic and projected data when possible); comprehensive research into reproductive ecologies and seed germination; consistent and long-term monitoring of augmentation and introduction sites; and strategic partnerships with scientists and organizations with specialties in species conservation and ecological restoration (Havens, Guerrant, and Maunder 1999; Havens, Kramer, and Guerrant 2014).

Conduct Assisted Migrations

With compelling evidence that climate change will be a significant driver of extinction (McCarthyet al. 2001; McLaughlin et al. 2002; Root 2003; Thomas et al. 2004), ecologists and land managersmust consider the implications of using assisted migration (sometimes referred to as "managed relocation") to protect plant diversity. Assisted migration is one way of facilitating range shifts for plant species that may not be able to adapt in place and are restricted—by limits to propagule dispersal or significant barriers to migration routes—in their ability to move outside their historicrange in response to climate or other environmental changes.

Over the past two decades, a healthy and often contentious debate has surfaced in the scientificcommunity over the costs and benefits of assisted migration as a climate-adaptation strategy for plants and wildlife (Hulme 2005; Hunter 2007; McClanahan et al. 2008; Sax et al. 2009). This discussion has led to the development of multiple frameworks for weighing and evaluatingecological, legal, and ethical factors (Hoegh-Guldberg et al. 2008; Joly and Fuller 2009; Richardsonet al. 2009; Sandler 2010).

Among the contentious issues is the lack of research into fundamental biological questions thatcould form the scientific basis for sound policies: Which species should be moved? What is the demographic threshold to initiate a need for assisted migration? How can populations be introduced while minimizing adverse ecological effects?


goldenseal (Hydrastis canadensis)
Dan Jaffe © Native Plant Trust

Those against assisted migration assert that it is folly to assume ecologists are capable of determining when assisted migration will be effective and whether translocated species will do more harm thangood (Ricciardi and Simberloff 2009; Seddon et al. 2009). They cite the unpredictable (and often negative) impacts of invasive species and a lack of comprehensive understanding into the function of ecological systems, particularly in a changing climate. Disconnected and fragmented lands furthercomplicate the migration of species and habitats, and those areas with high connectivity may be otherwise degraded or their biodiversity configurations may be different from what a particular species has adapted to within a given historic range. Often the arguments made against assisted migration as a conservation strategy refer directly or indirectly to the precautionary principle; and thus, due to many unknown variables in the process of moving and introducing plants, assisted migration should be avoided. Opponents argue that the potential for invasive spread of a plant species that has been relocated to avoid extinction is too great a riskto overall ecologicalfunction, and that the data are not available to determine the invasive potential of manyspecies (Simberloff 2009).

Those in favor of assisted migration also point to precautions, but focus on the unknown ecological impacts of allowing plants to become locally or regionally extirpated or driven to permanent extinction by rapidly changing climates (Sax et al. 2009). Further, those arguing for assisted migration rebuff the claims about the lack of knowledge on the invasion potential of native species beyond their historic ranges (as many examples of this are available, particularly for more common species) and disagree that assisted migration is or would be enacted haphaz- ardly, without ecological context. Most proponents of assisted migration argue for a systematic and gradual approach to moving species beyond their historic ranges, and frequently the methodsdescribed for moving plants mimic the typical dispersal range of their propagules. This nuanced approach often focuses on predicted climate envelopes that could support the species.

With this report, we hope to further the discussion about assisted migration by delineatingareas of high climate resilience where, if the sites are protected, plant species facing high extinction threats may find refuge, both within and beyond their historic ranges.


© Steven Scholom

Conservation of Habitats and Important Plant Areas

INTRODUCTION

Terminology

This report uses several terms that describe ecological units across a variety of scales. When describing a broad, ecologically-distinct area, we have chosen to use the terms (from broadest to finest scale): ecoregion, macrogroup, ecological system. When describing plant groups at a finer scale, we have chosen to use the terms (from broadest to finest scale): habitat, plant community, vegetation type, plant association. These terms, which denote particular groupings of plants, are used interchangeably, but are consistent throughout this report in reference to scale.

Each of these terms is defined as follows (NatureServe 2016; TNC 2020):

- **Ecoregion**: Part of a larger ecozone, ecoregions are large units of land and water that contain a geographically distinct combination of natural communities and species, share similar characteristics (such as climate and soils), and interact in ways that are critical for the long-term viability of the communities and species.
- **Macrogroup**: The fifth level in the U.S. National Vegetation Classification (NVC) natural vegetation hierarchy, in which each vegetation unit is defined by a group of plant communities with a common set of growth forms and many diagnostic plant taxa, including many charac-teristic taxa of the dominant growth forms, preferentially sharing a broadly similar geographic region and regional climate, and disturbance regime (cf. Pignatti et al. 1995, and Braun- Blanquet concept of “Class”).
- **Ecological system** (synonymous with “habitat”): A terrestrial ecological system is defined as a mosaic of plant community types that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients, in a pattern that repeats itself across landscapes. Systems occur at various scales, from “matrix” forested systems of thousands of hectares to small patch systems, such as cliffs, basin wetlands, or barrens on a particular bedrock type, of a hectare or two.
- **Habitat** (synonymous with “ecological system”): A general term referring to the locality, site, and particular type of local environment occupied by an organism or community (adapted from Lincoln et al. 1998).
- **Plant community**: A group of plant species living together and linked together by their effects on one another and their responses to the environment they share (modified from Whittaker 1975). Typically the plant species that co-occur in a plant community show a definite association or affinity with each other (Kent and Coker 1992).
- **Vegetation type**: A named category of plant community or vegetation defined on the basis of shared floristic and/or physiognomic characteristics that distinguish it from other kinds of plant communities or vegetation (Tart et al. 2005a).
- **Plant association**: A vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy (Jennings et al. 2006).

Ecological system, habitat, ecosystem, natural community, and natural association refer to a variety of scales but are generally applied to ecological facilitation, which encompasses climate, hydrology, geological structure, soil, flora, and fauna.

Plant community, vegetation type, and plant associations refer to the floristic makeup of an area, primarily focused on the plants and plant interactions.


Uli Lorimer. © Native Plant Trust

Overview and Methods

In this section we evaluate the conservation status of New England's habitats relative to global and regional targets, identify trends in securement and conversion, and make recommendationson where to focus conservation efforts. Additionally, we for the first time identify 234 ImportantPlant Areas, the conservation of which would move us a long way toward meeting both habitat and species goals.

We assess the conservation status of each habitat relative to well-developed international goals inthe Global Strategy for Plant Conservation (GSPC; Convention on Biological Diversity 2012) and regional goals developed for New England based on the Global Deal for Nature (Dinerstein et al. 2019; see "Background" for details).

GSPC Target 4: At least 15% of each vegetation type secured through effective managementand/or restoration (GAP 1-2 protection).

NE Target: At least 5-15% of each habitat protected (GAP 1-2) and at least 30% secured againstconversion (GAP 1-3). At least 75% of the securement on climate-resilient land.

The Global Deal for Nature advocates for conserving representatives of all native habitats and viable populations of all native species by protecting 30% of the landscape by 2030. The New England target builds on this by adding criteria to ensure that sites are more resilient to climate change and by adding more detail to the types of securement.

Why Focus on Climate Resilience?

A key tenet of this document is that to succeed in sustaining plant diversity over the next century,we must focus protection on sites with the highest climate resilience. Site resilience is defined asthe ability of a site to sustain diversity and ecological functions into the future, even as species move and vegetation types change in response to a changing climate (Anderson et al. 2014). To identify resilient sites, we use an approach known colloquially as "Conserving Nature's Stage" (Beier et al. 2015). This approach is based on the strong evidence and ample observations that although climate sets broad distribution limits and regulates the region's overall species pool, the places where species and communities are actually found, where they are persisting, and where they will be in the future are determined primarily by the properties of the land: soil, geology, topography, elevation (Anderson and Ferree 2010).

Our "Conserving Nature's Stage" approach asserts that rather than trying to protect biodiversity one species at a time, we should protect the ultimate drivers of biodiversity. The world has alwaysexperienced some measure of climate change, and species ranges are not fixed. Accordingly, we should seek to maintain the landscape features that ultimately control species richness. Plant distributions are coupled with moisture, light availability, and soil chemistry and texture, which in turn reflect geology and topography. This relationship is so tight that in New England, we can predict the total number of plant species present in every state (adj. $R2 = 0.94$) just by knowing theamount and types of geology present, the latitude, and the elevation range (Anderson and Ferree 2010). Studying how the current distribution of plant species and vegetation communities is coupledwith the distribution of geophysical variables enables us to develop a conservation plan that protectsdiversity under both current and future climates.

The vegetation map used in this assessment (figure 2, Ferree and Anderson 2013) provides a snapshot of how vegetation is currently distributed, and it illustrates how the current vegetation is correlated to landforms, geology, soils, and moisture patterns. The "random forest" models that underlie the distribution of each vegetation type integrate both climatic and geophysical variables. As the climate changes, the land's geophysical properties endure and can be used to predict where habitats might be in the future or where the land is buffered from change due to topography. This isthe principle behind the TNC climate resilience map used in this assessment (figure 2, Anderson et al. 2014), which was created directly from the geophysical variables with the understanding thatwhile the climate might change, the topography, soils and elevation gradients will not—at least not for the next several centuries. Using the two maps together enables us to create a conservation plan that starts with what is there now but incorporates a different future, while maintaining a highdegree of certainty with respect to what places will be important under many scenarios.

The geophysical variables used in the climate resilience map (figure 3, Anderson et al. 2014) were derived based on their importance to plant species and natural community distributions. That makes them useful as a basis for representation, because it gives us the tools to measurethe distribution of secured lands across all the landscape properties needed to support the fullspectrum of plant diversity.

FIGURE 2. The Northeast Terrestrial Habitat Map

This dataset (Ferree and Anderson 2015) maps the distribution of 140 types of forests, wetlands, unique communities, and tidal systems across the Northeast. To explore the map andview the legend, go to http://nature.ly/NEhabitat

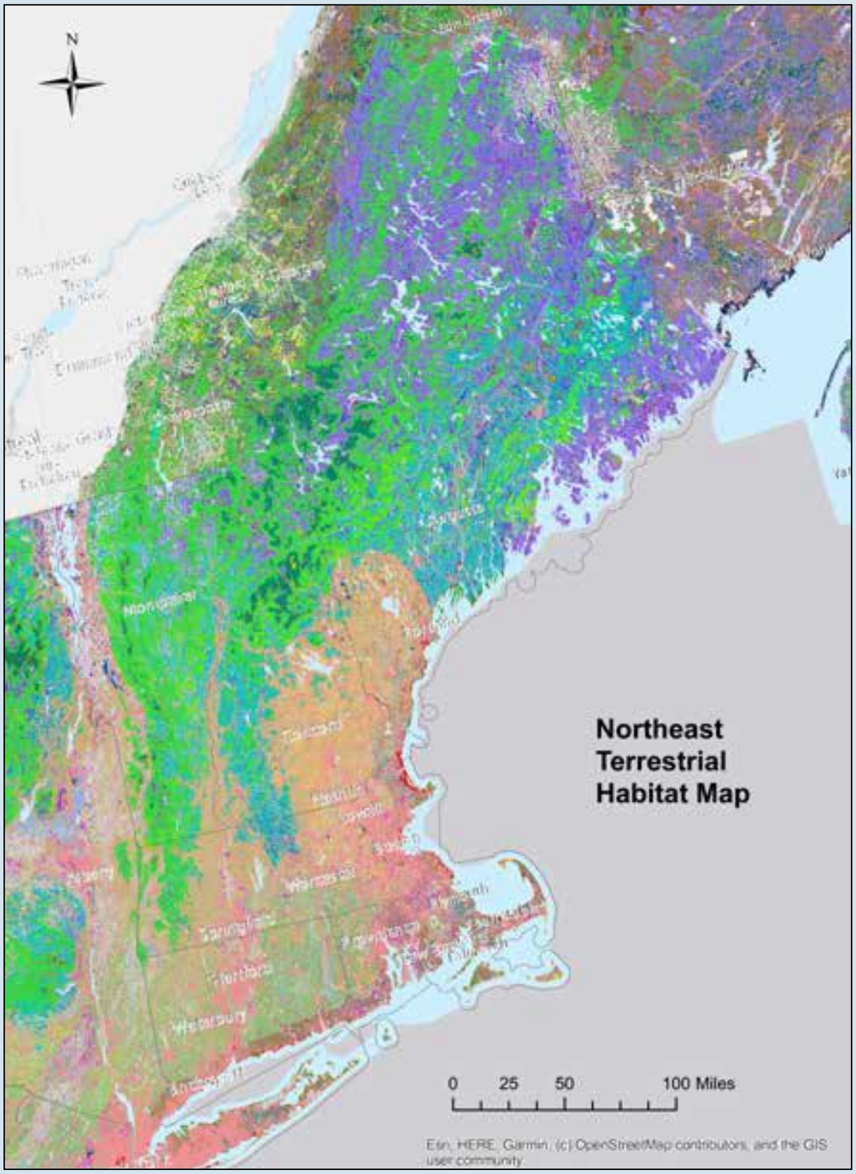
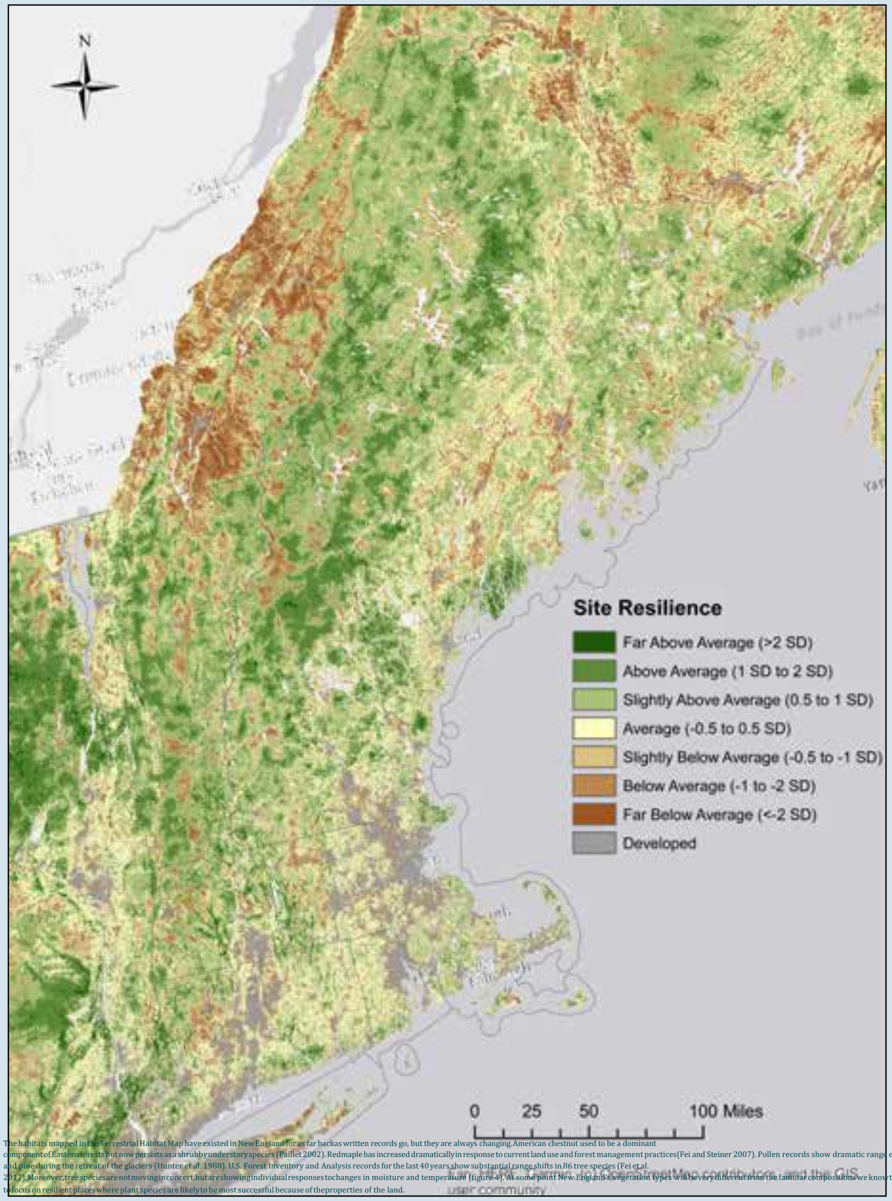


FIGURE 3. The Northeast Terrestrial Resilience Map

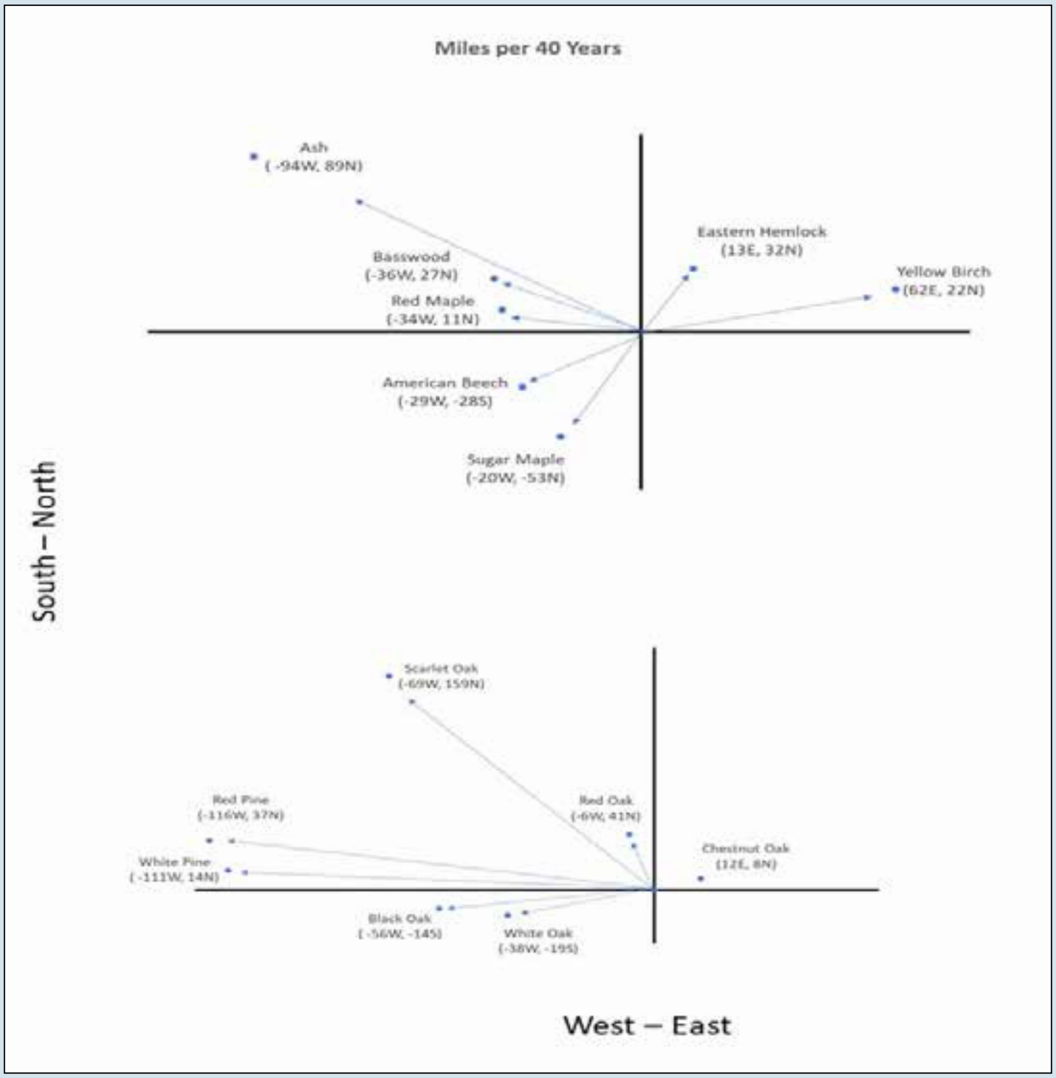
This map shows the areas with the most microclimates and the highest connectedness (i.e., highest resilience) relative to all the distinct geophysical settings within each ecoregion(Anderson et al. 2017). This map and underlying data can be explored using this web tool:http://maps.tnc.org/resilientland/



The habitats mapped in the Terrestrial Habitat Map have existed in New England for as far backas written records go, but they are always changing. American chestnut used to be a dominant component of Eastern forests but now persists as a shrubby understory species (Paillet 2002). Redmaple has increased dramatically in response to current land use and forest management practices(Fei and Steiner 2007). Pollen records show dramatic range expansions and complete range shiftsof oaks and pine during the retreat of the glaciers (Hunter et al. 1988). U.S. Forest Inventory and Analysis records for the last 40 years show substantial range shifts in 86 tree species (Fei et al. 2017). Moreover, tree species are not moving in concert, but are showing individual responses to changes in moisture and temperature (figure 4). At some point New England's vegetation types will be very different from the familiar compositions we know today. This reinforces the need to focus on resilient places where plant species are likely to be most successful because of the properties of the land.

FIGURE 4. Tree Range Shifts over the Last 40 Years

These charts show the direction and distances that the distribution centers of Eastern trees have shifted over the last 40 years, based on U.S. Forest Inventory and Analysis data (Fei et al.2017). The upper chart for Northern Hardwoods shows maple and beech moving west and south, likely following increases in moisture, while hemlock and yellow birch have moved north, likely following increases in temperature. The lower chart for Oak-Pine forests shows a similar pattern.



CONSERVATION OF HABITATS: PROGRESS TOWARD GLOBAL AND REGIONAL GOALS

The global and regional goals we use to evaluate the conservation status of New England's habitatswere fully described above. Below we compare each group of habitats to the GSPC targets and to a customized NE target that considers the scale of the habitat, the resilience of the land, and therelative amounts of securement and protection.

To create realistic ten-year NE targets, we divided the habitats into three groups:

- Matrix Forest: the ten dominant forest types that cover 86% of the natural landscape
- Wetland Habitats: the swamps, bogs, floodplains, and marshes that cover 12% of the natural landscape
- Patch-forming Habitats: the summits, cliffs, dune, and barrens that are embedded in the matrix of forests and wetlands. Although patch habitats make up only 2% of the natural landscape, they are hotspots of plant diversity.

Grouping the vegetation types this way enabled us to develop and assess New England-specifictargets that reflect the natural distribution and resilience of these communities.

Michael Piantedosi © Native Plant Trust

Matrix Forest

GSPC Target 4: At least 15% of each forest type secured through effective managementand/or restoration (i.e., GAP 1-2 protection).

NE Target: At least 5% of each forest type protected (GAP 1-2) and at least 30% of each securedagainst conversion (GAP 1-3). Resilient land makes up 75% of total securement.

New England's dominant vegetation is forest. The 28 million acres of forest create a connected matrixof natural cover composed of ten distinct habitats, each covering a half million to eight million acres.An additional four forest types are now so small and scattered that, with respect to goals, we treated them as patch-forming habitats (see section below).

Collectively, forests provide the region's primary ecosystem services, especially carbon sequestration.Climate regulation, water storage and filtering, pollution mitigation, and oxygen production. Eco- nomically, they support a century-long timber industry that harvests 8.2 million cords annually for building materials, fuel, fiber, and lumber (NEFF 2017) and support modest markets for maplesyrup, holiday decorations, edibles, and medicinal plants as well. New England forest forms the natural backdrop for hunting, fishing, hiking, and camping, and the surrounding matrix in which high-diversity wetlands or patch-forming habitats are embedded. Intact forests have a marked vertical structure of canopy, understory, and herbaceous layer, and sustain moderate levels of plant diversity skewed toward shade-tolerant species.

Most of New England's forest is privately owned and managed for wood supply; and the majority of secured forest is multiple use and actively managed for recreation and timber harvest. To ensure that carbon continues to be removed from the atmosphere and naturally filtered clean water is available for New England citizens, advocates like Harvard's David Foster have argued for keeping 70% of New England forested (Foster et al. 2017). That means retaining 100% of the existing forest. Foster's Wildlands and Woodlands initiative (W&W) aims for 10% of natural lands protected as wildlands (i.e., protected as GAP 1-2) and 70% actively and sustainably managed for wood, food, and other values. The New England Forestry Foundation has endorsed the W&W vision and argues that not all of the 70% needs to be under securement because a healthy forest-based economy and strategic tax incentives could ensure that much of the land stays forested (private land enrollment incurrent use tax programs is 58%; Perschel et al. 2014).

Currently, 21% of New England's forests are secured against conversion and 3% are protected. Securement is very unevenly distributed across forest types, with southern forests having less securement. Increasing securement to meet the NE target (30% and 5%) focused on resilient examples of every forest type would move us toward both the W&W 10% protection goal and the GSPC 15% protected target. The climate-resilience criteria in the NE target is critical if we are to ensure tangible, lasting results in the face of climate change.

Results: Only one forest habitat currently meets both the GSPC and NE targets: *Acadian- Appalachian Montane Spruce-Fir-Hardwood Forest* (table 3). This high-elevation forest forms the backdrop of New England's hiking and "peak-bagging" culture and is largely out of the range of practical timber management. *Laurentian-Acadian Northern Hardwood Forest*, the maple-beech-birch mix that gives New England its fall color and the dominant forest across the northern part of the region, also meets the NE target but not the GSPC target. This habitat is 30% secured against conversion, with 7% secured for nature; 96% of that is on resilient land.

Because this forest covers 8.3 million acres, this is a relative success story, although we still needanother 249,000 protected acres to reach the W&W 10% and another 415,000 protected acres beyond that to meet the GSPC target of 15%. Intelligently applied sustainable management practiceson the secured multiple-use land might be able to sustain many of the functions of the forest type.

A few other habitats are close to meeting the NE target. Maine's *Acadian Sub-boreal Spruce Flats* are just 21,000 acres short, and both the *Acadian Lowland Spruce-Fir-Hardwood Forest* and *Laurentian-Acadian Red Oak-Northern Hardwood Forest* partially meet the target, with more than 5% protected and more than 85% on resilient lands, but less than 30% secured against conversion. In all, reaching the full NE target will require an additional to 2 million acres of forest conservation on resilient lands as well as effective management on the 5.3 million acresalready in GAP 3 (table 4). Reaching the GSPC goal of 15% protection across all matrix forest habitats will require investing in 3 million acres, through a combination of acquisition and increasing GAP levels on already secured land.

TABLE 3. Goal Assessment for Matrix Forests

Columns 2-5 show the % protected, resilient (R), and secured. Columns 6-7 indicates if it meets (Y) or partially meets (P) the GSPC and NE targets. Column 8 estimates the acreage of resilientland to be secured/protected to meet the NE target of 30%.

MATRIX FORESTS	% PROTECTED (GAP 1-2)	% R	% SECURED FROM CONVERSION (GAP 1-3)	% R	GSPC	NET	RESILIENT ACRES FOR 30%
Montane Spruce-Fir-Hardwood Forest	38%	99%	62%	98%	Y	Y	
Northern Hardwood Forest	7%	96%	30%	89%		Y	
Lowland Spruce-Fir-Hardwood Forest	6%	85%	26%	72%		P	196,801
Sub-boreal Spruce Flat	5%	83%	29%	74%		P	20,806
Coastal Plain Hardwood Forest	5%	46%	19%	44%		P	67,475
Red Oak-Northern Hardwood Forest	5%	92%	18%	92%		P	131,907
Interior Dry-Mesic Oak Forest	4%	46%	18%	42%			166,952
Hemlock-Northern Hardwood Forest	3%	70%	18%	67%			463,408
Coastal & Interior Pine-Oak Forest	2%	40%	17%	38%			194,748
Pine-Hemlock-Hardwood Forest	2%	74%	14%	67%			735,828
TOTAL							**1,977,926**

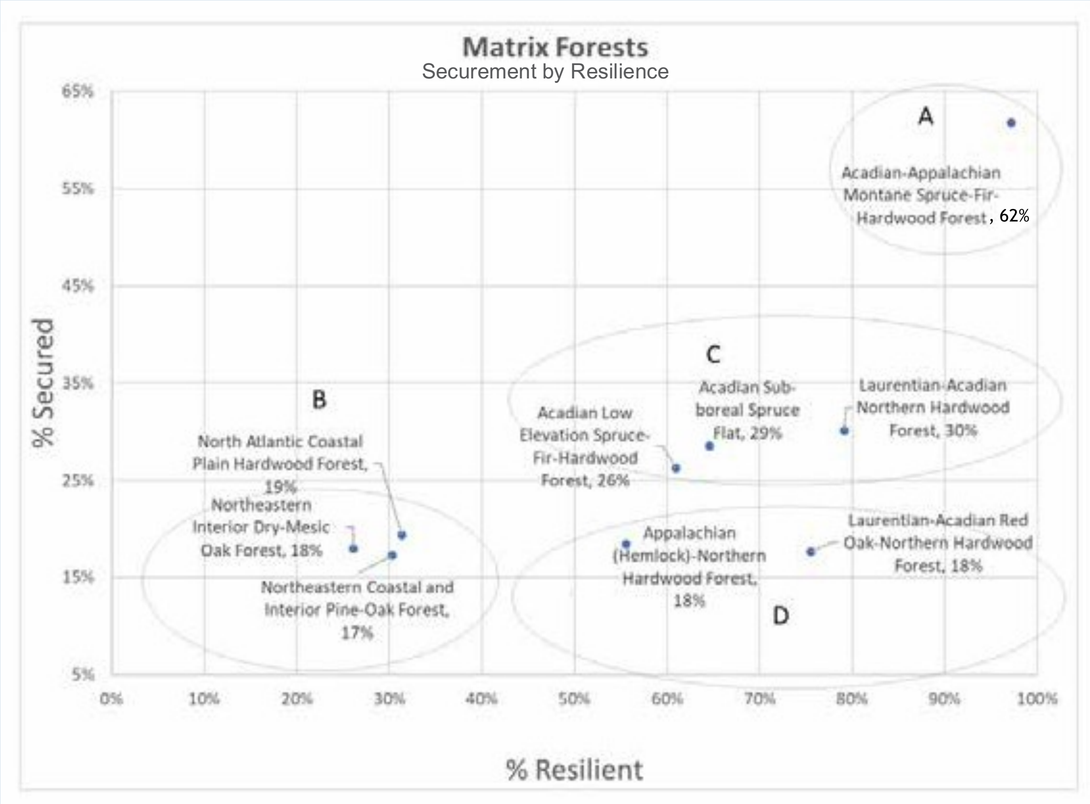
TABLE4. ImprovedManagement

Currentandpotentialacresofmultiple-useland(GAP3)byforesttype. Theselandswillneedrigorous creation and enforcement of best management practices if they are to provide the expectedbenefitstopeople,plants,andwildlife.

MATRIX FORESTS	% GAP	ACRES GAP 3	% INCREASE IN RESILIENT LAND FOR 30%	RESILIENT ACRES FOR 30%
Montane Spruce-Fir-Hardwood Forest	23%	204,967	0%	0
Northern Hardwood Forest	23%	1,914,169	0%	0
Red Oak-Northern Hardwood Forest	23%	326,824	16%	131,907
Sub-boreal Spruce Flat	20%	1,063,434	2%	20,806
Lowland Spruce-Fir-Hardwood Forest	15%	620,338	6%	196,801
Hemlock-Northern Hardwood Forest	13%	137,930	21%	463,408
Pine-Hemlock-Hardwood Forest	14%	90,825	34%	735,828
Coastal Plain Hardwood Forest	14%	188,525	34%	67,475
Coastal & Interior Pine-Oak Forest	15%	227,828	42%	194,748
Interior Dry-Mesic Oak Forest	11%	508,535	46%	166,952
TOTAL		**5,283,374**		**1,977,926**

FIGURE 5. Matrix Forest Securement by Resilience

This chart shows the average securement (GAP 1-3) and the average resilience score across all acres of each forest type. A = high securement, high resilience, B = low securement, low resilience, C = average securement, average resilience, and D = low securement, average resilience. Total securement (GAP 1-3) is listed after the forest name.



Some forest types are urgently in need of targeted conservation. The mid-elevation *Laurentian-Acadian Pine-Hemlock-Hardwood Forest* has relatively high resilience but the lowest protection (2%) and securement (14%) of any forest type. Our coastal and southern interior forests also have challenges with resilience. *North Atlantic Coastal Plain Hardwood Forest, Northeastern Interior Dry-Mesic Oak Forest,* and *Northeastern Coastal & Interior Pine-Oak Forest* have low securement, low resilience, and

fall far short of the GSPC and NE targets (figure 5, group b). The lower resilience is due to these forests occurring on gentle lowland topography and being more fragmented by roads, powerlines, and development, reflecting the populated portion of New England where they are found. *North Atlantic Coastal Plain Hardwood Forest* does meet the NE target of 5% protected, but less than half of that is on resilient land. *Northeastern Interior Dry-Mesic Oak Forest* and *Northeastern Coastal & Interior Pine-Oak Forest* are both in high need of conservation, with less than 20% secured against conversion, less than 5% protected, and less than half of land already secured being resilient. The collective acreage needed to reach the NE 30% target for both forest types is relatively small (361,700 acres), and there is an ampleamount of these forests on resilient land.

A large portion of our forests (5.3 million acres) are lands managed for multiple uses (table 4). This could be an effective and cost-efficient strategy for conservation, but if the strategy is to succeed, these lands will need science-based and rigorously applied management aimed at producing the natural benefits and sustaining the diversity that we depend on. A discussion of the best forest management practices to sustain biological diversity and increase carbon is beyond the scope of this report, but suffice it to say improving forest management to maintain biodiversity, store carbon,and yield a sustainable harvest is an area of active research.

Wetland Habitats

GSPC Target 4: At least 15% of each wetland type secured through effective management and/orrestoration (i.e., GAP 1-2 protection).

NE Target: At least 10% of eachwetland habitat protected (GAP 1-2) and at least 30% of eachsecured against conversion (GAP 1-3). Resilient land makes up 50% of securement.

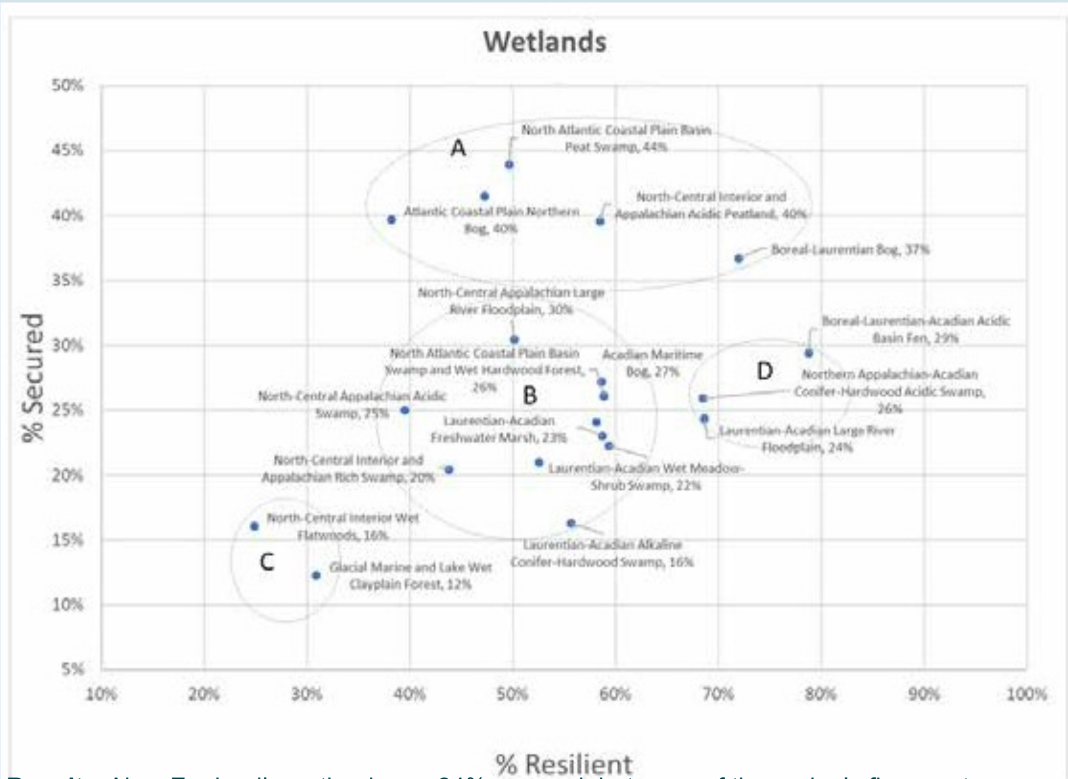
Wetlands are essential to sustaining New England's plant diversity. The four million acres of swamps, bogs, marshes, fens, and floodplains that punctuate the landscape contain four to five times the density of rare plant species of upland forests (based on an overlay of Natural Heritageprogram rare species locations on the vegetation map). Although wetlands make up only 12% of the natural lands, roughly 48% of the total vascular flora are legally considered to be obligate orfacultative to wetlands (Lichvar et al. 2016).

The resilience approach targets larger unfragmented wetland complexes that are likely to persist over time. Small individual wetlands occurring in fragmented landscapes tend to score low for resilience, reflecting their vulnerability to the effects of climate change. As some kinds of wetlands occur predominantly in the latter context (figure 6, group b), resilience scores are intertwined withwetland type. For example, less than half of New England's freshwater marshes occur as large unfragmented complexes; most are scattered and small. Wet basins, moist depressions, ponds, andlakes help sustain the resilience of larger areas because they are cooler and moister than their surroundings, and this function will likely become more important as temperatures rise (McLaughlinet al. 2017; Simsek and Odul 2018). To account for the differences between wetlands and matrix forests in the NE target, we kept the criterion for base securement at 30%, increased the percentage of protection to 10% (GAP 1-2), and lowered the resilience criteria to 50% on the existing securedlands. The aim is to focus new acquisition on wetlands with the highest resilience, while acknowl-edging that vulnerable wetlands currently secured will remain important in the future due to theirtopographic setting, even if the structure and composition are compromised.

FIGURE 6. Wetland Securement by Resilience

This chart shows the average securement (GAP 1-3) and the average resilience score acrossall acres of each wetland type. A = high securement, moderate resilience, B = moderate securement, moderate resilience, C = low securement, low resilience, and D = moderate securement, high resilience. Total securement (GAP 1-3) is listed after the wetland name.

Securement by Resilience



Results: New England's wetlands are 24% secured, but none of the region's five most common wetland types meet either GSPC or NE targets, although most do occur on resilient land, and most have more than 20% securement (table 5). Six wetland habitats meet the GSPC target of 15% protection, but they are all unique small-acreage swamps or peat bogs (table 5). Most of these alsomeet the NE target. *Acadian Maritime Bog* and *North Atlantic Coastal Plain Basin Swamp & Wet Hardwood Forest* are short in overall securement, and *Coastal Plain Basin Peat Swamp* falls short inresilience. Urgently in need of protection are *Laurentian-Acadian Alkaline Conifer-Hardwood Swamp*, *North-Central Interior Wet Flatwoods*, and the *Glacial Marine & Lake Wet Clayplain Forest*, which have little protection or securement (figure 6). Perhaps the protection of commonwetlands is lower thanexpected because regulations are in place to prevent the destruction of wetlands; however, without targeted conservation action, it is unlikely the full diversity of wetlands will persist. Reaching the NE target will require securing an additional 253,902 acres of resilient wetland, while meeting the GSPC target would require 405,083 acres of newly protected wetlands.

Tidal wetlands are a special case. Despite relatively high levels of securement, we are still losing these wetlands due to inundation by sea-level rise. This phenomenon has been studied in detailby The Nature Conservancy (Anderson and Barnett 2017), which recommends conserving the "migration space" adjacent to each wetland to facilitate its migration landward and thus support its persistence. Not all existing wetlands have access to migration space, and much of the availablemigration space is not necessarily even in natural cover; but currently 33% of the migration space is secured against conversion, including 17% that is already protected. Most of that is associated with resilient sites.

TABLE 5. Goal Assessment for Wetlands

Columns 2-5 show the percent secured and percent of that which is on resilient land (%R).Columns 6-7 indicate if the wetland type meets (Y) or partially meets (P) the GSPC and NE targets. Column 8 gives the acreage of resilient land to be secured to meet the NET 30%. Superscript next to the name indicates the rank in total acreage of five most common types.Although tidal salt marsh protection is included in the table, the protection of existing salt marsh is not a useful indicator due to inundation by sea-level rise.

WETLAND HABITATS	% PROTECTED (GAP1-2)	% R	% SECURED FROM CONVERSION (GAP 1-3)	% R	GSPC	NET TARGET	RESILIENT ACRES FOR 30%
Acadian Maritime Bog	25%	61%	27%	63%	Y	P	149
Boreal-Laurentian Bog	23%	71%	37%	74%	Y	Y	
Coastal Plain Basin Swamp/Hardwoods	22%	63%	26%	62%	Y	P	24
Coastal Plain Basin Peat Swamp	17%	49%	44%	48%	Y	P	
Tidal Salt Marsh	17%	56%	42%	52%	NA	NA	12,863
Tidal Marsh Migration Space	17%	94%	33%	91%	NA	NA	
Coastal Plain Northern Bog	16%	75%	40%	56%	Y	Y	
Interior/Appalachian Acidic Peatland	15%	33%	40%	52%	Y	Y	
Acadian Acidic Basin Fen	10%	80%	29%	85%		P	1,819
Appalachian Large River Floodplain	9%	43%	30%	56%		P	
Acadian Large River Floodplain	7%	73%	24%	81%			17,434
Freshwater Marsh[5]	7%	74%	23%	70%			25,734
N. Conifer-Hardwood Acidic Swamp[1]	6%	84%	26%	80%			31,289
Wet Meadow-Shrub Swamp[4]	5%	74%	22%	71%			38,109
Appalachian Acidic Swamp[2]	5%	51%	25%	46%			30,464
Interior/Appalachian Rich Swamp	5%	54%	20%	50%			24,048
Alkaline Conifer-Hardwood Swamp[3]	4%	71%	16%	75%			78,818
Wet Clayplain Forest	3%	71%	12%	37%			2,489
Interior Wet Flatwoods	3%	38%	16%	26%			3,525
TOTAL							**253,902**

Patch-forming Habitats

GSPCTarget 4: At least 15% of each habitat type secured through effective management and/orrestoration (i.e., GAP 1-2 protection).

NE Target: At least 15% of each patch-forming habitat protected (GAP 1-2) and at least30% of each secured against conversion (GAP 1-3). Resilient land makes up75% of securement.

Patch-forming habitats are terrestrial plant communities that occur in small patches on the land-scape, nested within, and often contrasting with, the background matrix of forest and wetlands. Although patch habitats make up only 2% of New England's natural land, and none of them has more than 150,000 acres of total extent, they are hotspots of plant diversity. The summits, cliffs,barrens, dunes, grassy openings, and talus slopes have a density of rare species ten times higherthan wetlands and forty times higher than upland forests, based on an overlay of species tracked by the state Natural Heritage programs. The overlay illustrates how important some of these communities are to rare plant species: alpine (66 species), acidic cliffs (38 species), calcareous cliffs (23), beach and dune (36), coastal grassland (8). The acreage of these communities may be dispersed as thousands of small patches (e.g., acidic cliffs) or clumped as in alpine tundra.

Patch-forming habitats are small in extent and concentrated in their biodiversity, and thus are more vulnerable to localized threats. Currently only 21% are secured against conversion. To recognize their high biodiversity value and small extent, we increased the NE protection targetto 15%, which matches the GSPC target, while keeping the securement target at 30% and the climate resilience target high: 75% occurring on resilient land.

We included four forest types in this section (instead of the matrix forest section, where they appear in Part Two) because their current distributions are so restricted to small patches that the higher NE target for patch-forming habitat is more appropriate. These are: *North Atlantic Coastal Plain Pitch Pine Barrens*, *Northeastern Interior Pine Barrens*, *North Atlantic Coastal Plain Maritime Forest,* and *Glacial Marine & Lake Mesic Clayplain Forest*.

Results: Seven patch habitats meet the GSPC target, but only four of those also meet the NE targetfor area and resilience (table 6). In general, the rocky landform-based habitats (e.g., cliff, summit) tend to have a high resilience score, reflecting the microclimates associated with their settings. Most of these habitats meet both targets. The coastal plain sand and silt communities occur mostly on climate-vulnerable land, with only 19-50% of the secured examples occurring on resilient sites. Two of these communities–*North Atlantic Coastal Plain Pitch Pine Barrens* and *North Atlantic*

Coastal Plain Heathland & Grassland–are also fire dependent. These habitats may be able to tolerate warming temperatures better than some, but their fragmented and developed settings could make burning difficult. The third, *North Atlantic Coastal Plain Beach & Dune*, is already experiencing a change in sea level. Unlike tidal salt marshes, which are literally migrating inland in response to sea-level rise, it is unclear what the future holds for the creation of new beaches to replace those drowned by inundation. Slightly elevated dune systems are more likely to persist through the next century, albeit as increasingly isolated islands.

The percent of the habitat that meets resilience goals differs dramatically between the bedrock- based communities, which are mostly above the 75% mark (figure 7 a & d) and the sand/silt-based communities, which score much lower (figure 7 b & c). Because patch habitats are small, only an additional 7,556 acres are needed to reach the GSPC 15% protected target and 17,726 to reach the NET 30% securement based on acres alone. But it would require an additional 88,620 acres of targeted resilient land to bring the sand/silt-based systems (pine barrens, dune, heathland) up to the target for climate resilience. Sustaining these habitats could be a challenge.

Two forest habitats are so restricted that they may be better thought of as patch-forming habitats need urgent conservation attention: *North Atlantic Coastal Plain Maritime Forest* and Vermont's *Glacial Marine & Lake Mesic Clayplain Forest*. The latter has very little protection or securement.

Two patch-forming habitats that just reach into New England are not included in the full assessment in Part Two but are shown in the tables and charts here for completeness. They are *Central Appalachian Dry Oak-Pine Forest* and *Central Appalachian Pine-Oak Rocky Woodland*.

TABLE 6. Goal Assessment for Patch-Forming Habitats

Columns 2—5 show the percent secured and percent of that which is on resilient land Columns 6–7 indicate if the habitat type meets (Y) or partially meets (P) the GSPC and NE targets. Column 8 gives the acreage of resilient land to be secured to meet the NET 30% and, in italics, *the additional resilient acres required to meet the 75% resilience criterion.*

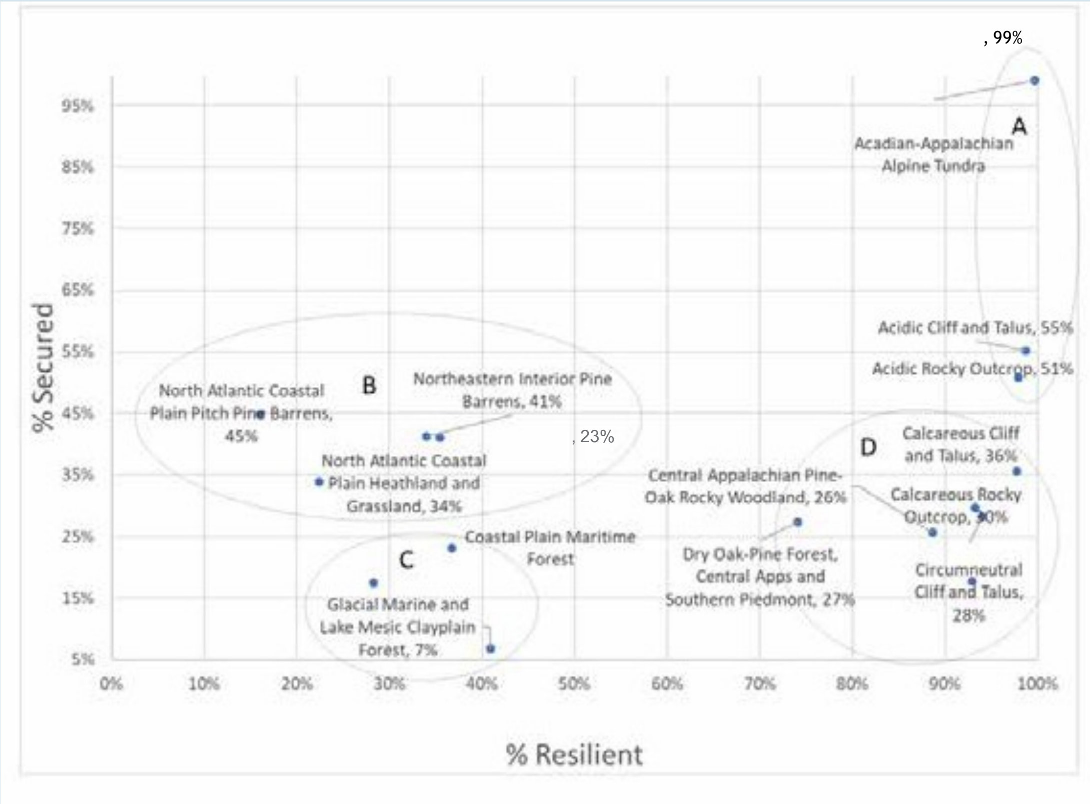
PATCH-FORMING TERRESTRIAL HABITATS	**% PROTECTED (GAP1-2)**	**% R**	**% SECURED FROM CONVERSION (GAP 1-3)**	**% R**	**GSPC**	**NET TARGET**	**RESILIENT ACRES FOR 30% SECURED / 75% RESILIENT**
Acadian-Appalachian Alpine Tundra	85%	100%	99%	100%	Y	Y	
Acidic Cliff & Talus	36%	99%	55%	99%	Y	Y	
Acidic Rocky Outcrop	30%	100%	51%	99%	Y	Y	
Coastal Plain Pitch Pine Barrens	16%	31%	45%	19%	Y	P	*58,431*
Northeastern Interior Pine Barrens	9%	49%	41%	33%			*8,403*
Coastal Plain Beach & Dune	27%	54%	41%	50%	Y	P	*9,140*
Calcareous Cliff & Talus	15%	99%	36%	99%	Y	Y	
Coastal Plain Heathland & Grassland	21%	23%	34%	25%	Y	P	*12,646*
Calcareous Rocky Outcrop	11%	100%	30%	99%			118
Circumneutral Cliff & Talus	9%	97%	28%	95%			242
Central Apps Dry Oak-Pine Forest	7%	87%	27%	80%			3,146
Central Apps Pine-Oak Rocky Woodland	7%	88%	26%	90%			1,366
Coastal Plain Maritime Forest	12%	51%	23%	47%			5,400
Mesic Clayplain Forest	3%	77%	7%	57%			7,454
TOTAL							**17,726 / 88,620**

FIGURE 7. Patch-Forming Habitats by Resilience

This chart shows the average securement (GAP 1-3) and the average resilience score across all acres of each patch habitat. A = high securement, high resilience, B = moderate securement, low resilience, C = low securement, low resilience, and D = moderate securement, high resilience.

Total securement (GAP 1-3) is listed after the community name.

Patch-Forming Habitats
Securement by Resilience



Risk of Conversion

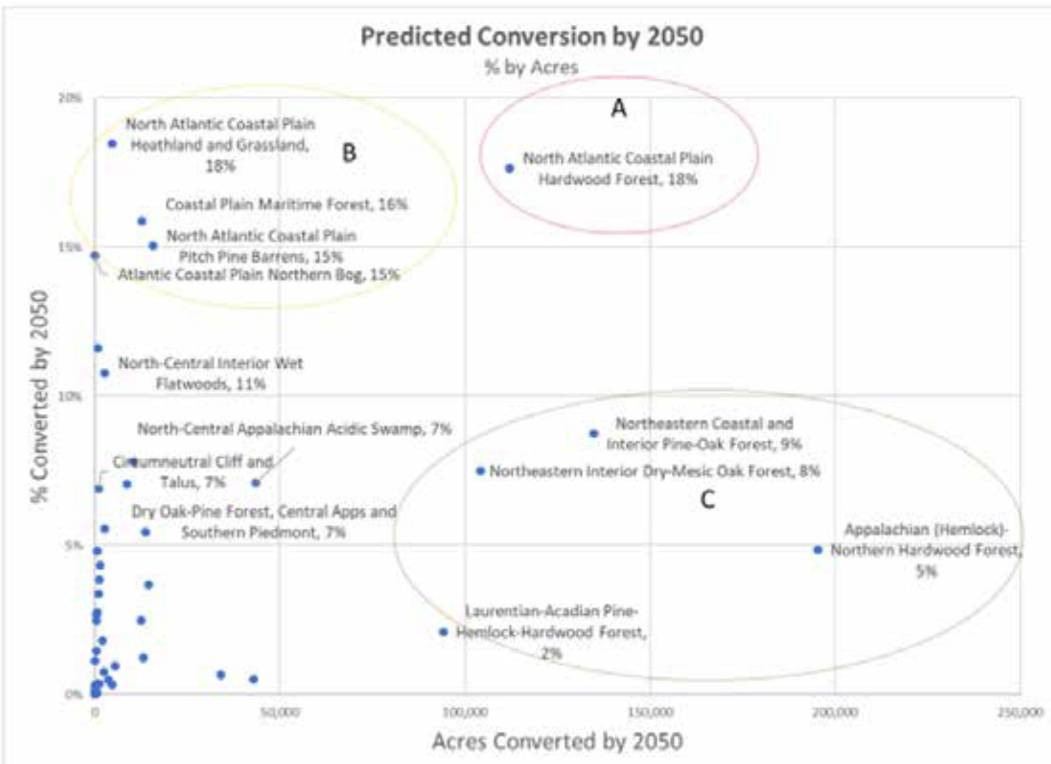
Throughout this report we note that securing land against conversion to development is often a first step toward protecting the land for nature and natural processes. In many parts of New England, the threat of habitat loss through direct conversion to development remains high and is estimated to total almost a million acres by 2050.

To understand how this is distributed across habitats, we used a Land Transformation Model developed by the Human-Environment Modeling and Analysis Laboratory at Purdue University (Tayyebi et al. 2012) to estimate the amount of each habitat predicted to be lost to development over the next 30 years. In this model, the quantity of urban growth at county and city scales is simulated using population, urban density, and nearest-neighbor-dependent attributes; areas near current development are the most likely to convert to development.

The results indicate large difference in the amount and percentage of likely development for each habitat. Several coastal plain patch-forming habitats are likely to lose a significant portion of their extent (15% to 18%), although because they are small, the total acres lost would be less than 75,000 (figure 8, group b). At the other end of the spectrum, three of southern New England's matrix forest types are predicted to lose more than 100,000 acres each (figure 8, group c), but because they are so dominant on the landscape, it is less than 10% of their respective extents. The most threatened habitat is *North Atlantic Coastal Plain Hardwood Forest*, which is predicted to lose more than 100,000 acres, equal to 18% of its current extent.

FIGURE 8. Threat of Conversion

The proportion of each habitat predicted to be developed is plotted against the total acreage predicted to be lost. A= high percent loss, high acreage loss. B = high percent loss, low acreage loss, C = low percentage loss, high acreage loss.



CONSERVATION OF IMPORTANT PLANT AREAS

Important Plant Areas for Diversity and Resilience

The GSPC calls for the identification and protection of Important Plant Areas (IPA) around the world, and several countries have completed IPA strategies as part of their national plans underthe Convention on Biological Diversity. We therefore made identifying IPAs in New England a high priority, as securing these areas would be one of the most substantial approaches to land conservation for plant diversity.

In this section, we assess the resilience and habitat characteristics of the land on which rarespecies occur. The goal is to ensure that we conserve the areas of highest site resilience thatalso support a diversity of rare species, and, if possible, a diversity of habitats. Areas of high site resilience have the most topographic microclimates and the highest degree of connectedness relative to their geology, soil, and elevation zone, making them natural strongholds where speciesare likely to persist longer in the face of climate change.

Definition and Location of IPAs

The GSPC sets three basic criteria for an Important Plant Area:Criteria A: threatened species

Criteria B: exceptional botanical richness

Criteria C: threatened habitats

A site can be identified as an IPA if it qualifies under **one or more** of these criteria(www.plantlife.com/criteria).

For this study, we defined an IPA as a contiguous patch of resilient land with a high diversity of rare plant species relative to its size. Rare plants were limited to globally and regionally rare specieslisted as division 1, 2 or 2a in *Flora Conservanda* (Brumback and Gerke 2013). Resilient land was defined as land with an above-average site resilience score based on the TNC resilience map (Anderson et al. 2014). We adopted the global GSPC goal and created a regional NE target as follows:

GSPC Target 5: At least 75% of the most important areas for plant diversity (IPA) of each ecological region protected, with effective management in place for conservingplants and their genetic diversity (i.e., GAP 1-2 protection).

NE Target: At least 30% of each resilient area with the highest rare plant diversity (IPA)protected and at least 75% of each IPA secured against conversion (GAP 1-3) across habitats and states.

To identify and map IPAs, we first created a dataset of contiguous resilient land in GIS by groupingadjacent cells of resilient land into larger aggregates and converting them to polygons, which we called "resilience patches." Next, we overlaid known locations of rare plants on the resilience patches and tabulated the size of the patch and the number of species and taxa per patch. To account for the size difference in the patches, we used a regression model to predict the average number of rare taxa based on the patch size ($R2= 0.11$, $P <0.0000$) and then calculated the standardized residuals (the difference between the observed value and the predicted value)
to identify sites that had more rare taxa than expected from their size. Note, the dataset andoverlay are from 2014 and were used with permission; however, they do not reflect recent years of inventory (details in Anderson et al. 2014).

golden-club
(Orontium aquaticum)
Liza Green © Native Plant Trust

The results identified 234 IPAs (figure 9) spread across all six states. Collectively the IPAs cover 2.6 million acres and contain multiple populations of 212 Flora Conservanda species. Each site supports an average of three rare taxa, but diversity ranges from 2 to 26 taxa depending on the size of the site. Large IPAs over 100,000 acres average 11 taxa (range 5-26), small 100-acre sites average 6 taxa (range 5-6), and tiny 10-acre patches average 2 taxa (range 2-5). All sites scored high for climate resilience, but small sites will need to be assessed for their landscape context and likely nested within larger protected sites if they are to retain their species.

FIGURE 9. Important Plant Areas (IPAs)

These 234 sites are climate-resilient areas with multiple populations of *Flora Conservanda* Division1 and 2 species. Very high diversity = 9 taxa, range 5-26; high diversity = 3 taxa, range 2-5.

Resilient and High Diversity Resilient and Very High Diversity

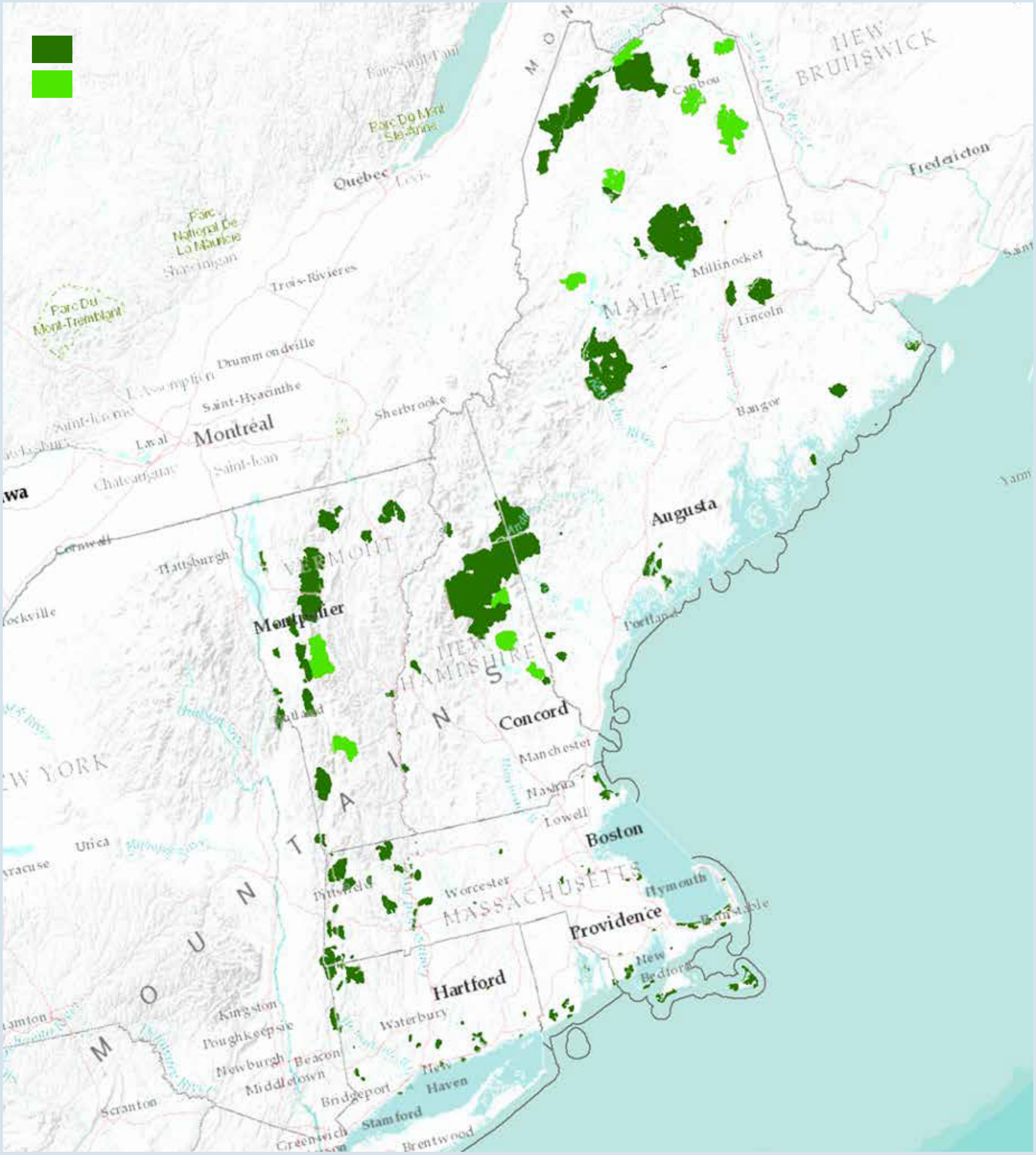
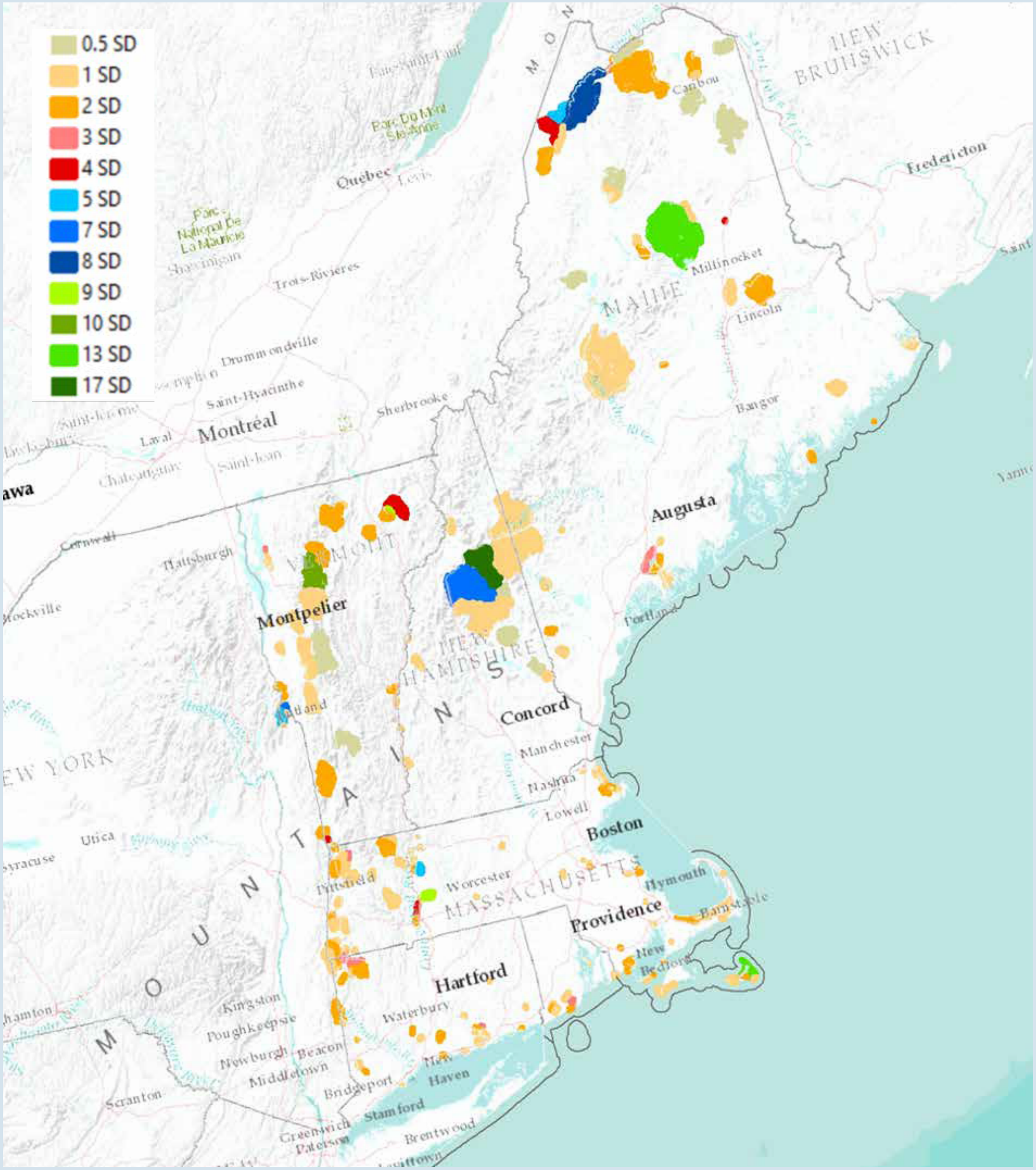


FIGURE 10. IPAs by Diversity Status

The average resilient site in New England has less than one rare species, but the IPAs have many more. The colors indicate the number of standard deviations above the mean each IPA has. The highest-scoring site (15 SD above the mean) is a 106,000-acre mountain site in NH with 26 rare plant taxa and 506 total rare species occurrences.



Conservation Status and Progress Toward IPA Goals

To assess conservation goals, we labeled the IPAs with their primary state of occurrence, dominant habitat type, and degree of protection. Although all IPAs contain multiple habitats, tagging them with the dominant habitat enabled us to assess their ecological distribution across the region.

Conservation Status of Sites: GSPC Target 5 defines its IPA goal in terms of the number of sites protected. Here we define a protected IPA as one with 75% or more of its area in GAP status 1 or 2. Of the 234 IPAs, only 10 (4%) meet this criterion, and these are distributed relatively evenly across matrix, patch, and wetland habitats (table 7). An additional 32 sites (14%) have 75% of their area secured (GAP 1-3) in a combination of protected and multiple-use land. These 32 sites are mostly forest dominated and occur on state lands or private lands with a conservation easement that permits management. A strategy for these places might be to raise the GAP status inside the IPA boundary by designating the area as a place of recognized biodiversity value or botanical concern. Of the remaining 192 IPAs, 155 have some level of securement, including 122 with GAP 1-2 in some portion of the site (although the securement does not add up to 75% of the area). These warrant further investigation, with a goal of either expanding the area protected or fee acquisition where possible and appropriate. The remaining 37 IPAs have no securement whatsoever and would benefit from on-the-ground investigation to establish both priority for and feasibility of conserving these sites.

Conservation Status by Area: The individual IPAs differ dramatically in size, so it is helpful to assess protection by total area rather than by counting the sites protected. This reveals a clearer picture of conservation progress. Of the 2.6 million acres included in the IPAs, 29% are protected (GAP 1-2) and another 23% are on multiple-use land (GAP 3); thus 52% of the IPA area is in some level of securement (table 7).

Collectively, the set of IPAs dominated by the following habitats are all more than 30% protected, although only two are more than 75% secured (table 7): *Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest, North Atlantic Coastal Plain Maritime Forest, North Atlantic Coastal Plain Pitch Pine Barrens, Laurentian-Acadian Northern Hardwood Forest, Boreal-Laurentian Bog, North-Central Appalachian Acidic Swamp,* and *Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp*.

These results reflect the fact that the IPAs differ in size and that protection may be concentrated in a few sites.

Individually, 19 IPAs meet both the protection (30%) and securement (75%) of the NE target. These are mostly forest-dominated IPAs.

Boreal Upland Forest: *Acadian Low-Elevation Spruce-Fir-Hardwood Forest (3), Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest (2)*

Northern Hardwood & Conifer Forest: *Appalachian (Hemlock)-Northern Hardwood Forest (3) Laurentian-Acadian Northern Hardwood Forest (7)*

Central Oak-Pine Forest: *North Atlantic Coastal Plain Maritime Forest (1), North Atlantic Coastal Plain Pitch Pine Barrens (1), Northeastern Interior Dry-Mesic Oak Forest (1)*

Grassland & Shrubland: *North Atlantic Coastal Plain Heathland & Grassland (1)*

Conversely, the set of IPAs dominated by the following habitats collectively have less than 10% protection: *Laurentian-Acadian Pine-Hemlock-Hardwood Forest, Northeastern Coastal & Interior Pine-Oak Forest, North-Central Interior Wet Flatwoods, Laurentian-Acadian Wet Meadow-Shrub Swamp, and North-Central Appalachian Large River Floodplain.*

See Appendix 3 for a complete list of IPAs by habitat and state, with acreage, GSPC protection status, and percent of area protected and secured.

TABLE 7. Protection and Securement Status of the IPAs #P = the number of IPAs with more than 75% protection#S = the number with more than 75% securement

#U includes 155 sites with some level of protection or securement but below 75% in total

IMPORTANT PLANT AREAS BY DOMINANT HABITAT	BY COUNT			BY AREA		
	#P	#S	#U	Protected (GAP 1-2)	Multiple Use (GAP 3)	Total Secured
MATRIX FOREST HABITATS	**9**	**26**	**145**	**29%**	**23%**	**52%**
Boreal Upland Forest	**3**	**5**	**13**	**35%**	**25%**	**60%**
Acadian Low-Elevation Spruce-Fir-Hardwood Forest	3	3	13	10%	22%	32%
Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest		2		68%	29%	97%
Central Oak-Pine Forest	**3**	**4**	**26**	**16%**	**12%**	**28%**
North Atlantic Coastal Plain Hardwood Forest		1	11	15%	12%	27%
North Atlantic Coastal Plain Maritime Forest	1		1	44%	0%	44%
North Atlantic Coastal Plain Pitch Pine Barrens	1	2	4	55%	34%	89%
Northeastern Interior Dry-Mesic Oak Forest	1	1	10	13%	12%	25%
Northern Hardwood & Conifer Forest	**3**	**17**	**106**	**27%**	**22%**	**49%**
Appalachian (Hemlock)-Northern Hardwood Forest	2	5	59	12%	19%	31%
Laurentian-Acadian Northern Hardwood Forest	1	11	35	30%	22%	52%
Laurentian-Acadian Pine-Hemlock-Hardwood Forest			11	5%	13%	18%
Northeastern Coastal & Interior Pine-Oak Forest		1	1	5%	27%	32%
PATCH-FORMING HABITATS	**1**	**1**	**11**	**14%**	**16%**	**30%**
Grassland & Shrubland	**1**	**1**	**11**	**14%**	**16%**	**30%**
Agriculture			7	15%	5%	20%
Atlantic Coastal Plain Beach & Dune			3	16%	8%	24%
North Atlantic Coastal Plain Heathland & Grassland	1	1	1	11%	37%	48%
WETLAND HABITATS		**5**	**34**	**29%**	**24%**	**53%**
Central Hardwood Swamp			**1**	**0%**	**0%**	**0%**
North-Central Interior Wet Flatwoods			1	0%	0%	0%
Freshwater Marsh & Shrub Swamp		**1**	**7**	**25%**	**21%**	**46%**
Laurentian-Acadian Freshwater Marsh			6	27%	16%	43%
Laurentian-Acadian Wet Meadow-Shrub Swamp		1	1	7%	60%	67%
Large River Floodplain		**1**	**2**	**0%**	**47%**	**47%**
North-Central Appalachian Large River Floodplain		1	2	0%	47%	47%
Northern Peatland			**1**	**37%**	**1%**	**38%**
Boreal-Laurentian Bog			1	37%	1%	38%
Northern Swamp		**2**	**9**	**34%**	**24%**	**58%**
North-Central Appalachian Acidic Swamp		1	6	32%	27%	59%
North-Central Interior & Appalachian Rich Swamp		1	2	28%	18%	46%
Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp			1	48%	9%	57%
Tidal Marsh		**1**	**14**	**24%**	**35%**	**59%**
North Atlantic Coastal Plain Tidal Salt Marsh		1	14	24%	35%	59%
Open Water / Lakeshore			**2**	**0%**	**0%**	**0%**
TOTAL	**10**	**32**	**192**	**29%**	**23%**	**52%**

Representation of Habitats in the IPAs

The IPAs make a perfect starting point for conserving resilient sites that contain rare species and represent a range of habitats. An efficient strategy would be to prioritize IPAs whose dominant habitat is generally not well conserved, as discussed in a previous section. Toward that end, we assessed the representation of habitats within the 234 IPAs to see how much of each habitat would be protected if conservation efforts focused on the IPAs. This assessment goes much deeper into the IPA composition than did the dominant-habitat analysis above, as many habitats (for example, *Cliff & Talus*) never dominate an IPA but occur across many sites.

For matrix forest (figure 11), most of the IPA acreage occurs in the more northern forest types, but it also occurs in types urgently in need of conservation, such as *North Atlantic Coastal Plain Hardwood Forest, Northeastern Coastal & Interior Pine-Oak Forest,* and *North Atlantic Coastal Plain Maritime Hardwood Forest.*

For wetlands, all the common habitats (figure 12) have ample IPA acreage, including *Laurentian- Acadian Wet Meadow-Shrub Swamp, Laurentian-Acadian Freshwater Marsh,* and *Laurentian-Acadian Large River Floodplain*. The wetland habitats most urgently in need of protection all occur in IPAs also needing protection, especially *Laurentian-Acadian Alkaline Conifer-Hardwood Swamp* and to a lesser extent *North-Central Interior Wet Flatwoods* and *Glacial Marine & Lake Wet Clayplain Forest.*

Patch habitats are well represented in the IPAs (figure 13). Among the habitats with IPAs needing protection are *North Atlantic Coastal Plain Heathland & Grassland, Calcareous Rocky Outcrop,* and *Circumneutral Cliff & Talus.*

Elizabeth Farnsworth © Native Plant Trust

FIGURE 11. IPA Representation of Matrix Forest Habitats
Collectively the 234 IPAs encompass 2.6 million acres, most of which is forest.

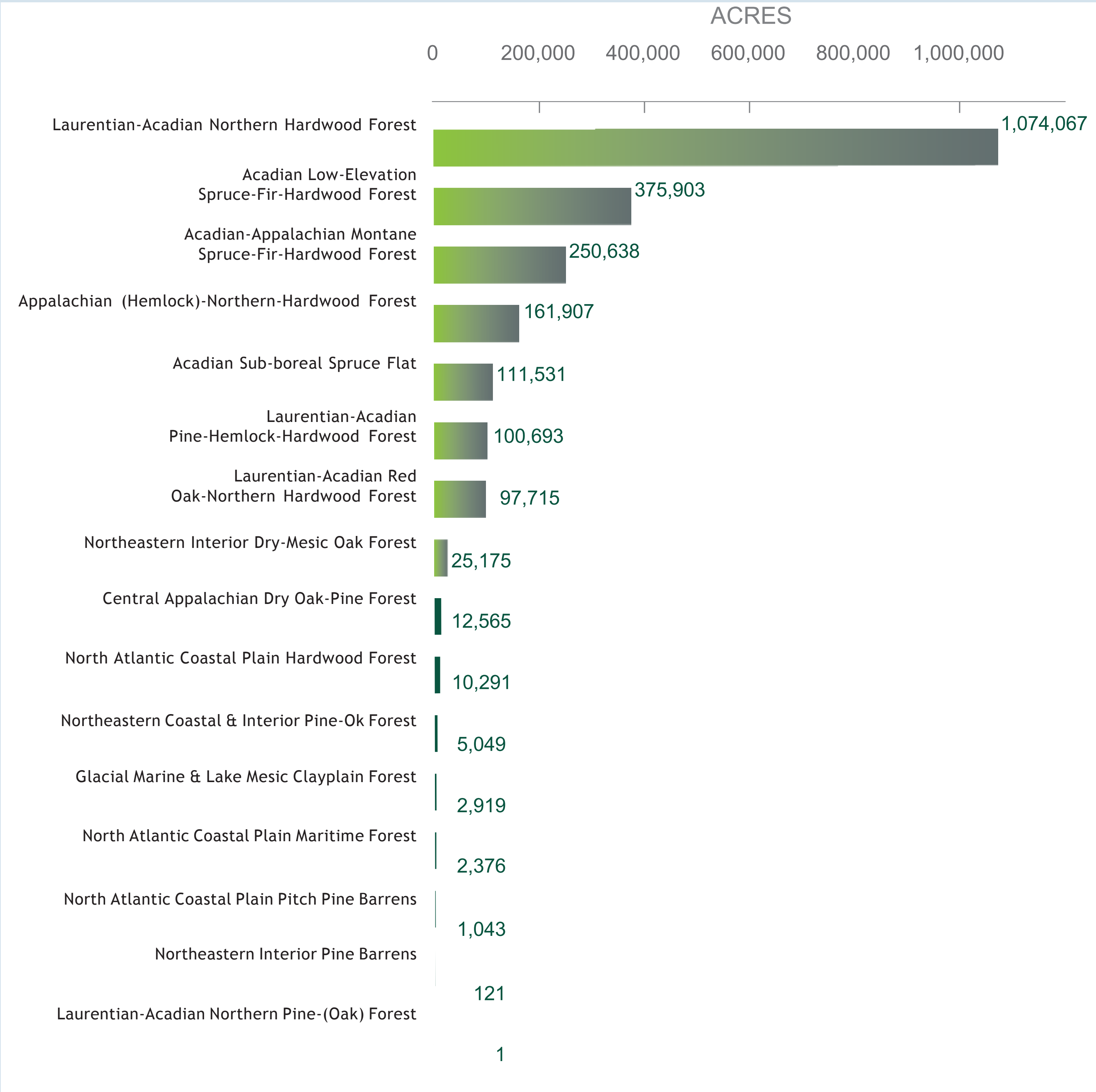


FIGURE 12. IPA Representation of Wetland Habitats

Collectively the 234 IPAs encompass 184,000 acres of wetland habitat.

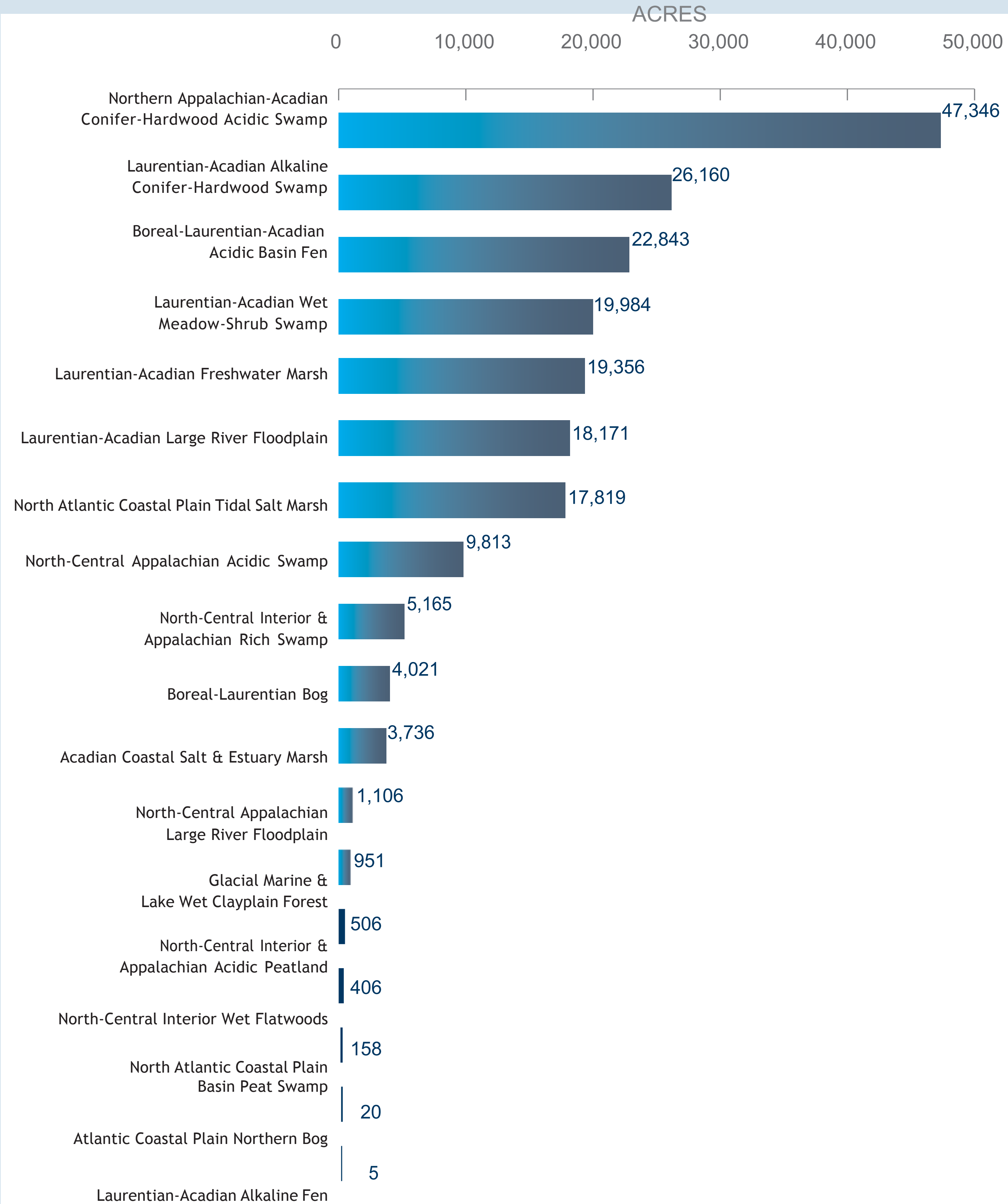
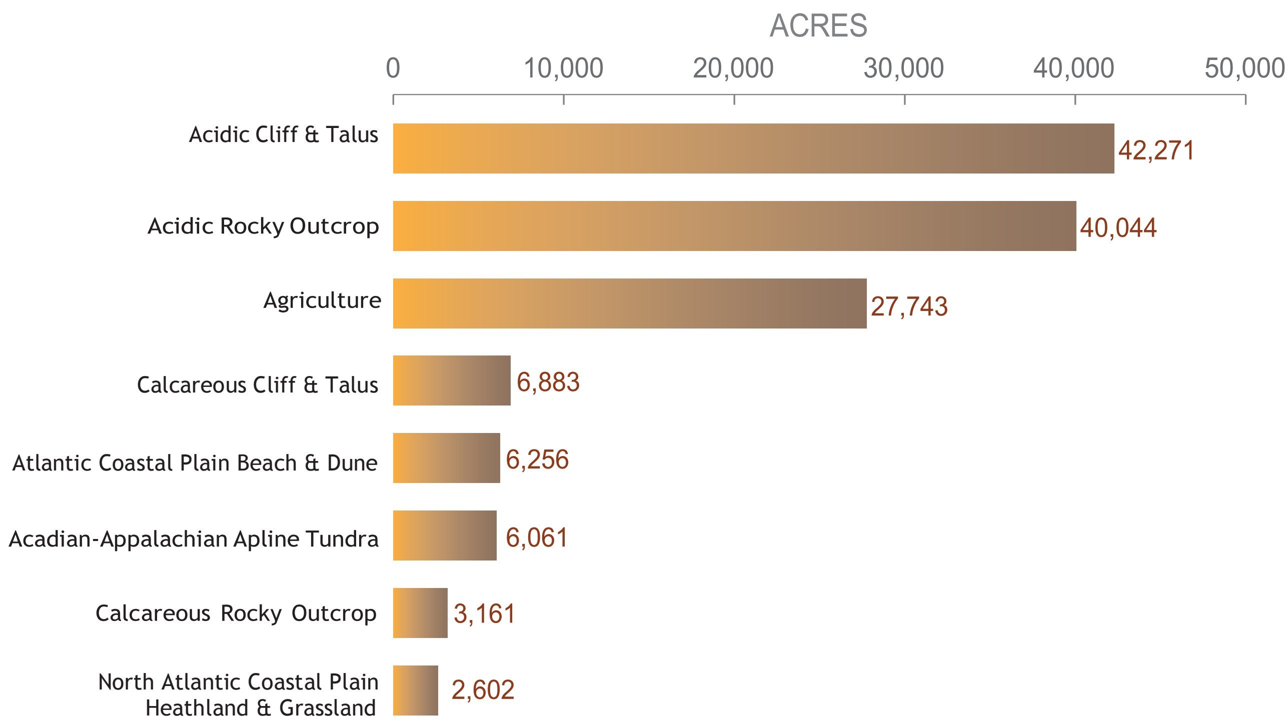


FIGURE 13. IPA Representation of Patch-forming Habitats

Collectively the 234 IPAs encompass 138,000 acres of patch-forming terrestrial habitat.



Top Sites: Another approach to prioritizing IPAs is simply by their diversity value. Of the 27 sites that scored far above average for diversity, only 1 is more than 75% protected (GSPC target), 9 are more than 30% protected (NE target), and 9 are less than 5% protected (table 8). The sites with the highest diversity are generally the best protected, with the exception of a large site on the St. John River in Maine and a small site on Mount Pisgah in Vermont.

Rare Plant Sites Outside IPAs: In New England, rare plant sites are often found on resilient land. More than 60% of all occurrences of *Flora Conservanda* Division 1 and Division 2 taxa are in the IPAs (resilient areas with high diversity of rare plants), while 39% are on resilient areas not in an IPA (resilient area with low diversity of rare plants – usually just one occurrence). Only 1% are on vulnerable areas (not resilient areas, figure 14). This bodes well for conservation of rare species populations in New England, but increases the importance of protecting the IPAs. Since only 4% of the 234 IPAs are fully protected, many rare plant occurrences are not secure. Element occurrences of rare species not located on resilient land or in IPAs are immediate candidates for *ex situ* conservation, particularly seed banking (figure 14).

TABLE 8. Top Sites

A list of sites scoring far above average for resilience AND diversity. GAP 1-2 is the percent of the site secured for nature and natural processes (i.e., protected).

SITE ID	STATE	ACRES	SITE NAME	# FLORA CONSERVANDA TAXA	GAP 1-2
74690	ME	231,550	Mt Katahdin	22	86.3
177296	NH	142,457	Mt Lincoln/Lafayette	12	72.9
166592	NH	106,908	Mt Eisenhower/Jackson/Crawford/	26	62.1
39751	ME	101,523	St John River-Basford Rips-Blue Brook	12	1.7
170730	VT	62,857	Mount Mansfield	14	22.8
52265	ME	25,411	White Pond Acidic Fen, Northwest Lobe	6	3.3
49094	ME	28,493	St John River-Blue Brook	8	2.3
167837	ME	10,134	Abagadasset Point	5	0.5
150311	VT	21,853	Bald Mountain-Westmore	7	0.0
245357	VT/NY	6,792	Bald Mountain-West Haven	8	50.1
309129	MA	6,734	Mt Greylock/Ragged Mt/Saddleball Mt	5	31.2
383349	CT	8,548	Canaan Mountain	5	20.1
382379	MA	4,675	Nantucket Harbor/Squam Head	17	52.9
332418	MA	3,445	Holyoke Range/Skinner State Park	12	48.3
331473	MA	4,068	Mt Norwottock/Devils Garden	11	40.6
407472	RI	1,364	Hot House Pond, Strange Pond	5	30.8
168001	VT	1,315	Eagle Mountain	5	16.7
243370	VT	3,506	Massachusetts Ledge	9	12.7
422809	CT	1,163	Eightmile River	5	7.2
381217	CT/MA	1,488	Toms Hill	5	4.8
315708	MA	4,292	No Name	7	3.3
153805	VT	3,664	Mount Pisgah	13	0.0
391955	MA	404	Nantucket/Shawkemo/Folgers Marsh	5	30.4
300520	VT	339	Pownal Hills-Quarry Hill	6	28.0
77427	ME	194	Crystal Bog	6	15.7
38769	ME	286	St John River, Wesley Brook	5	0.0

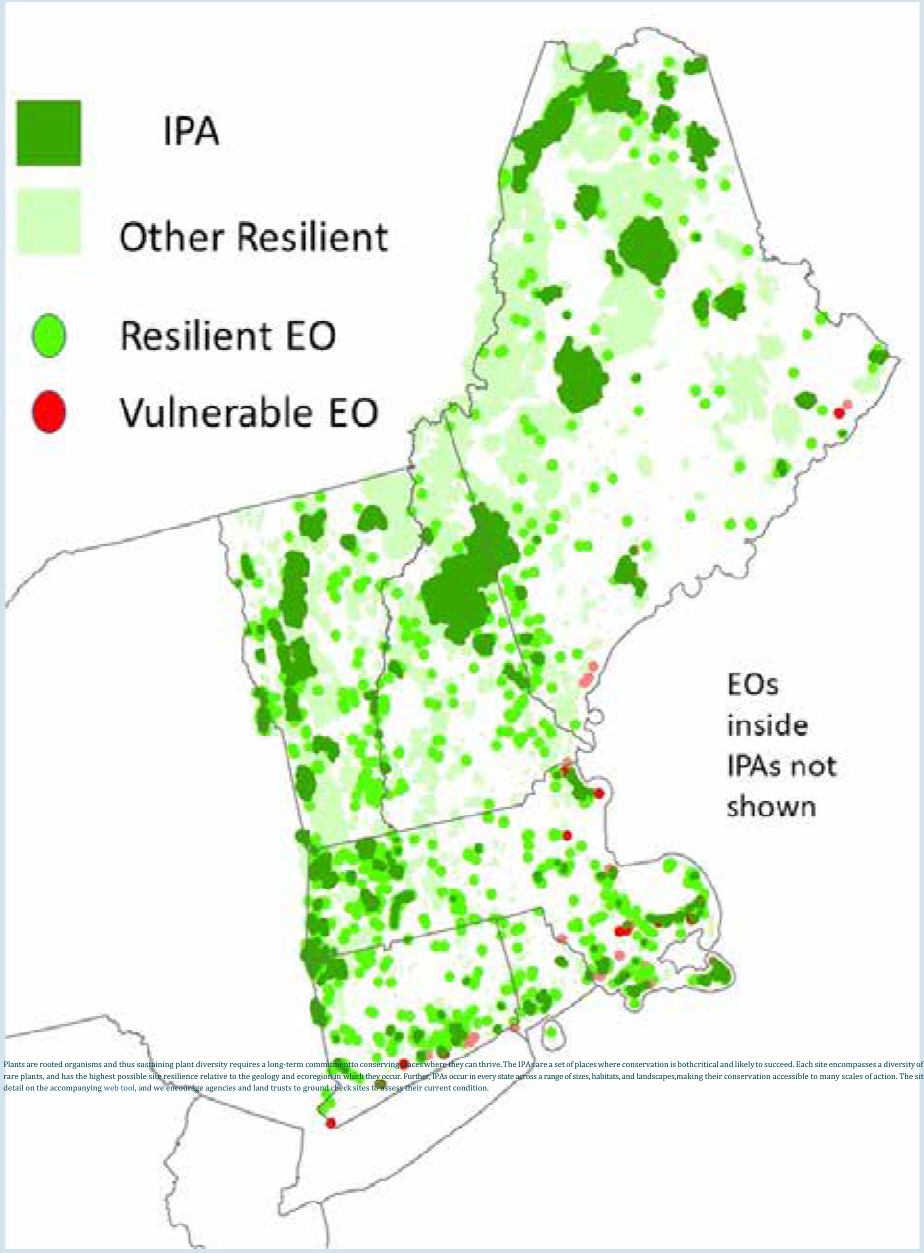


FIGURE 14. Element Occurrences of Rare Plant Sites in IPAs and on Other Resilient Land

Most occurrences of rare species are on resilient land, with only 24 on vulnerable land (red). Occurrences that are on resilient land but not in an IPA are shown in light green. The majority of occurrences are within the IPAs and hidden under the dark green areas on this map.

Plants are rooted organisms and thus sustaining plant diversity requires a long-term commitment to conserving places where they can thrive. The IPAs are a set of places where conservation is both critical and likely to succeed. Each site encompasses a diversity of habitats, contains a high density of rare plants, and has the highest possible site resilience relative to the geology and ecoregion in which they occur. Further, IPAs occur in every state across a range of sizes, habitats, and landscapes, making their conservation accessible to many scales of action. The sites and boundaries can be explored in detail on the accompanying web tool, and we encourage agencies and land trusts to ground check sites to assess their current condition.

Conservation of Threatened Species

Threatened Plants Conserved in situ

In 1996 and again in 2013, Native Plant Trust's *Flora Conservanda* (Brumback 1996; Brumback and Gerke 2013) designated the globally and regionally rare taxa in need of conservation. *In situ* protection is the primary method of conserving these species, and therefore knowing whether instances of rare taxa are located on protected land is important. Using 2015 data for numbers of plant occur- rences (called an Element Occurrence or EO*) provided primarily by Natural Heritage programs in each New England state (or their equivalent), we were able to describe GAP securement levels for 245 of the 388 taxa in Divisions 1 and 2 (globally and regionally rare taxa) on the 2013 *Flora Conservanda* list. The list of 245 taxa with GAP status appears in Appendix 4.

The results indicate that 226 (92%) of the 245 well-mapped threatened plant species have some occurrences on secured land in New England, which is above the threshold set by the GSPC:

> **GSPC Target 7**: At least 75% of known threatened plant species conserved *in situ*. "Conserved *in situ*" is understood to mean that biologically viable populations of these species occur in at least one protected area or the species is effectively managed outside the protected area network, through other *in situ* management measures.

However, fewer than half the taxa (42%) have 50% or more of their total occurrences on secured land, and of these only 16% occur on GAP 1-2 land. Nineteen taxa (8%) have no occurrences on secured land. Thus, a large percentage of threatened species are in GAP 3 securement. Although secured against conversion, plants on these lands are not protected from other threats, such as those associated with logging or recreation (Farnsworth 2015 identifies up to five threats for many of these species). The securement status of the remaining 143 of the 388 Division 1 and 2 taxa was not available. Threatened plants in GAP 1-2 are covered in more detail in the Important Plant Areas section above.

The data show significant effort by public and private land conservation agencies and organizations in New England to protect rare plant habitat. Several caveats should be mentioned:

- The GSPC target does not specify a number or percentage of occurrences that should be in protected areas, only that "biologically viable populations occur in at least one protected area." Most biologists would not consider a species sufficiently secure if only one of its occurrences is on protected (GAP 1-2) land. In New England, the presence of endangered or threatened species has been one of the main drivers of land protection, and thus it is not surprising that a large percentage of threatened plants exist on secured land.

- The total number of EOs for each taxon in the GAP analysis is usually more than the number of EOs listed for each taxon in *Flora Conservanda* (Brumback and Gerke 2013). This is probably the result of all EOs of each taxon, including some historic locations for the taxa, being included in the GAP percentages. *Flora Conservanda* lists only EOs that are currently extant, defined as existing at a location within 20 to 25 years from present.
  Thus, the percentages of current occurrences on secured land may not be current.

*The term Element Occurrence was devised by The Nature Conservancy and is used in conservation as an alternative to "population." Populations of organisms often are difficult to delineate without intensive research, and use of the term "population" often implies that its limits are known. Somewhat broader in scope, an occur-rence is defined as follows: the "area of land and/or water where a species is, or was, present and has practical conservation value"; it is the spatial representation of a species at a specific location (NatureServe 2012).

White Mountain avens (Geum peckii)
Liza Green © Native Plant Trust

- Based on the resilient-site analysis for the various ecological systems of New England (Part Two of this document), it seems likely that some current locations for a species may not be viable as climate change progresses. If this is the case, introduction to resilient sites within the historic range of a species or assisted migration to resilient sites outside its historic range may be necessary.

Threatened Plants Conserved in *ex situ* Collections

Ex situ conservation is an indispensable component of integrated plant conservation, especially for imperiled species facing multiple threats on the landscape as the climate changes rapidly. Botanic gardens worldwide have long maintained rare plants in their living collections as a way to ensure their survival, and one recent study estimates that 41% of known threatened plant species are in such collections, primarily holding species from temperate regions (Mounce et al. 2017).

In recent decades, seed banking has become the predominant tool for maintaining rare plant diversity (and increasingly for common species essential for habitat restoration). Seed banking has several distinct advantages over living collections, including the ability to store large quantities of plant material for long periods of time at relatively low cost. Seed banking enables the preservation of genetic diversity within a population as it was collected on the landscape, at a specific moment in time. Maintaining genetic diversity in *ex situ* living collections is logistically complicated, as plantings are more vulnerable to genetic drift, artificial selection, and active problems with pests and pathogens (Guerrant et al. 2004).

The value of seed bank collections with representative genetic diversity cannot be overstated as species and habitats shift ranges as the climate changes. Seed collections give conservationists the option to augment, introduce, or assist in the migration of imperiled plant species to prevent local extirpation or extinction.

Native Plant Trust established its seed bank in 1985 and has spent decades refining protocols to maximize potential viability of seeds and to ensure representative genetic diversity in each seed collection. Recently, Native Plant Trust has focused on achieving goals set by the GSPC; for seedbanking, it is Target 8:

GSPC Target 8: At least 75% of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs.

The GSPC sets a target for species conservation but lacks a target for the percentage of element occurrences collected of any individual species. To ensure genetic diversity, which safeguards adaptive abilities inherent in each occurrence of the species, research suggests collecting from at least two-thirds of the occurrences. The focus of such collection is on occurrences that are large in number of individual plants and representative of the geographic and ecological distribution of the species in New England.

Native Plant Trust has made significant strides in banking the rare flora of our region. In New England, there are 388 globally and regionally rare species (defined as Div. 1, 2, and 2[a] in *Flora Conservanda*) with approximately 3,300 element occurrences. The seed bank currently has ~800 collections, representating 244 occurrences of 167 globally or regionally rare species, plus ~500 collections of 20 locally rare and historic taxa (Div. 3, 3(a), 4). These represent 73 rare plant families and just under a tenth of the known occurrences of the most imperiled plants in New England.

seaside threeawn (Aristida tuberculosa)
Michael Piantedosi © Native Plant Trust

Among our highest priorities is to collect viable representatives of all globally and regionally rarespecies and to have sufficient quantities of each for research, augmentation, or other conservationinitiatives. We are also focusing on acquiring seed from regional endemics, where New England is host to the majority of occurrences of a rare species. As we learn more about the presence of globallyrare or endemic species on areas designated as "low resiliency" to climate change, or thosewith range strongholds in precarious positions on unsecured lands, we will focus collection targets more heavily on occurrences in those vulnerable locations.

Despite decades of effort to bank seeds of the region's imperiled species, work remains to bankthose taxa which either do not produce true seeds (typically producing spores or vegetative propagules) or otherwise produce recalcitrant and unorthodox seeds. Among rare New England taxa, "unorthodox" plant groups—such as ferns and fern allies, many orchids (Orchidaceae), adder's tongues (Ophioglossaceae), and willows (Salicaceae)—will need continued research andexpanded infrastructure for effective *ex situ* storage.

Shared knowledge has become a crucial research utility in applied *ex situ* conservation and often informs protocols and best practices for effective long-term storage of seed (and increasinglysporeand gemmae). As of 2018 the number of botanical institutions that collect and bank seed of wild species has grown to 370 in 74 countries (Sharrocket al. 2018). Many, like Native Plant Trust, have partnered with the Millennium Seed Bank at the Royal Botanic Gardens, Kew, or with umbrella organizations, such Botanic Gardens Conservation International and the Center for Plant Conservation, which is a network of conservation partners that collectively work to save the imperiled plants of the United States and Canada.

NATIVE PLANT TRUST SEED BANK STATISTICS

- Total collections (cleaned, frozen): 1,639
- Total unique taxa: 419
  - Div.1, 2, 2[a] (globally and regionally rare) taxa: 167
  - Div. 3(a), 3(b), (taxa declining in a large portion of the region 3(a) or common taxa with strongly disjunct occurrences 3(b)): 20
- Total rare plant families: 73
- Of the 388 Div. 1, 2, and 2a (globally and regionally rare) taxa: 167 collected and banked, 43%
- Of the ~309 Div. 1, 2, and 2a (globally and regionally rare) taxa that are considered orthodox seed producers (excludes most ferns and orchids): 167 collected and banked, 54%
- Of the ~3,300 occurrences of the 388 taxa, 244 occurrences collected and banked, 7%
- Of the ~3,000 occurrences of ~309 taxa, 244 occurrences collected and banked, 8%

beaked spikesedge (Eleocharis rostellata)
Michael Piantedosi © Native Plant Trust

CASE STUDIES

Conservation of Rare Plants and Resilient Habitats: Two Case Studies

While this report focuses on resilient habitat, there is value in considering individual species that will likely benefit from an abundance of resilient habitat or be negatively affected by its scarcity. The discussion here examines two taxa that are rare or endangered across the New England states, the potential loss or security of habitats for these taxa in a changing climate, and the conservation measures (such as *ex situ* seed banking) that may prevent their extirpation from the landscape. The locations of rare taxa included here have been obscured for protection of the plants and are based on data collected by the New England Plant Conservation Program (NEPCoP) and Natural Heritage programs in each New England state.

These case studies of two species of conservation concern in New England—purple milkweed (*Asclepias purpurascens* L.) and American ginseng (*Panax quinquefolius*)— demonstrate that the impacts of climate change will not be consistent across macrogrouphabitats nor on individual plant species, and will require evaluation over time. Shifts and changes in plant assemblages, plant communities, and overall plant diversity will require integrative and adaptive conservation measures, including *in situ* protection of habitats and *ex situ* seed banking, as well as continued analysis and applied research.

Purple milkweed
(Asclepias purpurascens L.)

© bjeanhart / Flickr CC

Asclepias purpurascens – Purple milkweed

Purple milkweed (*Asclepias purpurascens* L., Asclepiadaceae) is a rare but widely distributed species currently recorded from twenty-five Eastern and Midwestern states and Ontario, with historic records from another four states. All extant New England populations are restricted to Connecticut and Massachusetts; the species is considered historic in Rhode Island and New Hampshire. Only 11 occurrences have been seen since 1980, of 82 collected before that time (Table 11 includes all occurrences documented in the last 25 years). Of these, only 6 have been observed recently and 1 remains to be confirmed as purple milkweed. Both confirmed populations are small (with fewer than 30 plants) and appear precarious.

Exhibiting a broad ecological amplitude, purple milkweed typically inhabits semi-open margins of woodlands (often with oak-pine associations), roadsides, utility corridors, and old fields on soil substrates ranging from dry to quite moist. Many of its populations in North America occur on calcium-rich parent material, indicating a loose affinity for richer soils with high cation exchange capacity. Although succession to forest, road maintenance, and development has negatively impacted these habitats, there is still ample area available to support the taxon range-wide. However, existing populations rarely produce fruit; therefore, population growth and range expansion proceed very slowly. Reasons for the decline of purple milkweed may include major intrinsic limits to reproduction (including self-incompatibility), competition with other plant species, and other environmental factors that have yet to be identified (Farnsworth and Gregorio 2001).

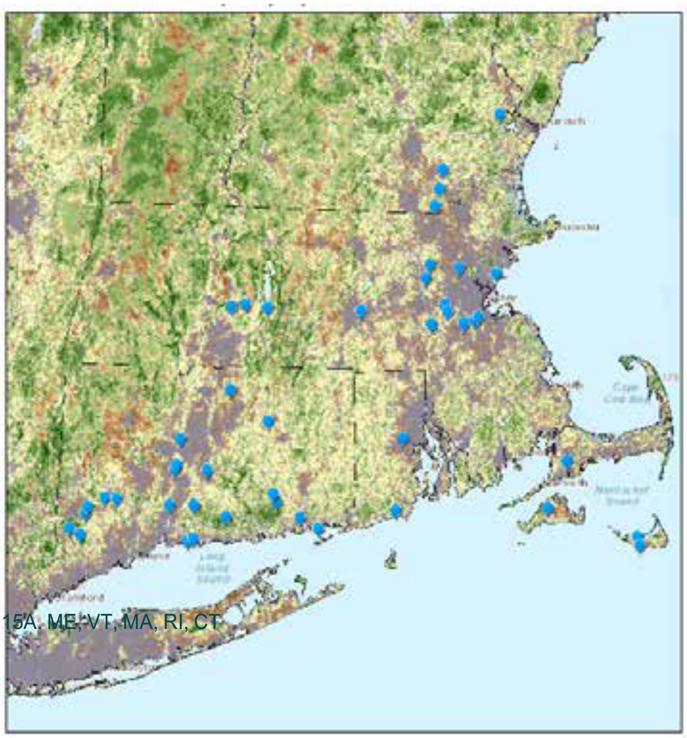
TABLE 9. Conservation Status of Asclepias purpurascens L. (purple milkweed),

Flora Conservanda Div. 2, G4G5

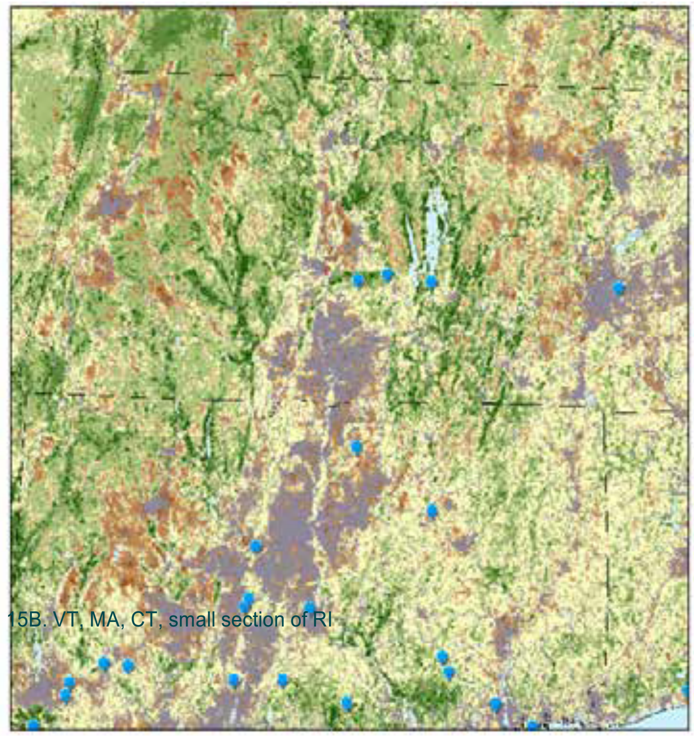
STATE	CONSERVATION STATUS
CT	rare to uncommon (S-rank: S2S3), special concern (code: SC)
MA	extremely rare (S-rank: S1), endangered (code: E)
NH	historical (S-rank: SH), endangered (code: E)
RI	historical (S-rank: SH), state endangered (code: SE)

FIGURE 15. Resilience

These maps depict areas of resiliency (highest in dark green to green; lowest in gray-brownand brown) overlaid with generalized population areas of purple milkweed (*Asclepias purpurascens* L.) in the New England states. Most extant populations of purple milkweed are located in low-resiliency areas.



15A. ME, VT, MA, RI, CT



15B. VT, MA, CT, small section of RI

TABLE 10. Resilience Status of Land on which *Asclepias purpurascens* L. Occurs

ASCLEPIAS PURPURASCENS L. (PURPLE MILKWEED)	**CONTEXT**		**SITE RESILIENCE**		
HABITAT OR MACROGROUP	OCCURENCES	% HABITAT	RESILIENT	AVERAGE	VULNERABLE
Central Oak-Pine Forest	14	31%	28%	21%	50%
Urban/Suburban Built	13	29%	8%	8%	85%
Northern Hardwood & Conifer Forest	12	27%	16%	42%	41%
Agricultural Grassland	2	4%	0%	50%	50%
Water	2	4%	0%	0%	0%
Northern Swamp	1	2%	0%	0%	100%
Ruderal Shrubland & Grassland	1	2%	0%	100%	0%
Total	**45**	**100%**	**16%**	**24%**	**55%**

As described in the conservation plan authored by Farnsworth and Gregorio (2001), the primaryconservation objectives for purple milkweed in New England are to locate, protect, maintain, or establish at least twenty separate occurrences in Massachusetts and Connecticut. They recommend that the majority of these populations occur on protected land, and we would add that, in addition to protected land, purple milkweed element occurrences located on land areas of high-resilience to climate change should be given greater priority for protection and management. Consistent, quantitative monitoring of all known element occurrences of purple milkweed is taking place through Native Plant Trust's New England Plant Conservation Program,and with targeted monitoring by state Natural Heritage programs. Among the most critical research needs for purple milkweed are improved understanding of the reproductive biology of this species and the protocols for augmenting or establishing new populations from seed.

Based on the distribution of most purple milkweed across *Central-Oak Pine* (31%), *Urban/ Suburban Built* (29%), and *Northern Hardwood & Conifer* (27%) macrogroups (total 87%), and with individual element occurrences largely located outside resilient habitat areas (66%), it is likely that purple milkweed will face significant losses as climate change alters temperature andprecipitation. This is particularly concerning for locations of this species on islands (Nantucket, Martha's Vineyard), where remnants of isolated genetic diversity in this species are likelyto be negatively impacted. With many of the populations of purple milkweed considered historic in New Hampshire and historic or lacking recent observational data in eastern and northeastern Massachusetts, many of the exemplary occurrences are located in areas ofcentral Massachusetts and southern Connecticut where habitats are likely to degrade with climate change. The 16% of purple milkweed occurrences located in resilient areas are largelyconcentrated in south-central Connecticut and near the Quabbin Reservoir in Worcester County, Massachusetts. Occurrences of purple milkweed outside these resilient areas, particularly those located in *Urban/Suburban Built* environments where development pressuresremain high, should be the immediate focus of monitoring and seed banking efforts, if sizeableand reproductive populations are observed. Large occurrences in resilient habitat areas shouldalso be monitored and seed banked, but also considered as introduction or augmentation sites for ensuring the survival of this species in the New England portion of its range. Areas of high resilience within the *Central Oak-Pine* macrogroup habitats, largely in south-central and north-coastal Massachusetts, coastal New Hampshire, and southwestern Maine, may also be areas of value for assisted migration of this species from seed bank resources.

As outlined in Farnsworth and Gregorio (2001) and several other sources (USDA 2003; NHESP2015), this species is self-incompatible and has high potential for inbreeding depression; as a result, it rarely produces fruits (NHESP 2015). Given its small population numbers, further hindrance to production of follicles and seeds will likely slow the increase in individuals in both resilient and non-resilient areas and will likely cause losses and significant declines in the genetic diversity of this species. Although cross-fertilization may be tried as a means of conservation, seed banking from large occurrences of purple milkweed is an immediate priority.

Panax quinquefolius – American ginseng

American ginseng (*Panax quinuefolius* L., Apiaceae) is distributed over the easternhalf of North America and is present in all New England states, though rare and protected in most.

Based on the New England distribution of American ginseng across *Northern Hardwood & Conifer Forest* (78%), *Cliff & Talus* (10%), *Central Oak-Pine Forest* (6%), and *Outcrop, Summit & Alpine* (5%) macrogroups, and with individual plant populations primarily located within resilient areas (84% in far above average, above average, and slightly above average), it is likely that many of the Americanginseng occurrences will not be significantly impacted by changing temperature and precipitation. Further, threats from development in these primary macrogroupareas is quite low, with only 4% of the key habitat areas for this species facing any development. Highest areas for resilience include parts of the White Mountain National Forest of New Hampshire and Maine, northwestern Vermont, and smaller areas near the Quabbin Reservoir in central Massachusetts.

Given the likelihood of American ginseng's primary habitat areas persisting under climate change, other more numerous and severe threats should be a major focusof conservation plans for the species. Impacts from fragmentation of unsecured habitat areas within these macrogroups (see detailed maps of each macrogroup for GAP 1–3 status) could cause dislocation of important genetic variation among what are often small populations. This potential habitat-scale threat is compounded by immediate anthropogenic threats, such as over-harvesting in the wild for medicinal components, proliferation of invasive species (such as exotic earthworms and pathogens affecting dominant tree species), and impactsto insect and avian wildlife populations that contribute to fruit development and dispersal. Perhaps the most important conservation action in the case of Americanginseng is protection *in situ*, where parcels of unprotected land (lacking GAP 1–3status) should be managed to retain connectivity and above-average resiliency. Other strategies include augmentation and restoration to ensure the persistence of minimum viable populations throughout American ginseng's New England range(USFS Eastern Reg. 2003). A minimum viable population is defined as a population size likely to give a population a 95% probability of surviving over a 100-year period (Nantel 1996). Maintaining or increasing the size of the existing populations of American ginseng will also ensure that local seed sources are available for future reintroductions of the species.

TABLE 11. Conservation status of Panax quinquefolius L. (American ginseng).

Flora Conservanda Div. 1, G3

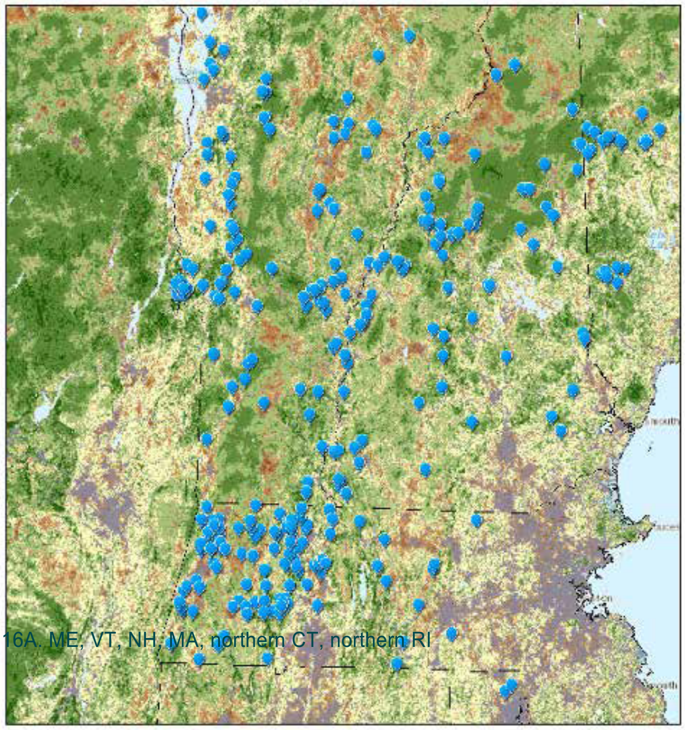
STATE	CONSERVATION STATUS
CT	rare (S-rank: S2), special concern (code: SC)
MA	uncommon (S-rank: S3), special concern (code: SC)
ME	uncommon (S-rank: S3), endangered (code: E)
NH	rare (S-rank: S2), threatened (code: T)
RI	extremely rare (S-rank: S1), state endangered (code: SE)
VT	uncommon (S-rank: S3)

TABLE 12. Resilience Status of Land on which Panax quinquefolius L. Occurs

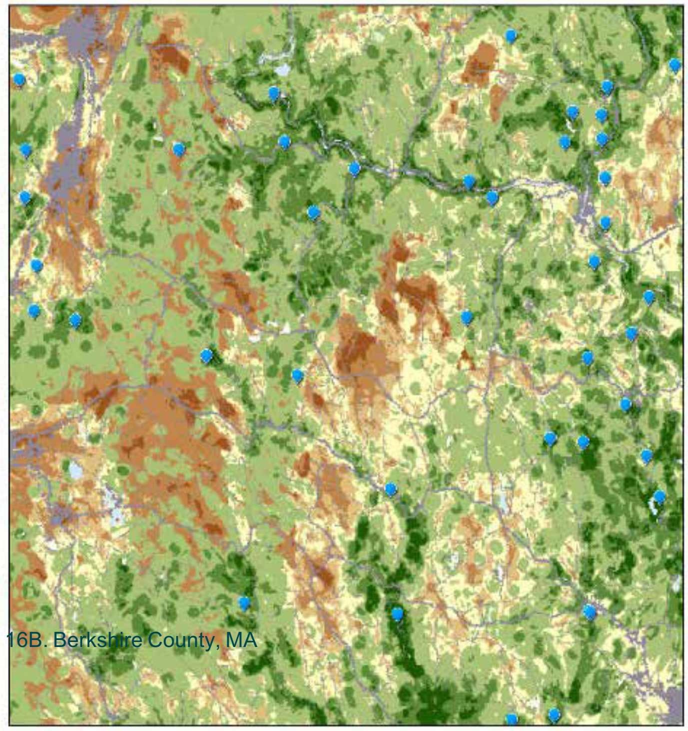
PANAX QUINQUEFOLIUS L. (AMERICAN GINSENG)	CONTEXT		SITE RESILIENCE		
HABITAT OR MACROGROUP	OCCURENCES	% HABITAT	RESILIENT	AVERAGE	VULNERABLE
Northern Hardwood & Conifer Forest	251	78%	85%	8%	7%
Cliff & Talus	32	10%	94%	0%	6%
Central Oak-Pine Forest	18	6%	83%	11%	6%
Outcrop, Summit & Alpine	6	2%	100%	0%	0%
Water	4	1%	0%	0%	0%
Agricultural Grassland	3	1%	33%	0%	66%
Northern Swamp	3	1%	66%	33%	0%
Urban/Suburban Built	2	1%	50%	0%	50%
Central Hardwood Swamp	1	0%	100%	0%	0%
Freshwater Marsh & Shrub Swamp	1	0%	0%	100%	0%
Total	**321**	**100%**	**84%**	**7%**	**8%**

FIGURE 16. Resilience

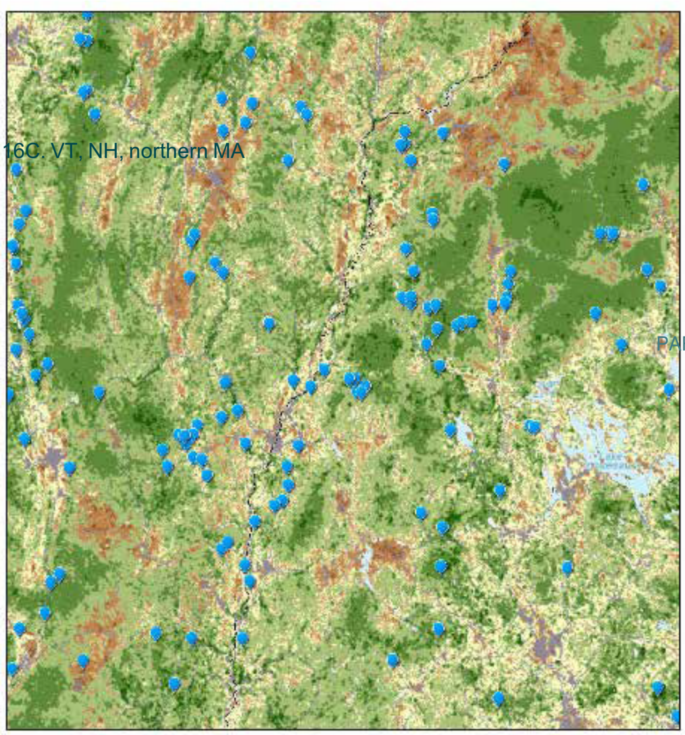
These maps depict areas of resiliency (highest in dark green to green; lowest in gray-brown and brown) overlaidwith generalized population areas of American ginseng (*Panax quinquefolius*) in the New England states. Mostextant populations of American ginseng are located within above-average to high-resiliency areas.



16A. ME, VT, NH, MA, northern CT, northern RI



16B. Berkshire County, MA



16C. VT, NH, northern MA

Results and Recommendations

INTRODUCTION

In this study, we analyzed whether a century or more of land conservation in New England has protected enough land in the right places to save the region's plant diversity. While governmentagencies, land trusts, and private landowners have together made significant progress toward conserving natural environments, there are large biases in the distribution of conserved landsthat need to be corrected if we are to sustain the full spectrum of plant and habitat diversity.

Ofthe 36 million acres of natural lands in New England, approximately 8.3 million acres (22%) aresecured against conversion, with 2.1 million protected for nature and natural processes (GAP 1-2)and 6.2 million secured and managed for multiple uses (GAP 3). To achieve the goal of 30% of the region's lands conserved by 2030—a goal incorporated into both international and nationalinitiatives—will require securing another 2.3 million acres against conversion and protecting atleast 419,000 acres of that for nature.

Identifying which specific acres to preserve, especially in the context of a changing climate andthus a changing flora, is a goal of this report. As explained earlier, we used habitat diversity and scale, rather than species richness, as a metric for plant diversity. We then analyzed securementlevels for 43 habitats and 234 newly identified Important Plant Areas (IPAs) in their distribution across the region and set conservation targets based on scientifically defined benchmarks. In addition, we assessed the climate resilience of the land that is currently conserved and factored site resilience into the recommendations for future conservation.

The data in this report coupled with the interactive mapping tool provide a robust framework for conservation action that effectively directs limited funding to habitats, areas, and specific sites thatwill help sustain plant diversity—and indeed biodiversity—in New England as the climate changes.

MAJOR FINDINGS

Our analysis is framed by two sets of benchmarks: the Global Strategy for Plant Conservation (GSPC) in the United Nations' Convention on Biological Diversity and the Global Deal for Nature (Dinerstein et al. 2019). The New England targets (NET) derived from the latter are tailored to the scale and diversity of habitats in New England and explicitly include climate resilience. To recap, the primary land conservation goals by 2030 are:

Global Strategy for Plant Conservation Targets

- **Target 4**: At least 15% of each vegetation type secured through effective management or restoration (GAP 1-2 protection)
- **Target 5**: At least 75% of the most important areas for plant diversity (IPAs) of each ecological region protected with effective management in place for conserving plants and their genetic diversity. We defined IPAs in New England as habitats with exceptionally high rare plant diversity (>1 rare species per 10,000 acres), with the Target 5 goal attained through at least 75% of the areas with high resilience conserved with GAP 1-2.
- **Target 7**: At least 75% of known threatened plant species conserved *in situ* (in their natural place in the wild).

New England Targets

- At least 5-15% of each habitat protected and at least 30% secured against conversion, with at least 50-75% securement on climate-resilient land, depending upon habitat type. The target sets the protected level (conserved to protect nature and natural processes) needed based on habitat scale: dominant matrix forests 5%, wetlands 10%, patch-forming habitats 15%. Similarly, the resilience criteria are adjusted downward to 50% for wetlands to include some vulnerable but already protected examples of these critical habitats.
- At least 30% of each climate resilient area with the highest rare plant diversity (IPA) protected, and at least 75% of each IPA secured against conversion across habitats and states.

Reaching the NE target of 30% secured by 2030 will require conserving an additional 2.3 million acres focused on specific habitats and climate-resilient sites.

Results

Matrix forests cover 86% of the natural landscape and provide essential benefits to people and wildlife, but of New England's ten dominant forest types only one meets the GSPC target and only two meet the NE target.

- Reaching the NET 30% will require adding 2 million acres of new conservation land targeted toward climate-resilient areas.
- Increasing GAP 1-2 protection to 15% across resilient land for the other nine matrix forest types to meet the GSPC target would require an investment in three million acres of land, including increasing the GAP level on land that is already secured.
- Existing conservation is concentrated in the northern and high-elevation forest types. Urgently in need of securement and protection are the oak-pine and coastal hardwood forests of southern New England that have limited climate resilience and are predicted to lose up to 18% of their current distribution to development by 2050.
- Saving plant diversity will also require improved and science-based management of the 5.3 million acres already secured against conversion but open to multiple uses.

Wetlands are less conserved than we expected. Of the eighteen types of bogs, swamps, flood-plains, and marshes that are critical to sustaining almost half our plants, birds, and other wildlife, only six meet the GSPC and three the NE targets.

- Wetlands cover 12% of the region, but the types that meet the targets are largely small unique bogs and peatlands covering less than 1% of land area. None of the five most common wetland types meet either the GSPC or NE targets, although all of them have more than 20% securement and most meet the goals for climate resilience.
- Reaching the NE target will require conservation of an additional 253,902 acres of resilient wetland, including 151,901 acres protected explicitly for nature.
- Meeting the NE target also steps nearly 40% of the way toward the GSPC goal of protecting 405,083 more acres for nature.

Patch-forming terrestrial habitats are hotspots of plant diversity and of particular importance as habitats of rare and endangered plant species. Covering only 2% of the land- scape, these summits, cliffs, barrens, and dunes sustain densities of rare species ten times higher than wetlands and forty times higher than upland forests, according to an overlay of Natural Heritage program rare species locations. Results indicate that seven of the fourteen habitats
meet the GSPC goal, but when resilience is factored in, only four of these also meet the NE target. These are all bedrock-based habitats like cliffs and summits.

- Large conservation challenges are apparent in the low-elevation sand- and silt-based patch habitats such as pine barrens and coastal grasslands. These habitats are under high threat of conversion (15%-18% of current extent by 2050), and much of the current protection is on flat and fragmented land that is vulnerable to climate change.
- An additional 7,556 acres are needed to reach the GSPC 15% protected target.
- Meeting the NE target requires only 17,726 acres to reach 30% securement based on acres alone, but it would require an additional 88,620 acres of targeted resilient land to bring the silt- and sand-based systems up to the standard for climate resilience.

Important Plant Areas (IPAs) are patches of resilient land that contain a high density of rare plant species. We identified 234 IPAs for New England that cover 2.6 million acres, contain multiple occurrences of 212 globally and regionally rare taxa, and have resilient examples of 92% of the habitats. Each IPA's rare plant diversity ranges from 2 to 26 taxa depending on the site's size and location.

- For the GSPC target, 10 IPAs (4%) are more than 75% protected, and 32 (14%) have more than 75% securement by a combination of protected and multiple-use land.
- Of the remaining 192 IPAs, 155 have some level of securement, including 122 with GAP 1-2 in some portion of the site (although securement does not add up to 75% of the area). The remaining 37 IPAs have no securement.
- By acreage, the IPAs are 29% protected, with another 23% secured against conversion on multiple-use land.

Elizabeth Farnsworth © Native Plant Trust

We also examined two additional GSPC targets that are critical to saving plant diversity.

- **Target 7**: "At least 75% of known threatened plant species conserved *in situ*." Of the 245 rare taxa for which we have securement status, 226 (92%) have at least one occurrence on secured land (GAP 1-3), leaving 19 taxa with no permanent protection. For most taxa, more than 50% of their known locations are on secured land. However, only 16% of the occurrences of these threatened species are on GAP 1-2 land, and the securement status of the remainder of the 388 globally and regionally rare taxa was not available.

- **Target 8**: "At least 75% of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs." In New England, Native Plant Trust manages the primary seed bank of rare and endangered species. Currently the seed bank holds collections of 43% of globally and regionally rare taxa. However, the collections are from only 7% of the populations.

RECOMMENDATIONS

We recommend an approach to land conservation that focuses on more proportional representation of the region's habitats across their ranges, rather than on securing more acres of habitat types that are abundantly conserved already. Our findings show the conservation of New England's habitat and plant diversity is an achievable goal, yet one which requires significant increases in resilient habitat areas effectively secured against conversion (30%), with a smaller proportion protected for nature (5-15% depending on the habitat type). To achieve these percentages, 2.3 million acres of additional resilient land targeted toward specific habitats must be secured against conversion, with at least 419,000 acres of that protected for nature. Conserving the unsecured IPAs (1.3 million acres) is an important focus, as it would save rare plant species and would go a long way toward sustaining the region's floristic and habitat diversity. In addition, we must ensure the effective management of 5.3 million acres of existing GAP 3 forest land, which is open to multiple uses.

By increasing the amount of area targeted for habitat conservation and incorporating effectively managed multiple-use land (GAP 3) as part of the solution, meeting the New England target will also maintain critical carbon resources and source water areas needed for people. Of course, there is no substitute for permanent GAP 1-2 protection, which is an essential measure for the health and longevity of trees and plants, many of which have multi-century life spans and develop complex co-evolutions and intertwined ecological networks. The New England target addresses this by targeting at least 5% GAP 1-2 protection in every forest type, and higher amounts for wetlands and patch habitats. We hope this target will help spur conservation of the more southern and low- elevation forests, which are vastly under-protected compared with their northern and high-elevation counterparts. Additionally, by increasing the area goal for securement and focusing on resilient land, we keep the options open for more protection, which can be achieved through redesignation of existing secured land (GAP 3) into a higher protection status (GAP 1-2).

The report's interactive maps and state-specific data will enable policy makers, federal and state agencies, and land trusts in each state to effectively target the most significant areas for protecting New England's plant diversity and the biodiversity it supports. For example:

- Habitats that are rare within New England, such as coastal plain habitats primarily in Massachusetts and Rhode Island, warrant greater protection efforts, with a higher proportion protected within the states where they occur.
- States with relatively large areas of a common habitat lacking conservation protection should also increase the amount of that habitat secured in their state. For example, 90% of the regional habitat area of *Laurentian-Acadian Alkaline Conifer-Hardwood Swamp* is found in Maine, yet 84% of this habitat is unsecured in the state.
- Habitats facing significant losses to development by 2050, such as the *North Atlantic Coastal Plain Hardwood Forest* of southern New England, are also high priority.

A recommended starting point is **conserving the IPAs in each state**, which saves rare species across multiple habitats. The two primary strategies are focusing on IPAs that are unsecured and increasing the amount of protection within IPAs that are partially secured, either by conserving more acres or raising the level of securement to GAP 1 or GAP 2, depending upon the density of rare species. The table in Appendix 3 lists all 234 IPAs by dominant habitat and primary state (some cross boundaries), with acreage, number of rare species, and protection status. Using that table with the mapping tool, conservationists can also see the range of habitats within each IPA.


©Jenny Wollensak Lussier

The securement and resilience data in the report's tables and on the mapping tool provide a regional, state, and ultimately parcel view of both conservation achievements and the path to either GSPC or New England targets by 2030. While most of the 43 habitats need additional securement, we highlight several, and their IPAs, that need urgent conservation action. See the state summaries for more detail.

Matrix Forests

- Mid-elevation *Laurentian-Acadian Pine-Hemlock-Hardwood Forest* in Maine and Vermont has relatively high resilience but the lowest protection (2%) and securement (14%) of any forest type.
  - In Maine, there are eight unsecured IPAs within this habitat, totaling 22,980 acres.
  - New Hampshire has a single unsecured IPA of 5,537 acres.
  - Vermont has two unsecured IPAs totaling 3,515 acres.
- *North Atlantic Coastal Plain Hardwood Forest* (in all states but Vermont) meets the NE target of 5% protected, but less than half of that is on resilient land; it is also only 19% secured and highly threatened by development. All states should focus on this habitat, but Connecticut, Maine, and Rhode Island have the least securement.
  - In this habitat, there are twelve IPAs needing protection: six in Connecticut (6,402 acres), three in Massachusetts (2,085 acres), and three in Rhode Island (3,175 acres).
- *Northeastern Interior Dry-Mesic-Forest* and *Northeastern Coastal & Interior Pine-Oak Forest* have low securement, low resilience, fall short of the GSPC and NE targets, and are moderately threatened by development. The former needs securement in Connecticut, Massachusetts, and Rhode Island, and the latter is especially unsecured in southern Maine. The small IPAs will likely need to be embedded in a larger matrix of protected lands to remain viable.
  - In *Northeastern Interior Dry-Mesic Forest*, Connecticut has ten IPAs on a total of 7,754 acres, nine of which are unsecured. Massachusetts has two IPAs on 2,441 acres needing protection.
  - In *Northeastern Coastal & Interior Pine-Oak Forest*, Maine (9 acres), Massachusetts (468 acres), and New Hampshire (2,612 acres) each have a single IPA needing protection.

Wetland Habitats

- *Laurentian-Acadian Alkaline Conifer-Hardwood Swamp* is well-secured in the southern part of its range, but it is predominantly in Maine, where it is largely unsecured. The habitat also needs conservation in Vermont, where only 14% of total acres and 21% of resilient acres are secured.
- *North-Central Interior Wet Flatwoods* is a rare habitat with only 25,306 acres across five states (all but Rhode Island), very little of which is protected, and most of the 16% total securement is not on resilient land. The habitat is also threatened by development. A single unsecured IPA in Massachusetts of only 67 acres should be a high priority for investigation.
- The 14,032 acres of *Glacial Marine & Wet Clayplain Forest* occur only in Vermont and are a high priority for conservation. Only 3% of total acreage is protected and 12% secured; only 14% of resilient acres are secured.
- *Laurentian-Acadian Large River Floodplain* is home to an exceptionally high density of regionally or globally rare plant species, with more than 30 rare taxa, many of which occur primarily in this habitat type. While 29% of the resilient acreage of this habitat (212,136 acres) is secured regionally, only 7% is protected (GAP 1-2). This habitat is predominantly found in Maine, where 71% of the 186,857 resilient acres are unsecured.

Michael Piantedosi © Native Plant Trust

Patch-forming Habitats

- Four forest habitats are so restricted that they are included in the patch-forming habitat analysis, and two are high priority for conservation. The *North Atlantic Coastal Plain Maritime Forest* is only 15% secured in Maine, and only 18% of resilient acres are secured. Vermont's *Glacial Marine & Lake Mesic Clayplain Forest*, encompassing 32,066 acres, is only 7% secured.
    - Of the two IPAs in the maritime forest, a 500-acre site in Massachusetts needs protection.
- The coastal plain sand- and silt-based habitats are especially vulnerable to climate change. While the number of acres needed to reach targets is relatively small, it may be difficult to sustain these habitats over time. A clear focus should be saving the 36 rare plant species in the beach and dune habitats and the 8 in the coastal grassland.
    - Three *North Atlantic Coastal Plain Heathland & Grassland* IPAs in Massachusetts, encompassing 2,657 acres, are priorities; only one is protected.

While this report focuses primarily on land conservation, we also examine and recommend addi- tional conservation strategies, such as assisted migration, restoration and augmentation of sites and populations, and seed banking to preserve genetic diversity. What is certain in a changing climate is that we need multi-layered, science-based approaches to saving plant diversity and the life it sustains. We know that a rapidly changing climate will stress the ability of individual species and entire habitats to adapt, and thus recognize that some will migrate, some will die, and some will form new assemblages. With this report and its mapping tool, we aim to ensure that New England's native plants—the green foundation for functioning ecosystems—are at the forefront of conservation policy and action as climate plans develop.

PART TWO

TATUS REPORT AND MAPS

Elizabeth Farnsworth © Native Plant Trust

Cushion plant *(Diapensia lapponica)* and Lapland rosebay *(Rhododendron lapponicum)*
Liza Green © Native Plant Trust

OVERVIEW

Approach

Plants have evolved to exploit almost every terrestrial situation on Earth, and in each they negotiate the challenges and limitations of the local conditions. Thus, plant communities translatethe land's geophysical variation into living habitats that support many types of species. In this report, we focus on the diversity and resilience of habitats as an embodiment of plant diversity, rather than on plant diversity defined more simply as "richness," the number of species within a given area or the average number of species within a habitat. Conserving multiple intact examples of every habitat across its range within a region is a strategy for preserving plant diversity, sustaining the natural benefits plants provide, and maintaining the full diversity of species that depend on them. As the climate changes, we expect the compositional details of each habitat to adjust in response, but the underlying geophysical settings and terrain-driven processes toremain stable.

This section describes 43 of New England's terrestrial habitats and analyzes them with respect todistribution, resilience, securement, associated species, and threat of conversion. Our ability to understand the trends and spatial relationships among habitats was made possible by the recent development of several key datasets, which are described in the main body of the report. Here we briefly review the data sources and provide more detail on the Northeast Terrestrial Habitat Map. Synthetic analysis comparing habitats to one another is also provided in the main body of the report, but we realize that readers may not be familiar with the full range of habitats found throughout the region. In this section, we profile each habitat individually; provide information on its distribution, composition, and associated species; and assess its level of securement and resilience to climate change.

Data Sources

The method of mapping terrestrial habitat types is described below. To assess the status of eachhabitat, we relied on three key datasets described in detail in the main report.

Climate Resilient Land

As climate change drives shifts in species and ecosystems, conservation plans basedon current biodiversity patterns will become less effective at sustaining species and natural processes over the long term (Pressey et al. 2007). Thus, conservationists need away to ensure that sites targeted for protection will continue to conserve biological diversity and ecological functions into the future. To address this issue, The Nature Conservancy (TNC) devised an approach for assessing climate resilience based on enduring geophysical characteristics of the land (Anderson et al. 2014; seenature.org/climateresilience).

Plants experience climate at a very fine scale (inches toyards), such that a site with ampletopographic and hydrologic variation is experienced by plants as a mix of microclimates. Ifwell connected, areas of high topoclimate variation have the potential to buffer climate-change impacts by enabling local dispersal to more favorable microclimates and mayalso provide stepping-stones to facilitate longer-distance range shifts (Suggitt et al. 2018).

In New England, topography, landforms, and elevation modify local conditions and createmicroclimatic patterns that are relatively predictable at the site scale. These factors can be used in combination with moisture models to estimate the variety of climatic environments available to resident species. The TNC dataset (Anderson et al. 2014) evaluates and scores every pixel of land with respect to the diversity of microclimates anddegree of connectedness. Scores are calculated relative to the land's geophysical setting (geology and soil) and ecoregion. Scores are expressed as standard deviations above or below the average values for the setting.

Securement

Measures of land securement are based on The Nature Conservancy's Secured Land dataset (Prince et al. 2018), which is developed and maintained by each state office and aggregated by the regional science office. The dataset contains the boundaries of all land that is permanently secured against conversion to development, including public and private land held in fee or easement by state agencies, federal agencies, land trusts, and private conservation holders. The land is classified by GAP status (Crist et al. 1998)into three categories:

- **GAP Status 1**: 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 withinwhich disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management.
Examples: nature reserves, Forever Wild easements, wilderness areas.

- **GAP Status 2**: Secured for nature with management

An area having permanent protection from conversion of natural land cover anda mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality ofexisting natural communities, including suppression of natural disturbance.
Examples: national wildlife refuges, national parks.

- **GAP Status 3**: Secured for multiple uses

An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low- intensity type (e.g., logging) or localized intense type (e.g., mining), or motorized recreation. It also confers protection on federally listed endangered and threatened species throughout the area. *Examples*: state forests, forest management easements, conservation restrictions on working forest.

- **Unsecured**: Land that is not permanently secured against conversion; this includes most private land.

GAP 1 and 2 lands are considered **protected**, which is the term we use in this report, and are the only lands that satisfy the GSPC targets. The New England targets include GAP 1-3 lands in the benchmark of 30% secured and use GAP 1-2 for the 5-15% that should be "secured for nature."

Predicted Loss to Development

To estimate the threat of conversion, we used a Land Transformation Model developed by the Human-Environment Modeling and Analysis Laboratory at Purdue University (Tayyebi et al. 2013). In this model the quantity of urban growth at county and city scales is simulated using population, urban density, and nearest-neighbor-dependent attributes. Future land use predictions were created for every 30-m pixel in the region in five-year increments from 2010 to 2060 and used NLCD 2001 version 2 as the basis for projections. To estimate loss, we calculated acres of each habitat present in 2020 that are predicted to be developed by 2050.

© Josh Royte (The Nature Conservancy, Maine)

New England’s Terrestrial Habitats

The terrestrial habitats defined and described in this report follow the Northeast Terrestrial Wildlife Habitat Classification (Gawler et al. 2008) with modifications as necessary to enable consistent mapping in the Northeast Terrestrial Habitat Map (Ferree and Anderson 2014) – our key data source. The latter is a comprehensive and standardized representation of natural habitats across fourteen states and four Canadian provinces (figure 1. us portion). The habitats are equivalent in scale and concept to the NatureServe ecological system (Comer 2010), 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 is not intended to replace state classifications, which often have more detail and nuance.

Concepts and Terminology

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. It does not include aquatic freshwater or marine habitats.

In this report, as in Gawler et al. (2008), we use the term “terrestrial habitat” as synonymous with “ecological system” and roughly equivalent to “vegetation type” or “plant community.” Although ecological systems are tied to the U.S. National Vegetation Classification (USNVC, FGDC 2008), they are not a formally recognized level of the USNVS hierarchy, which is based on physiognomy, not on a common ecological setting. Users should also realize that within a single terrestrial habitat, such as Acadian Low-Elevation Spruce-Fir-Hardwood Forest, there may be variation related to local conditions that may be described at a finer “plant association” level.

The classification system describes terrestrial habitats in relation to ecological setting, but these may occur on the land at fundamentally different scales. To account for this, each habitat has been assigned to one of three landscape patterns:

- **matrix forest**: dominant forest types that occupy large contiguous areas (generally >5,000 acres under natural conditions) and form the background matrix of a geographic region. Other habitats tend to nest within the 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.

- **wetland**: swamps, 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 Swamp, which is a peat-accumulating forested wetland common to the coastal plain.

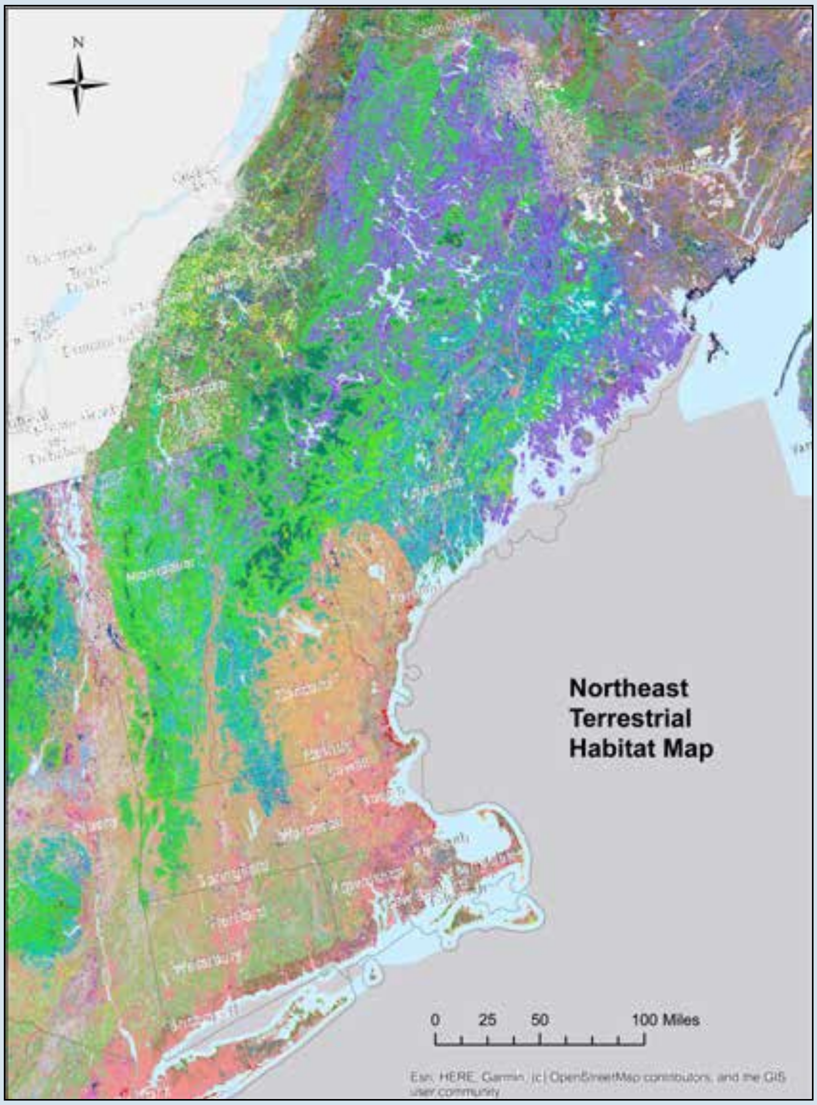
- **patch-forming habitats**: these habitats occur under very localized environmental conditions that are distinctly different from the surrounding landscape (e.g., Acidic Rocky Outcrop). The habitat often reflects extreme conditions in soil (bedrock or shifting sand), exposure (alpine winds, steep slopes), or disturbance regime (fire, mowing). Patch habitats tend to have high plant diversity and host some of New England's rarest species.

In addition, newly identified Important Plant Areas (IPAs) occur within all three landscape patterns in New England. Based on criteria in the Global Strategy for Plant Conservation (GSPC),here an IPA is defined as a contiguous patch of resilient land with a diversity of rare plant species relative to its size. The IPAs are characterized by their dominant habitat but can be evaluated by the number of other habitats and the number of rare species contained within. Collectively they contain multiple occurrences of 212 of our rarest species and resilient examples of 92% of the habitats.

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

FIGURE 1. The Northeast Terrestrial Habitat Map

This dataset (Ferree and Anderson 2015) 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



Geography

The map used for this study covers the six New England states as well as PA, NJ, MD, DE, WV, VA and the Canadian provinces of New Brunswick, Novia Scotia, Prince Edward Island, and Quebec. All statistics in this report are for New England only: CT, MA, ME, NH, RI, VT.

Naming Conventions

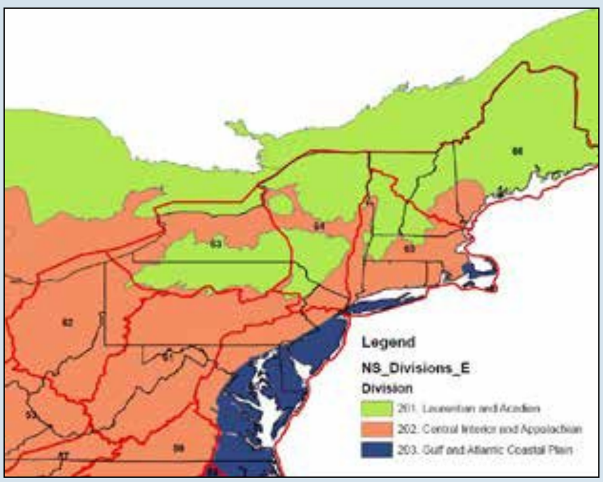
The names of ecological systems incorporate a biogeographic reference, and the ecological systemsclassification for the continental United States uses major geographic divisions as an upper-scale descriptor (Comer et al. 2003). Those divisions were adapted from Bailey (1995 and 1998), with division lines modified according to ecoregion lines developed by The Nature Conservancy (Groves et al. 2002) and World Wildlife Fund (Olson et al. 2001). These divisions (figure 2) aresub-continental landscapes reflecting similar climate and biogeography. Three divisions cover the Northeast:

- Laurentian-Acadian (Div. 201)
- Central Interior and Appalachian (Div. 202)
- Gulf and Atlantic Coastal Plain (Div. 203).

Each ecological system has a "home" division with which it is most closely allied ecologically, and the Northeast terrestrial habitat classification uses the three divisions as one of the groupingvariables. An ecological system name may use its "home" division in its name (e.g., Laurentian–Acadian) or, depending upon the system range, a narrower biogeographic reference such as "Central Appalachian" (part of Div. 202).

FIGURE 2. Biogeographic Divisions Used in the Classification

The map on the left shows the major divisions used in naming the ecological system types The map on the right shows the TNC ecoregions, which are occasionally used to add further limits to the distribution of a system type.



Mapping Methods

The methods used to create the Terrestrial Habitat map are relatively detailed and summarized in a methods document with further detail on the classification system (Ferree and Anderson 2013).

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. 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.

© Jenny Wollensak Lussier

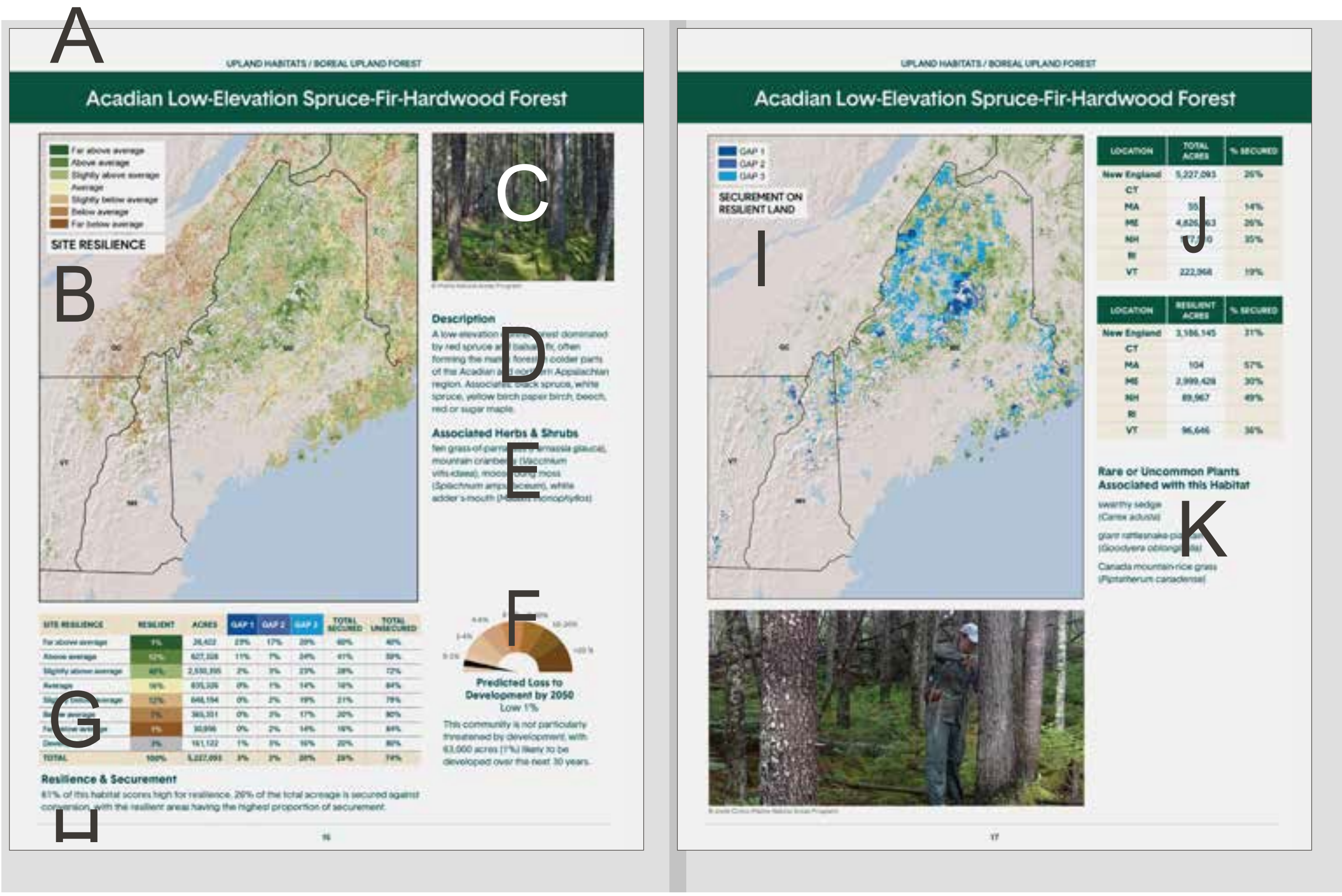
TABLE 1. Terrestrial Habitats and Level of Securement

UPLAND HABITATS	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED
MATRIX FOREST HABITATS	**29,141,876**	**4%**	**5%**	**18%**	**74%**
Boreal Upland Forest	**7,520,051**	**8%**	**8%**	**22%**	**61%**
Acadian Low-Elevation Spruce-Fir-Hardwood Forest	5,227,093	3%	3%	20%	74%
Acadian Sub-boreal Spruce Flat	1,418,525	2%	3%	23%	71%
Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest	874,432	19%	19%	23%	38%
Central Oak-Pine Forest	**2,257,390**	**3%**	**5%**	**17%**	**74%**
North Atlantic Coastal Plain Hardwood Forest	634,467	2%	4%	14%	81%
North Atlantic Coastal Plain Maritime Forest	79,051	1%	10%	12%	77%
North Atlantic Coastal Plain Pitch Pine Barrens	104,801	8%	7%	29%	55%
Northeastern Interior Pine Barrens	19,829	6%	3%	32%	59%
Northeastern Interior Dry-Mesic Oak Forest	1,387,176	1%	3%	14%	82%
Glacial Marine & Lake Mesic Clayplain Forest	32,066	3%	1%	4%	93%
Northern Hardwood & Conifer Forest	**19,364,435**	**2%**	**2%**	**16%**	**81%**
Laurentian-Acadian Northern Hardwood Forest	8,280,091	4%	3%	23%	70%
Laurentian-Acadian Pine-Hemlock-Hardwood Forest	4,460,233	1%	1%	11%	86%
Laurentian-Acadian Red Oak-Northern Hardwood Forest	1,071,860	2%	3%	13%	82%
Appalachian (Hemlock)-Northern Hardwood Forest	4,016,594	1%	2%	15%	82%
Northeastern Coastal & Interior Pine-Oak Forest	1,535,658	1%	2%	15%	83%
PATCH-FORMING HABITATS					
Cliff & Talus	**156,190**	**11%**	**10%**	**20%**	**60%**
Acidic Cliff & Talus	113,213	19%	17%	19%	45%
Calcareous Cliff & Talus	29,225	8%	7%	21%	64%
Circumneutral Cliff & Talus	13,752	5%	4%	19%	72%
Outcrop, Summit & Alpine	**191,618**	**32%**	**10%**	**18%**	**40%**
Acadian-Appalachian Alpine Tundra	7,900	76%	9%	14%	1%
Acidic Rocky Outcrop	152,972	15%	15%	21%	49%
Calcareous Rocky Outcrop	30,746	5%	6%	19%	70%
Grassland & Shrubland					
Atlantic Coastal Plain Beach & Dune	36,484	1%	26%	14%	59%
North Atlantic Coastal Plain Heathland & Grassland	25,219	2%	18%	13%	66%
Ruderal Grassland & Shrubland	53,047	1%	1%	13%	85%
Agricultural Grassland	2,571,409	0%	0%	3%	97%

TABLE 2. Palustrine Habitats and Level of Securement

	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED
WETLAND HABITATS	**3,947,104**	**3%**	**7%**	**18%**	**72%**
Northern Swamp	**2,195,240**	**2%**	**3%**	**17%**	**78%**
Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp	761,511	4%	3%	20%	74%
Laurentian-Acadian Alkaline Conifer-Hardwood Swamp	573,968	1%	3%	13%	84%
North-Central Appalachian Acidic Swamp	608,230	2%	4%	20%	75%
North-Central Interior & Appalachian Rich Swamp	251,531	2%	3%	16%	80%
Northern Peatland	**381,256**	**4%**	**11%**	**18%**	**67%**
Boreal-Laurentian-Acadian Acidic Basin Fen	323,874	5%	5%	19%	71%
Boreal-Laurentian Bog	37,537	9%	14%	14%	63%
Acadian Maritime Bog	5,223	4%	21%	3%	73%
Laurentian-Acadian Alkaline Fen	217	2%	0%	29%	69%
North-Central Interior & Appalachian Acidic Peatland	14,406	2%	13%	24%	60%
Coastal Plain Swamp & Peatland	**18,628**	**7%**	**10%**	**25%**	**58%**
North Atlantic Coastal Plain Basin Peat Swamp	17,783	11%	7%	27%	56%
Atlantic Coastal Plain Northern Bog	845	3%	13%	24%	60%
Central Hardwood Swamp	**39,338**	**2%**	**2%**	**11%**	**86%**
North-Central Interior Wet Flatwoods	25,306	0%	3%	13%	84%
Glacial Marine & Lake Wet Clayplain Forest	14,032	3%	0%	9%	88%
Large River Floodplain	**340,645**	**2%**	**5%**	**19%**	**73%**
Laurentian-Acadian Large River Floodplain	309,055	3%	5%	17%	76%
North-Central Appalachian Large River Floodplain	31,590	2%	6%	22%	70%
Freshwater Marsh & Shrub Swamp	860,248	2%	4%	16%	77%
Laurentian-Acadian Freshwater Marsh	367,506	3%	4%	16%	77%
Laurentian-Acadian Wet Meadow-Shrub Swamp	492,741	2%	3%	17%	78%
Tidal Marsh	111,748	2%	14%	22%	62%
Acadian Coastal Salt & Estuary Marsh	23,350	1%	11%	19%	69%
North Atlantic Coastal Plain Tidal Salt Marsh	88,398	2%	16%	25%	56%

PAGE LAYOUT



A. Habitat Name

B. Map of Relative Climate Resilience of the Habitat

C. Photo

D. Description

E. Associated Herbs and Shrubs

F. Predicted Loss to Development by 2050

G. Resilience by Securement Table

H. Resilience and Securement

I. Map of Resilient Areas and Securement

J. State Statistics on Resilience and Securement

K. Associated Rare Plant Species

Click on any map to go to the mapping tool.

A. Habitat Name

The standardized name or macrogroup based on NatureServe ecological systems. More detail canbe found on the terrestrial habitats here.

B. Map of Relative Climate Resilience of the Habitat

The boundaries of the habitat come directly from the Northeast Terrestrial Habitat map, but the information displayed is the climate resilience score for each pixel of land. Climate resilience is scored on a relative scale adjusted to the average score of the underlying physical habitat on whichthis habitat/vegetation type occurs. The legend is:

- Far above average (> 2 standard deviations) Most Resilient
- Above average (1 to 2 standard deviations) More Resilient
- Slightly above average (0.5 to 1 standard deviation) Somewhat Resilient
- Average (-0.5 to 0.5 standard deviations) Average
- Slightly below average (-0.5 to -1 standard deviation) Somewhat Vulnerable
- Below average (-1 to -2 standard deviations) More Vulnerable
- Far below average (<-2 standard deviations) Most

Vulnerable More detail can be found on TNC's climate resilience map here.

C. Photo

Photos were provided by the state Natural Heritage Programs or TNC staff and are intended toconvey the look and structure of the habitat.

D. Description

The text for this field was taken directly from the Northeastern Terrestrial Wildlife HabitatClassification (Gawler et al. 2008) with editing to shorten the description. The original document is here.

When a description was not provided in Gawler (2008), we modified a description of the habitat from one of the state natural community classification documents, usually from the state with the majority of the habitat. The state classifications provide much more detail on the habitat and a more localized description of environmental setting and associated species. We encourage readersto check out these terrific documents, which contain a body of information not readily found in anyother source.

E. Associated Herbs and Shrubs

This section includes species that are tracked by the state Natural Heritage programs and that occur in statistically higher numbers in this habitat than any other (chi-squared test). These species were determined by an overlay of 117,000 species locations obtained from the Natural Heritage programs and used with permission. Lists were not corrected for current range, so if a habitat occurs from CT to ME and a plant species is common in the habitat only in CT, it will stillshow up in the list.

F.Predicted Loss to Development by 2050

This chart shows the percent of the habitat projected to be converted to development by 2050, if development keeps the same pace as the last two decades. The estimate was made using a Land Transformation Model developed by Amin Tayyebias and others at Purdue University (Tayyebi et al. 2013). When combined with the habitat grid, the model predicts the amount of habitat lostto development in future decades based on the past decade (1990–2000 data and validated usingchange in the 2001 and 2006 National Land Cover Databases).

G. Resilience by Securement Table

This table lists the acres and percentages of each resilience category by its GAP status. With respect to the global diversity targets 4 and 5, the securement status of the entire habitat is given in the top row. For the New England Target, the area and securement status of the most resilient land is equal to the sum of the three highest resilience categories shaded in green (>0.5 SD, i.e., slightlyabove average or higher).

On the macrogroup pages, this table is securement by state and includes the number of ImportantPlant Areas (IPAs) and the number that meet the GSPC target of 75% protected (GAP 1-2), have 75% of their area secured (GAP 1-3) in a combination of protected and multiple-use land, or are unsecured, although many have some level of securement below the 75% threshold. IPAs are assigned to their dominant habitat, although they include a variety of habitats. Two unsecured open-water IPAs in Maine and Vermont are not included here.

H. Resilience and Securement

This text summarizes proportion of resilience land and the degree of securements (GAP 1-3) forthe habitat across all of New England.

I. Map of Resilient Areas and Securement

This map shows only the resilient portion of the habitat (areas with a resilience score >0.5 SD, i.e., slightlyabove average, or better). Blue colors indicate that the resilient areas are alreadyundersome sort of securement (GAP 1, 2, or 3). The accompanying web map lets users explore these areas in detail.

J. State Statistics on Resilience and Securement

This box includes relevant statistics on the distribution, resilience, and securement by state.

UPPER BOX: Total areas of the habitat in each state, and proportion that is secured (GAP 1-3)

LOWER BOX: Total resilient acres of the habitat (>0.5 SD) in the state and the proportionthat is secured (GAP 1-3)

K. Associated Rare Plant Species

This list comes from expert knowledge of rare species distributions in the habitats described here.

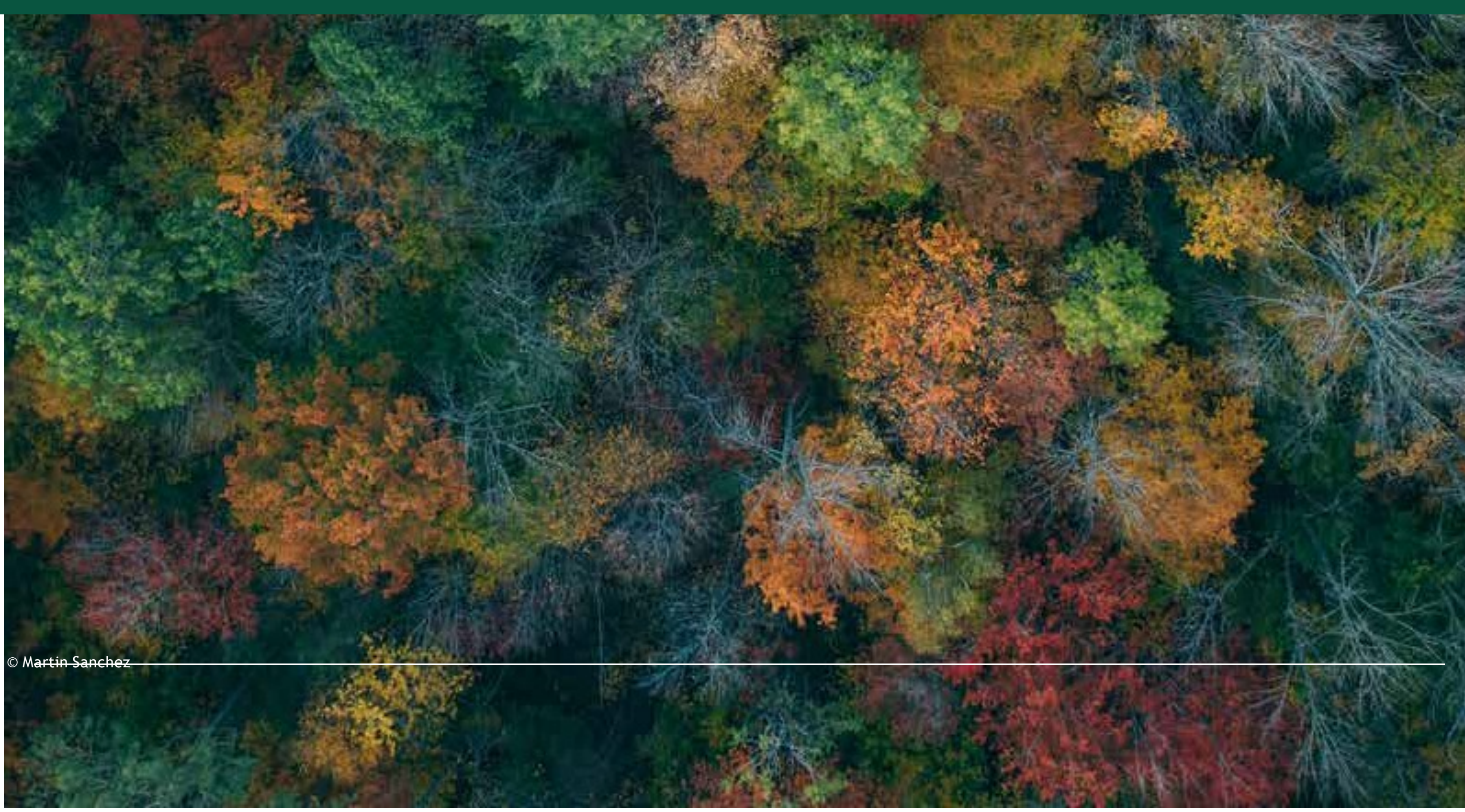
Variations: Macrogroups and Tidal Systems

The habitats are organized by NatureServe Macrogroups. Each macrogroup page shows the distribution and securement of the group, a table showing GAP status by state, and a chart of predicted loss to development. The page is followed by maps and photos of each individual habitatwithin the macrogroup that occurs in New England.

Tidal systems are treated differently, as they are subject to the unique threat of sea-level rise, which is analyzed differently from the climate-resilient land.

Jpland HabItats

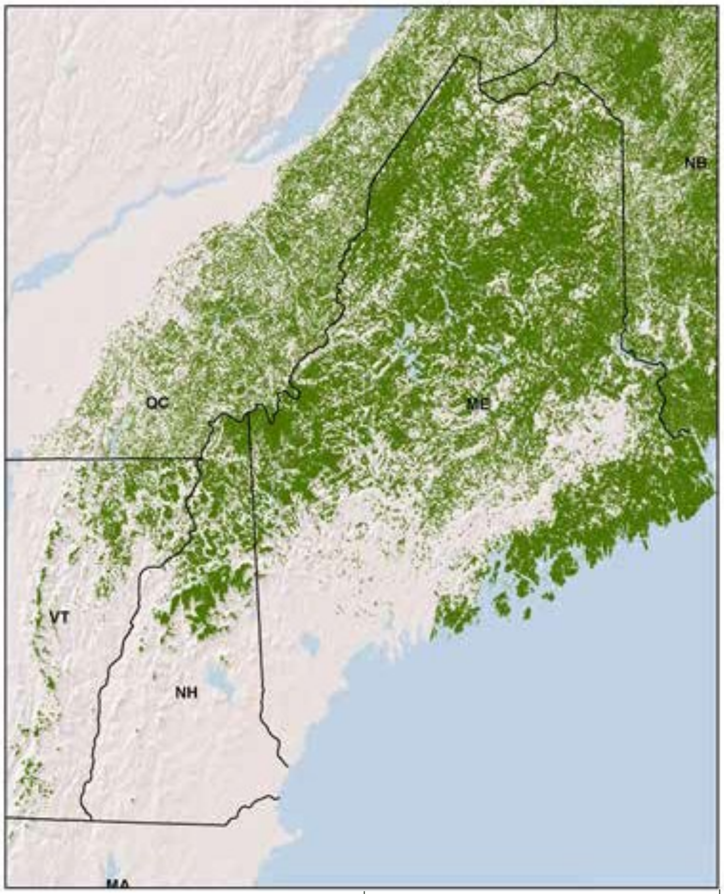
ıatrix forest

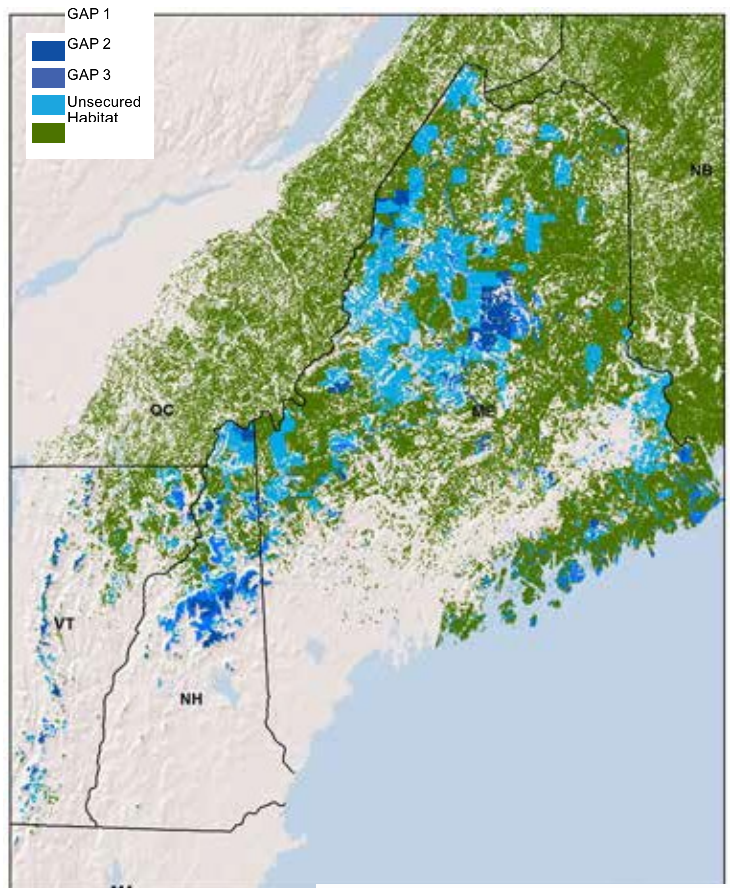


© Martin Sanchez

MACROGROUP

OREAL UPLAND FOREST





Boreal Upland Forest

Conifer-dominated forests of cold northern climates characterized by spruce and fir.

Acres in New England

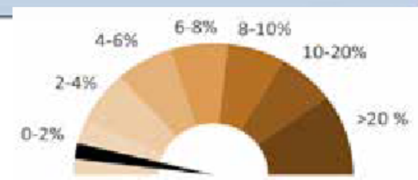
7.5 million

Percent Secured

GAP 1 = 5%

GAP 2 = 5%

GAP 3 = 21%



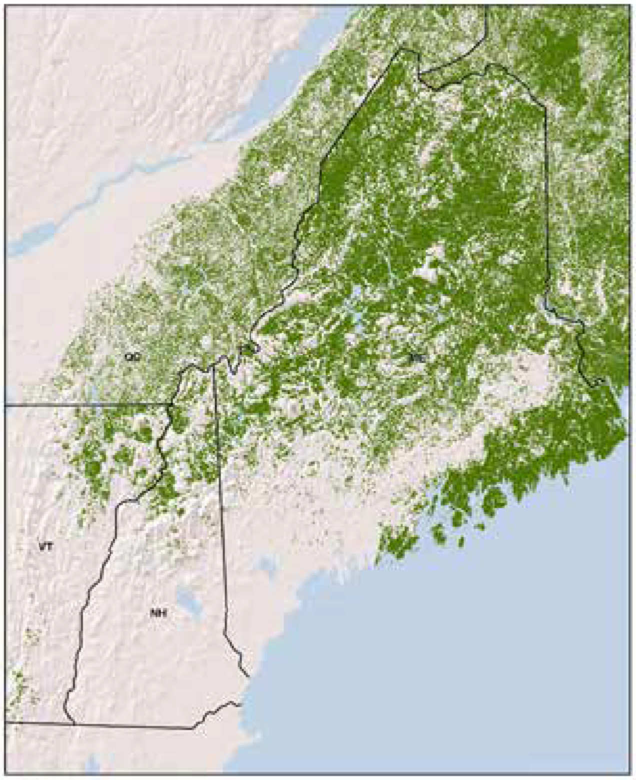
Predicted Loss to Development by 2050

38,731 acres (<1%)

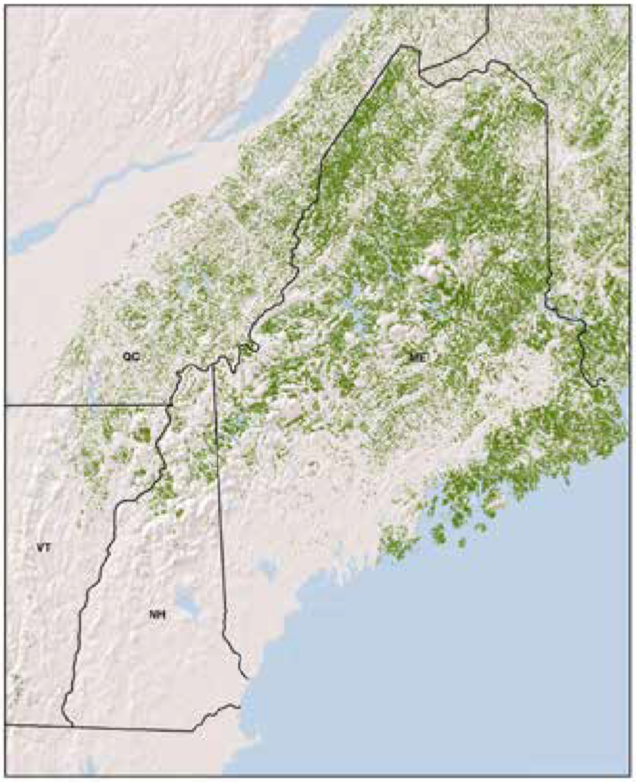
	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS TOTAL	P	S	U
Boreal Upland Forest	**7,520,051**	**5%**	**5%**	**21%**	**69%**	**21**	**3**	**5**	**13**
Massachusetts	1,248	26%	0%	29%	45%				
Maine	6,574,320	3%	3%	21%	72%	19	3	3	13
New Hampshire	573,597	18%	27%	23%	32%	2		2	
Vermont	370,886	10%	5%	16%	69%				
New England	**7,520,051**	**348,045**	**373,204**	**1,595,224**	**5,203,578**				

P = Protected S = Secured U = Unsecured

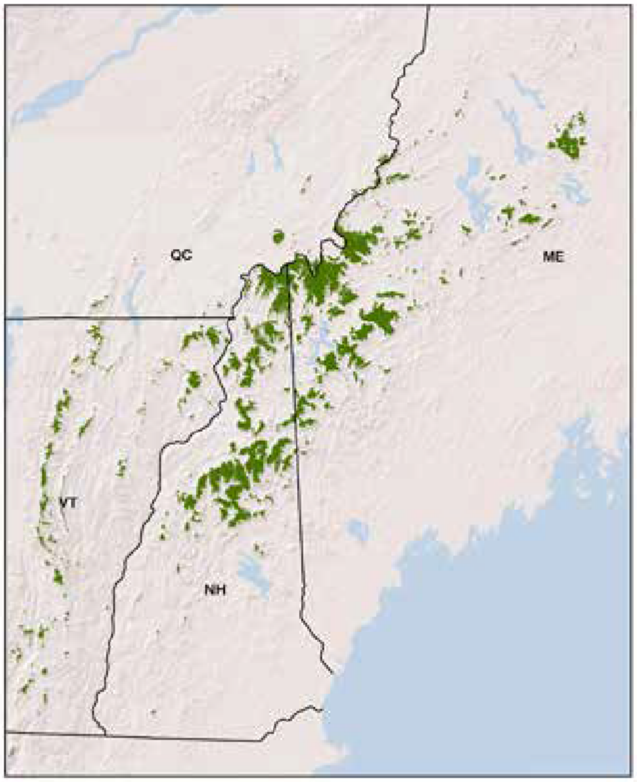
DISTRIBUTION OF HABITATS



Acadian Low-Elevation Spruce-Fir-Hardwood Forest

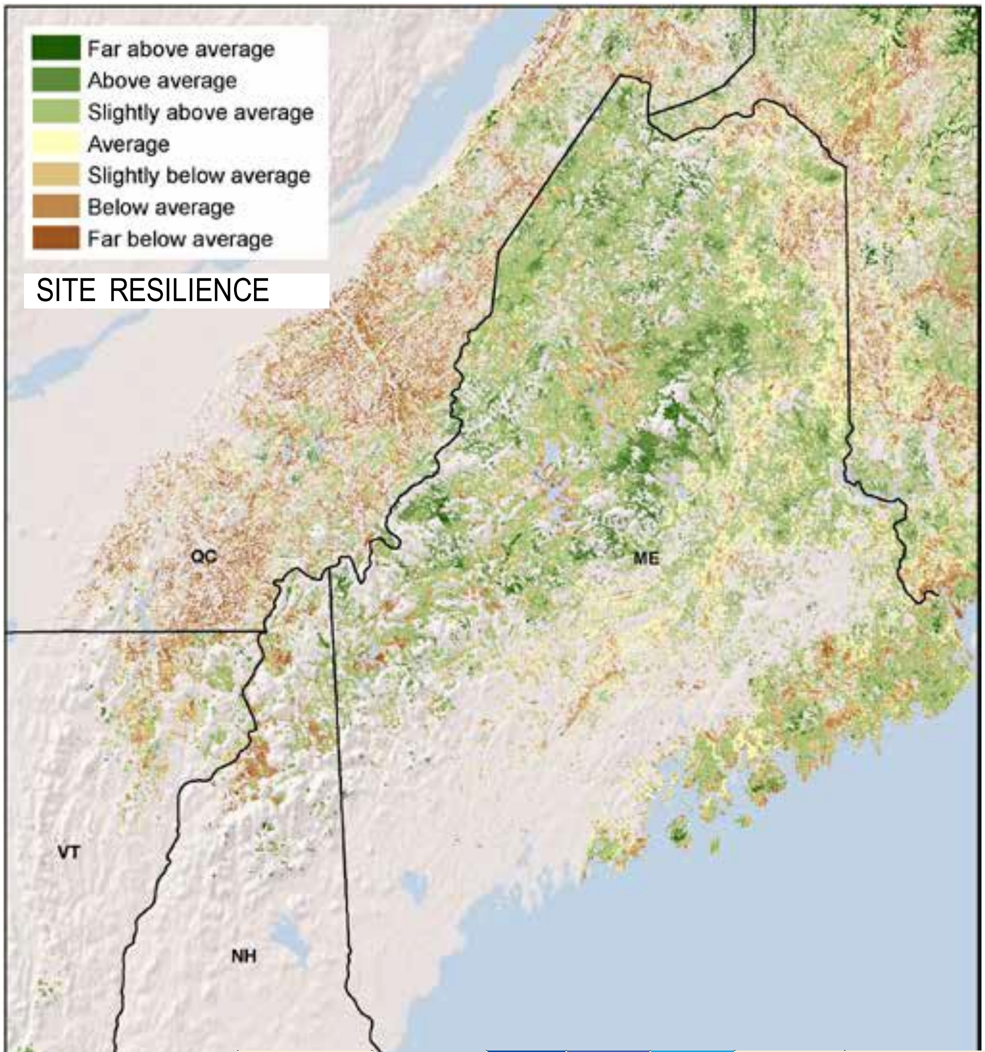


Acadian Sub-boreal Spruce Flat



Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest

Acadian Low-Elevation Spruce-Fir-Hardwood Forest



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	28,422	23%	17%	20%	60%	40%
Above average	12%	627,328	11%	7%	24%	41%	59%
Slightly above average	48%	2,530,395	2%	3%	23%	28%	72%
Average	16%	835,326	0%	1%	14%	16%	84%
Slightly below average	12%	648,194	0%	2%	19%	21%	79%
Below average	7%	365,351	0%	3%	17%	20%	80%
Far below average	1%	30,956	0%	2%	14%	16%	84%
Developed	3%	161,122	1%	3%	16%	20%	80%
TOTAL	**100%**	**5,227,093**	**3%**	**3%**	**20%**	**26%**	**74%**

Resilience & Securement

61% of this habitat scores high for resilience, and 26% of the total acreage is secured against conversion, with the resilient areas having the highest proportion of securement.

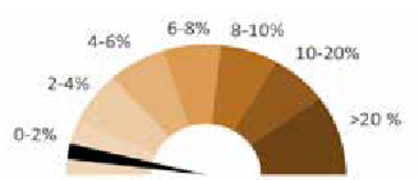

© Maine Natural Areas Program

Description

A low-elevation conifer forest dominatedby red spruce and balsam fir, often forming the matrix forest in colder parts of the Acadian and northern Appalachianregion. Associates: black spruce, white spruce, yellow birch paper birch, beech, red or sugar maple.

Associated Herbs & Shrubs

fen grass-of-parnassus (*Parnassia glauca*), mountain cranberry (*Vaccinium vitis-idaea*), moose dung moss (*Splachnum ampullaceum*), white adder's-mouth (*Malaxis monophyllos*)

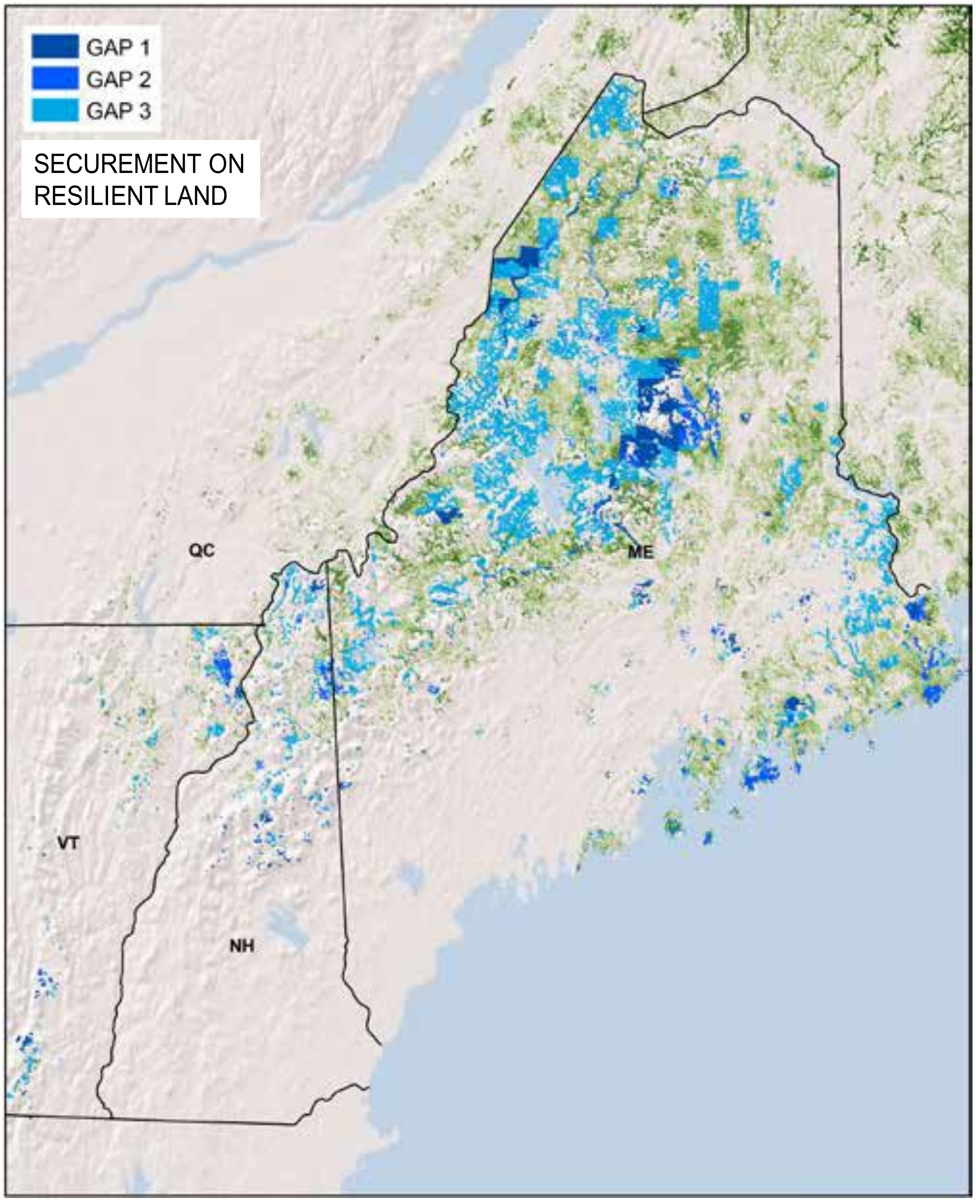


Predicted Loss to Development by 2050

Very low 1%

This community is not particularly threatened by development, with 34,136 acres (<1%) likely to be lost over the next 30 years.

Acadian Low-Elevation Spruce-Fir-Hardwood Forest



LOCATION	TOTAL ACRES	% SECURED
New England	5,227,093	26%
CT		
MA	553	14%
ME	4,826,063	26%
NH	177,510	35%
RI		
VT	222,968	19%

LOCATION	RESILIENT ACRES	% SECURED
New England	3,186,145	31%
CT		
MA	104	57%
ME	2,999,428	30%
NH	89,967	49%
RI		
VT	96,646	36%

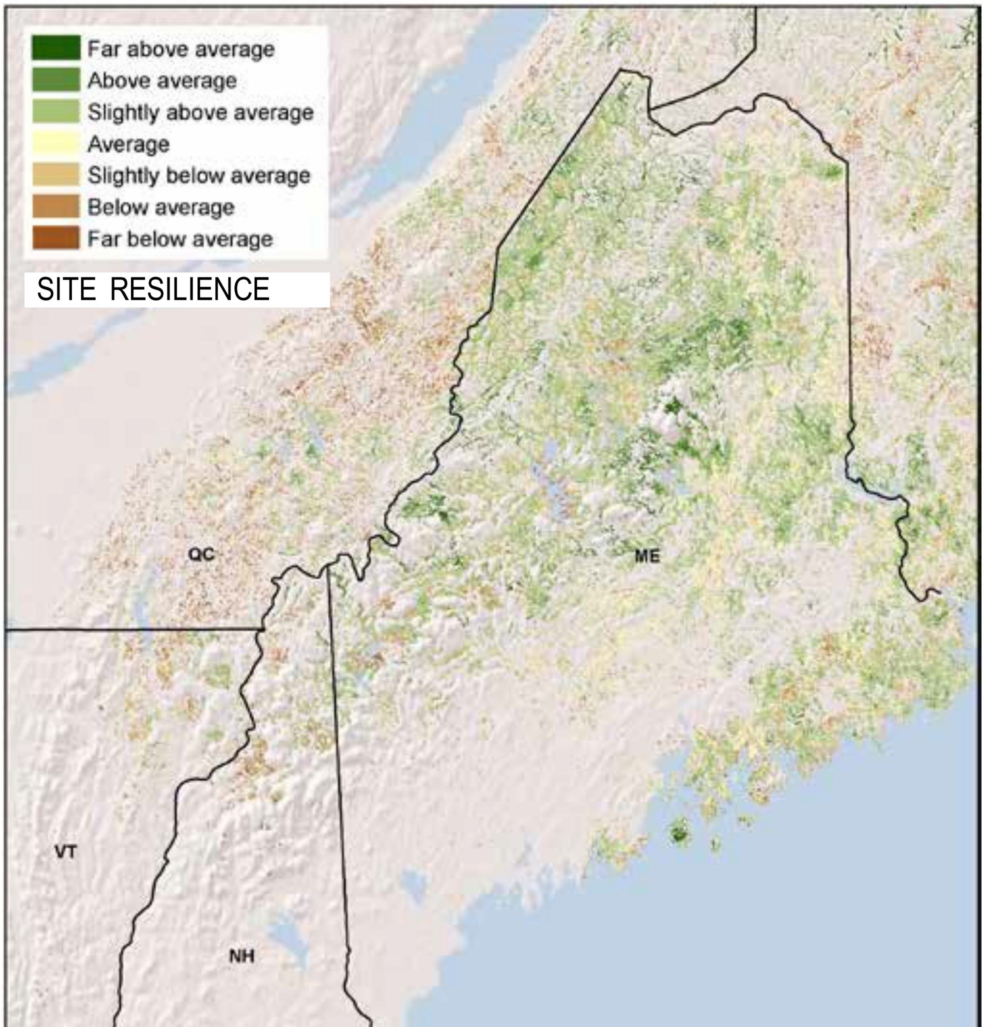
Rare or Uncommon Plants Associated with this Habitat

swarthy sedge
(*Carex adusta*)

giant rattlesnake-plantain
(*Goodyera oblongifolia)*

Canada mountain-rice grass
(*Piptatherum canadense*)

Acadian Sub-boreal Spruce Flat



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	3,121	27%	13%	19%	58%	42%
Above average	11%	149,814	9%	5%	25%	39%	61%
Slightly above average	54%	762,799	2%	3%	26%	31%	69%
Average	17%	234,211	1%	1%	16%	18%	82%
Slightly below average	10%	148,563	1%	2%	21%	24%	76%
Below average	6%	83,053	0%	3%	19%	23%	77%
Far below average	0%	6,491	0%	3%	20%	23%	77%
Developed	2%	30,473	1%	3%	20%	24%	76%
TOTAL	**100%**	**1,418,525**	**2%**	**3%**	**23%**	**28%**	**72%**

Resilience & Securement

66% of this habitat scores high for resilience, and 28% of the total acreage is secured against conversion, with the resilient areas having the highest proportion of securement.

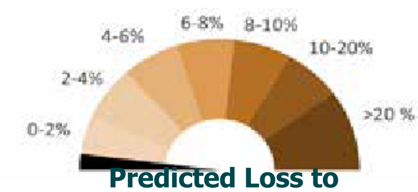
© Maine Natural Areas Program

Description

A conifer or mixed forest forming extensive flats on areas of imperfectly drained soils. Black spruce, red spruce, and balsam fir dominate a mostly closed canopy; yellow birch, hemlock, black cherry, and red maple are sometimes present in smaller numbers. Bryophytes and low herbs are abundant.

Associated Herbs & Shrubs

mountain fly-honeysuckle (*Lonicera villosa*), fen grass-of-parnassus (*Parnassia glauca*), sheathed sedge (*Carex vaginata*)

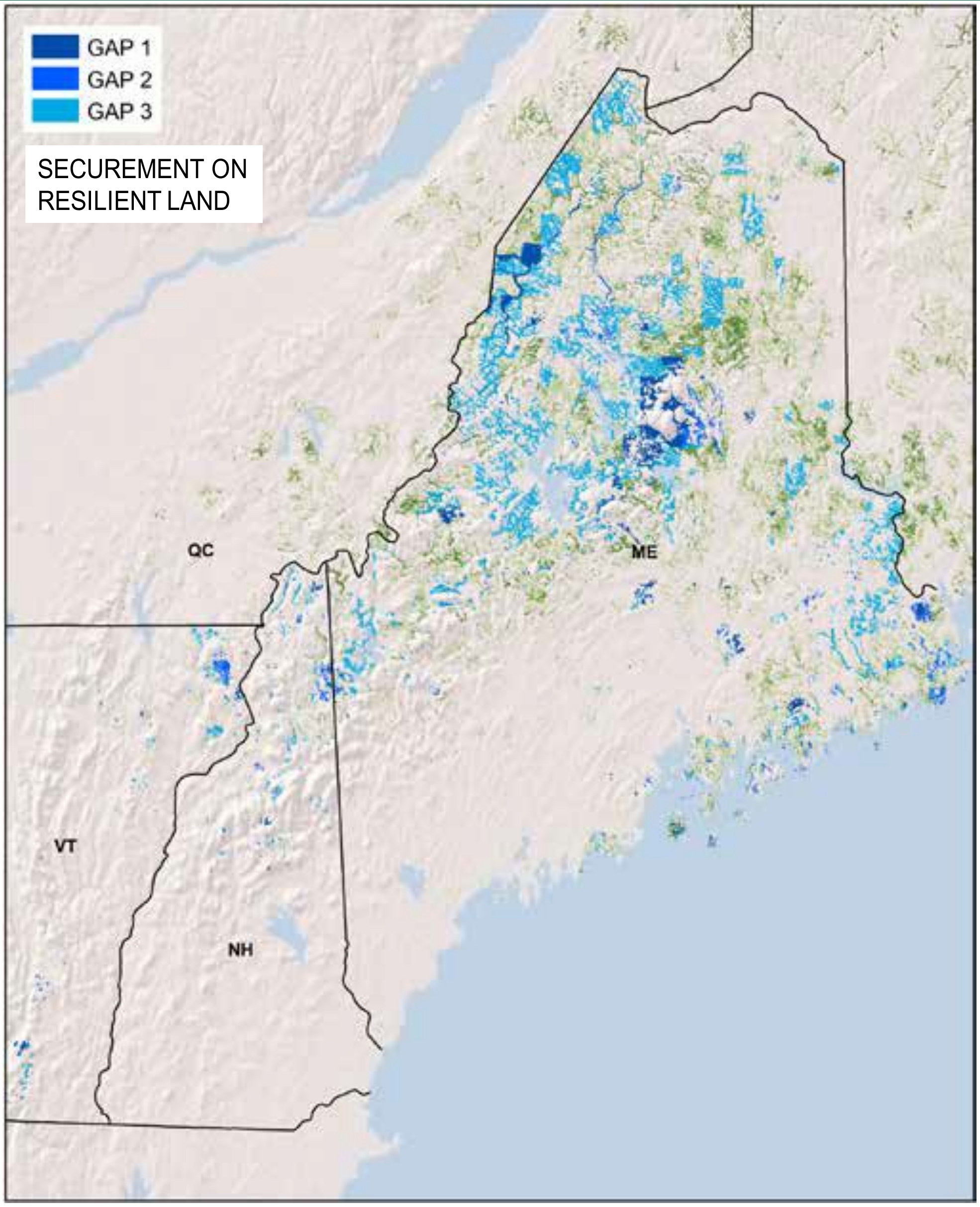


Predicted Loss to Development by 2050

Very low 1%

This community is not threatened by development. Only 4,169 acres (<1%) are likely to be lost over the next 30 years.

Acadian Sub-boreal Spruce Flat



LOCATION	TOTAL ACRES	% SECURED
New England	1,418,525	29%
CT		
MA	91	3%
ME	1,328,319	28%
NH	43,952	35%
RI		
VT	46,164	27%

LOCATION	RESILIENT ACRES	% SECURED
New England	915,734	33%
CT		
MA	3	100%
ME	875,583	32%
NH	21,296	48%
RI		
VT	18,852	53%

Rare or Uncommon Plants Associated with this Habitat

mountain cranberry
(*Vaccinium vitis-idaea*)

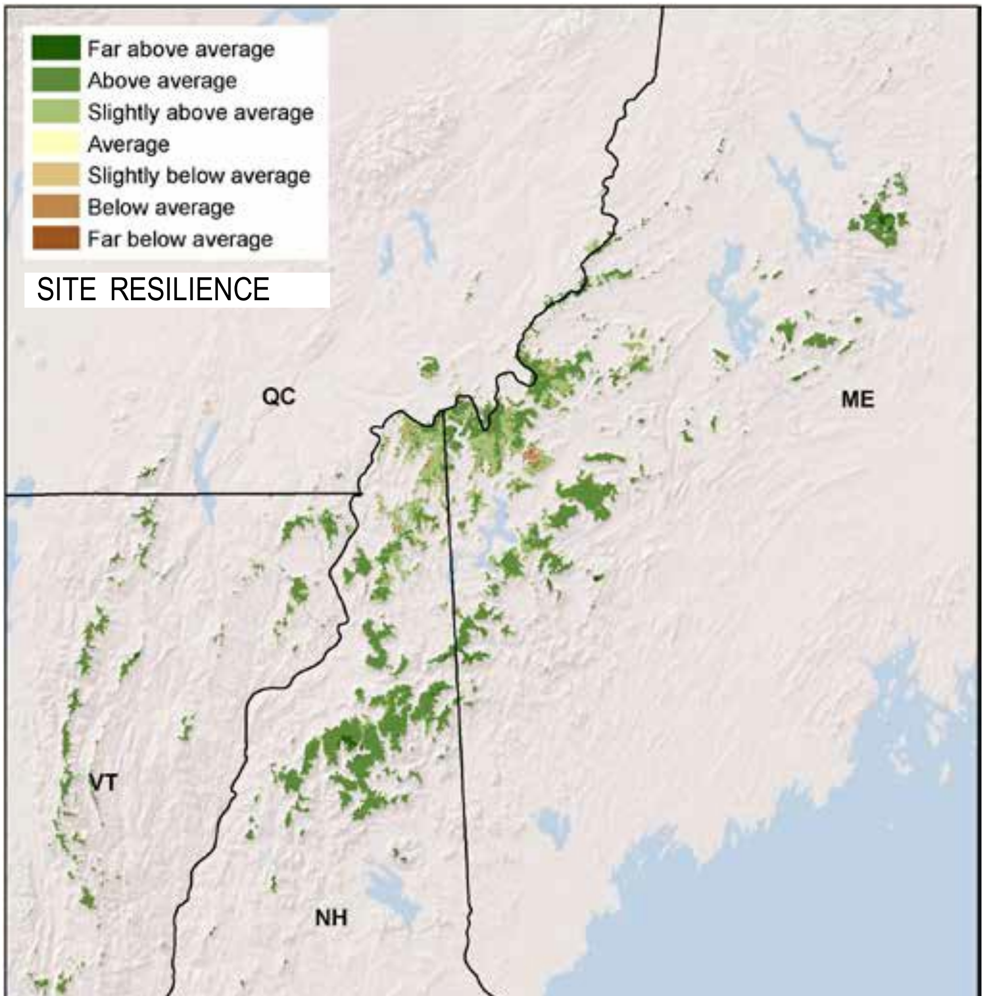
Lapland-crowfoot
(*Coptidium lapponicum*)

swamp thistle
(*Cirsium muticum*)

lance-leaved violet
(*Viola lanceolata*)

© Andy Cutco (Maine Natural Areas Program)

Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	2%	19,013	52%	17%	9%	77%	23%
Above average	70%	609,688	24%	24%	19%	67%	33%
Slightly above average	25%	221,127	5%	7%	37%	49%	51%
Average	0%	0	0%	0%	0%	0%	0%
Slightly below average	0%	13	0%	0%	67%	67%	33%
Below average	1%	13,038	3%	7%	41%	51%	49%
Far below average	0%	3,626	2%	1%	32%	36%	64%
Developed	1%	7,926	4%	4%	37%	45%	55%
TOTAL	**100%**	**874,432**	**19%**	**19%**	**23%**	**62%**	**38%**

Resilience & Securement

97% of this habitat scores high for resilience, and 62% of the total acreage is securedagainst conversion, and 38% is protected.

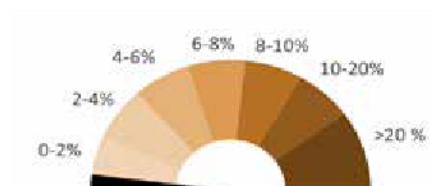
© Maine Natural Areas Program

Description

A high-elevation conifer forest dominatedby red spruce and balsam fir and formingsmall to very large patches on the highest peaks of the Northern Appalachian mountains. Heart-leaved birch is a characteristic tree, along with yellow birch, white birch, mountain maple, striped maple, mountain ash, and occasionally black spruce.

Associated Herbs & Shrubs

boreal bedstraw (*Galium kamtschaticum*), Bartram shadbush (*Amelanchier bartramiana*), Hornemann's willow-herb (*Epilobium hornemannii*), purple crowberry (*Empetrum atropurpureum*), northern bentgrass (*Agrostis mertensii*), cushion-plant (*Diapensia lapponica*), small-flowered wood rush (*Luzula parviflora*), squashberry (*Viburnum edule*), bearberry willow (*Salix uva-ursi*), little shinleaf (*Pyrola minor*), false toadflax (*Geocaulon lividum*)

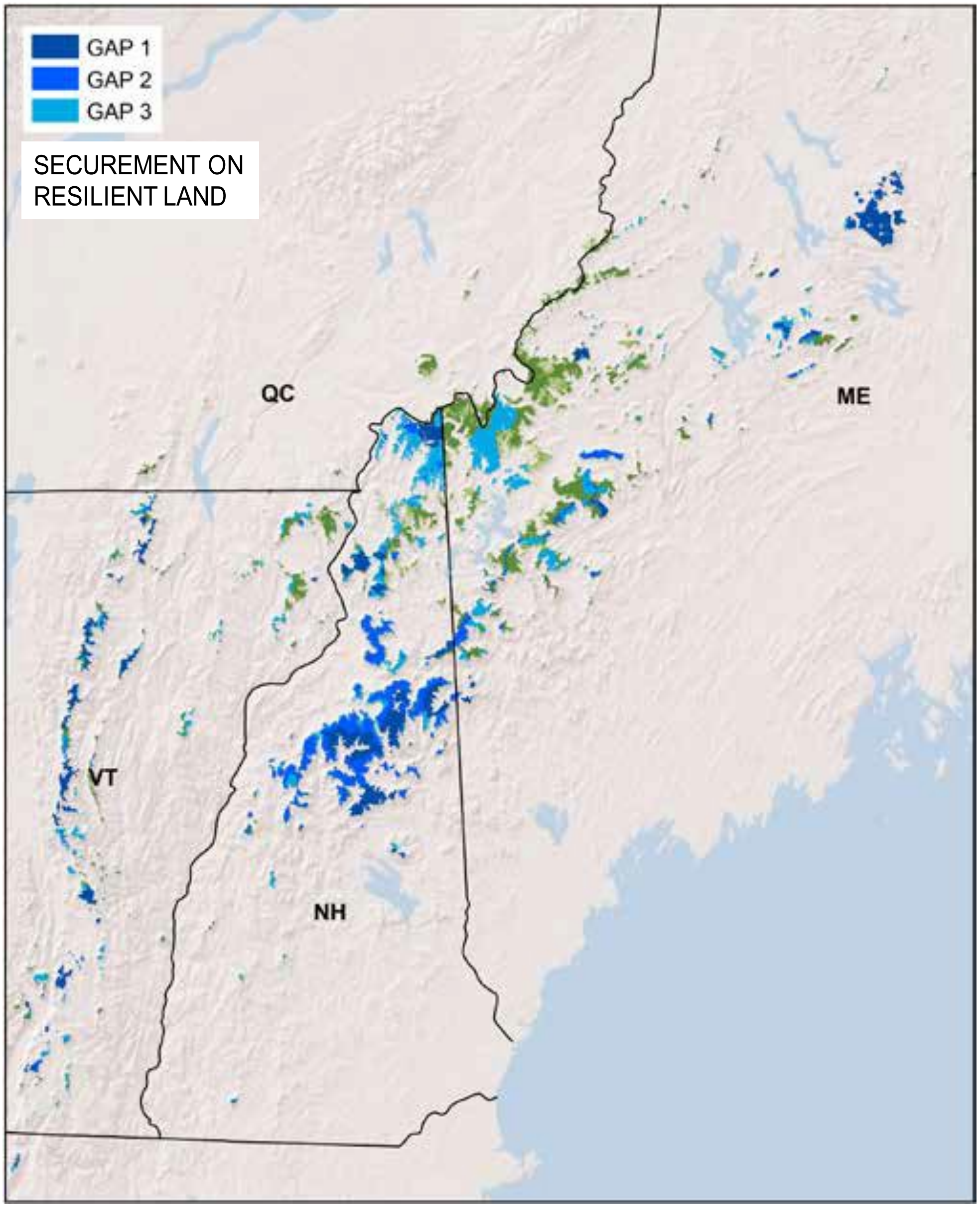


Predicted Loss to Development by 2050

Very low 0%

This community is not threatenedby development. Only 434 acres (<1%) are likely to be lost over thenext30 years.

Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest




© Maine Natural Areas Program

LOCATION	TOTAL ACRES	% SECURED
New England	874,432	62%
CT		
MA	605	100%
ME	419,938	40%
NH	352,135	89%
RI		
VT	101,753	60%

LOCATION	RESILIENT ACRES	% SECURED
New England	849,828	62%
CT		
MA	584	100%
ME	406,177	40%
NH	342,263	89%
RI		
VT	100,804	60%

Rare or Uncommon Plants Associated with this Habitat

lance-leaved arnica (*Arnica lanceolata*)

open field sedge (*Carex conoidea*)

russet sedge (*Carex saxatilis*)

heart-leaved twayblade (*Neottia cordata*)

spiked wood rush (*Luzula spicata*)

woodland arctic-cudweed (*Omalotheca sylvatica*)

silvery whitlow-wort (*Paronychia argyrocoma*)

little yellow-rattle (*Rhinanthus minor* ssp. *groenlandicus*)

purple crowberry (*Empetrum atropurpureum*)

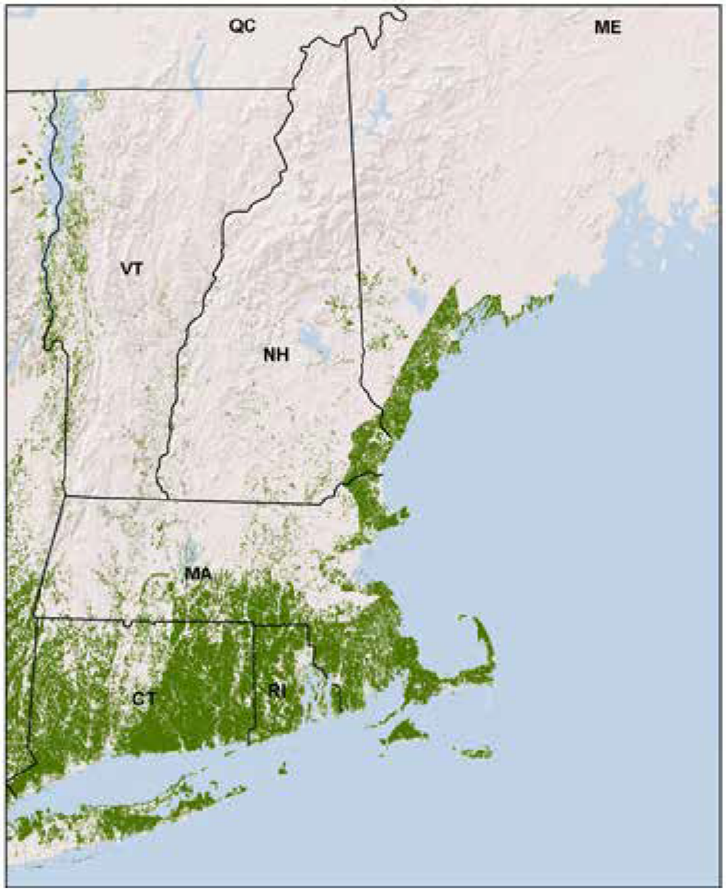
Hornemann's willow-herb (*Epilobium hornemannii*)

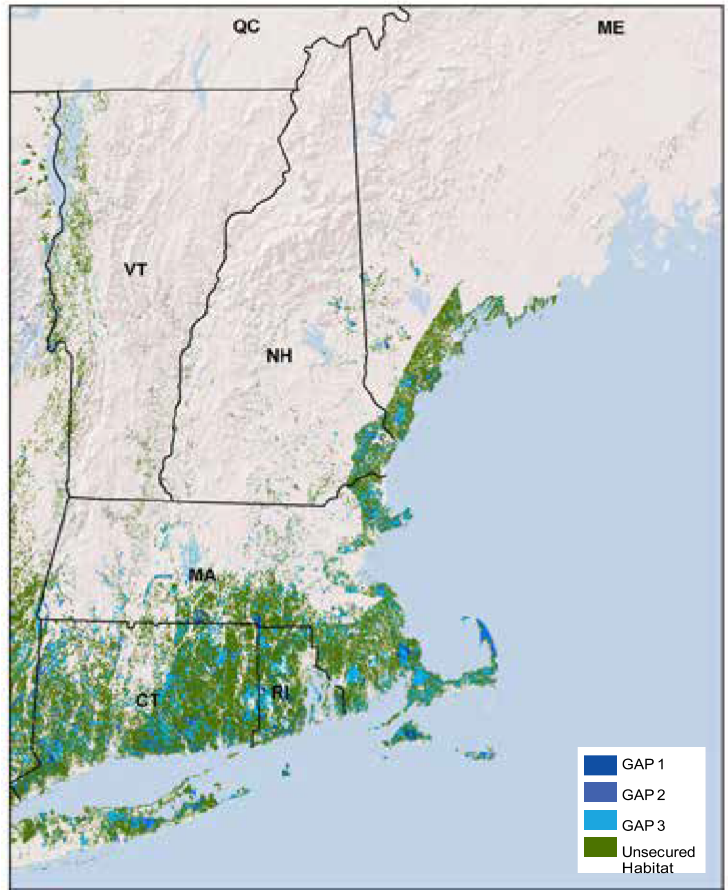
boreal bedstraw (*Galium kamtschaticum*)

northern willow (*Salix arctophila*)

MACROGROUP

CENTRAL OAK-PINE FOREST

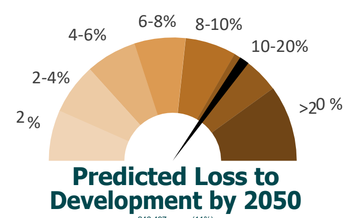




Central Oak-Pine Forest
Mixed hardwood-conifer forest of southern New England dominated by oaks (red, black, scarlet, chestnut) and pine (white, pitch).

Acres in New England
2.4 million

Percent Secured
GAP 1 = 2%
GAP 2 = 4%
GAP 3 = 14%

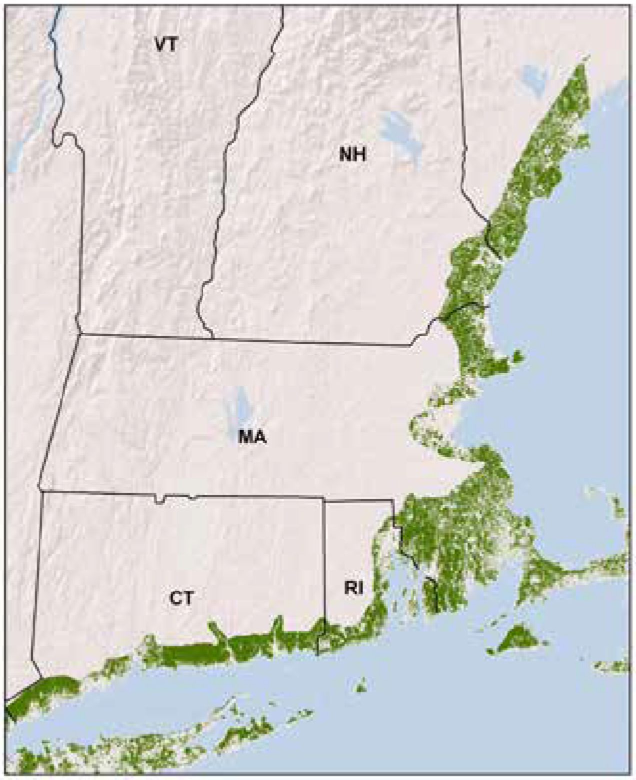


	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS			
						TOTAL	P	S	U
Central Oak-Pine Forest	**2,257,390**	**2%**	**4%**	**14%**	**80%**	**33**	**3**	**4**	**26**
Connecticut	1,164,346	1%	4%	12%	83%	17	2		15
Massachusetts	642,197	4%	3%	19%	74%	13	1	4	8
Maine	117,372	1%	5%	10%	85%				
New Hampshire	42,310	3%	4%	16%	77%				
Rhode Island	258,565	2%	4%	15%	79%	3			3
Vermont	32,599	2%	1%	4%	93%				

New England	**2,257,390**	**41,892**	**79,149**	**326,660**	**1,809,688**

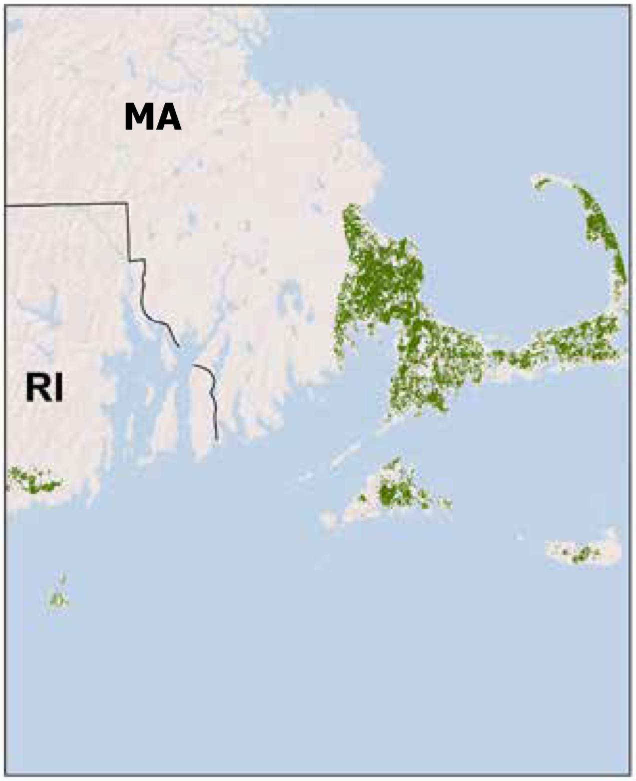
P = Protected S = Secured
U = Unsecured

DISTRIBUTION OF HABITATS



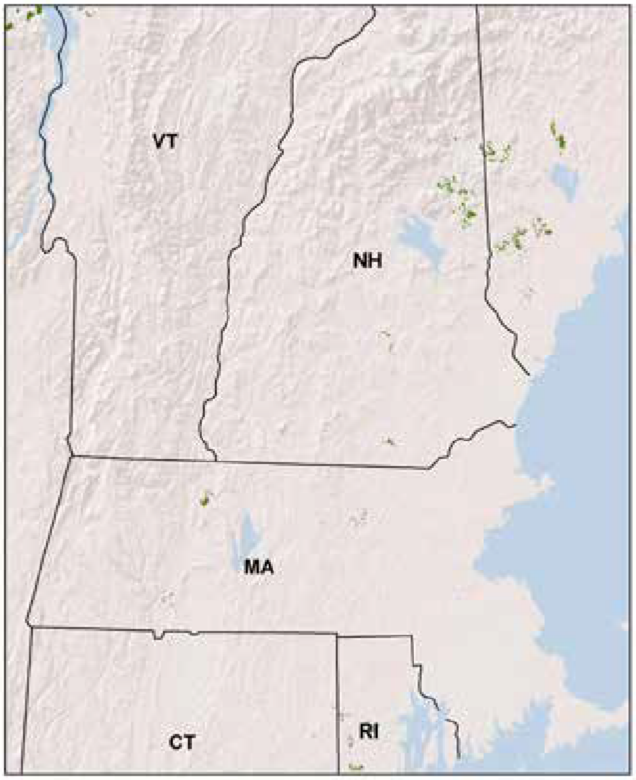
COASTAL | **North Atlantic Coastal Plain Hardwood Forest**

COASTAL | **North Atlantic Coastal Plain Maritime Forest**

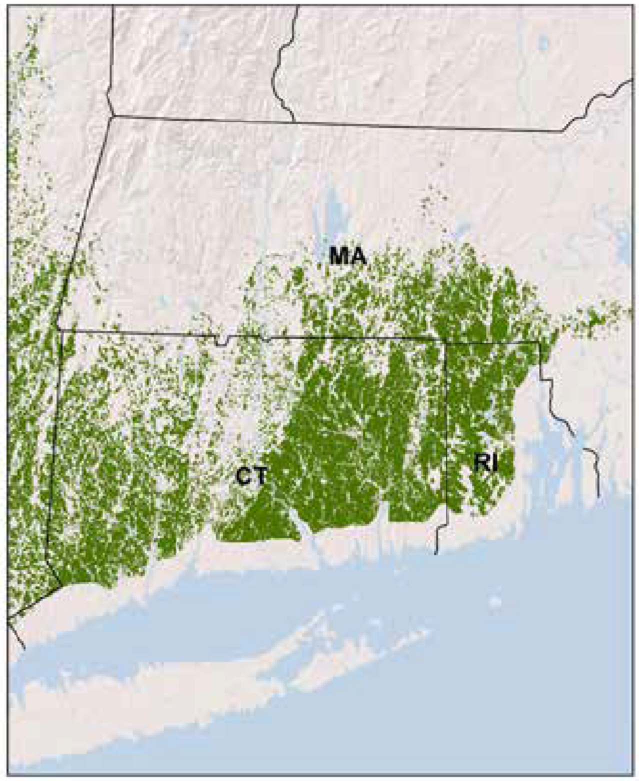


COASTAL | **North Atlantic Coastal Plain Pitch Pine Barrens**

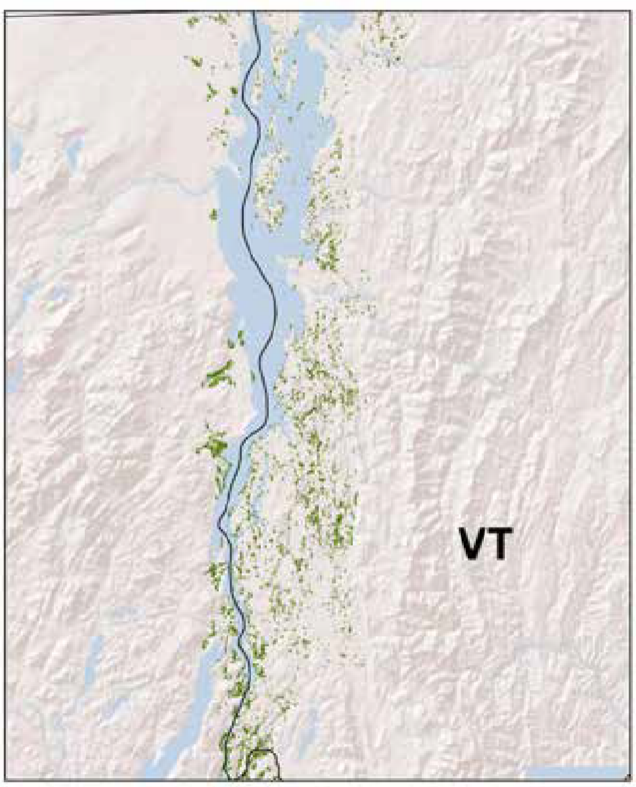
DISTRIBUTION OF HABITATS



INTERIOR | **Northeastern Interior Pine Barrens**

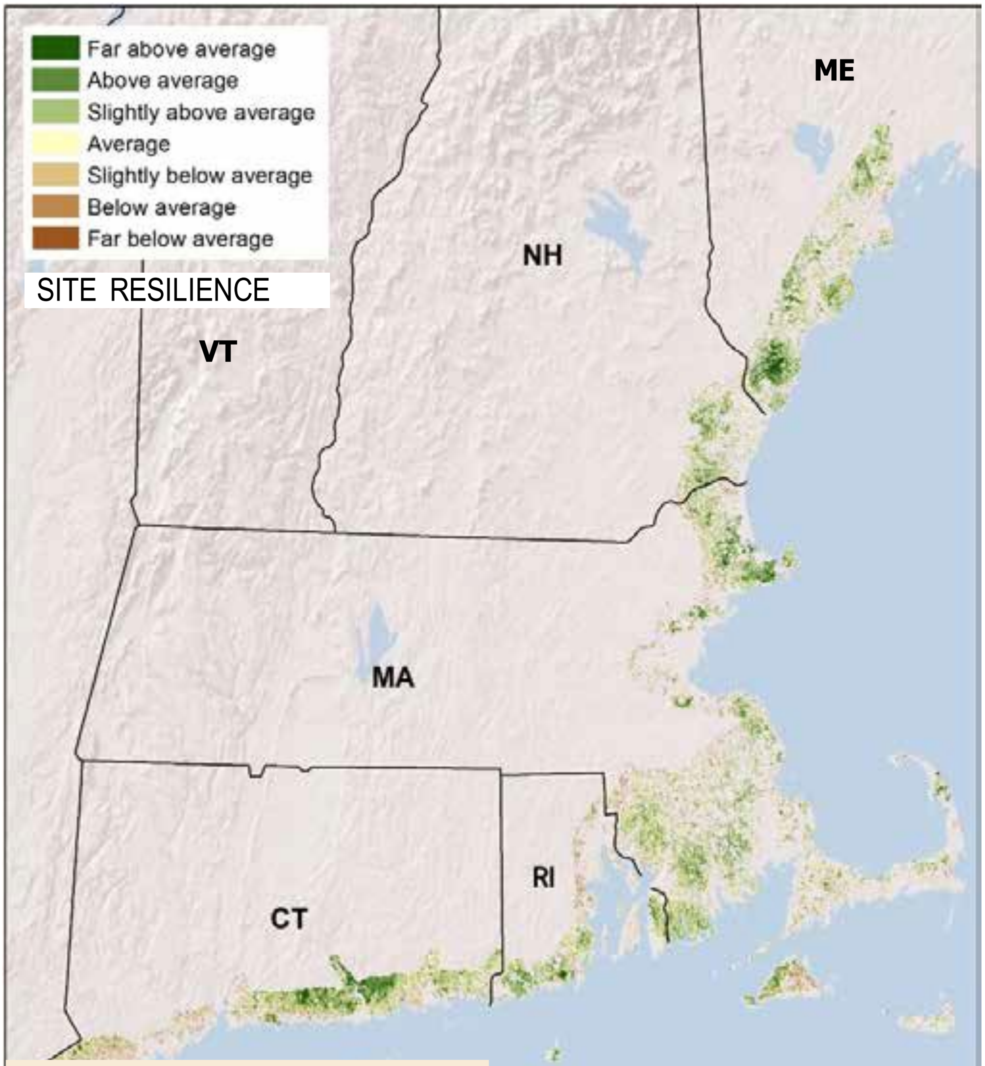


INTERIOR | **Northeastern Interior Dry-Mesic Oak Forest**



INTERIOR | **Glacial Marine & Lake Clayplain Forest**

North Atlantic Coastal Plain Hardwood Forest



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	2%	11,865	3%	11%	30%	44%	56%
Above average	12%	75,212	2%	6%	23%	31%	69%
Slightly above average	18%	111,672	2%	4%	17%	22%	78%
Average	38%	241,398	1%	4%	14%	19%	81%
Slightly below average	11%	66,978	2%	2%	12%	15%	85%
Below average	7%	45,680	2%	2%	10%	14%	86%
Far below average	1%	9,290	1%	1%	7%	10%	90%
Developed	11%	72,373	1%	1%	7%	8%	92%
TOTAL	**100%**	**634,467**	**2%**	**4%**	**14%**	**20%**	**80%**

Resilience & Securement

32% of this habitat scores high for resilience, and 20% of the total acreage is secured against conversion, with the resilient areas having the highest proportion of securement.

© Robert Coxe (Delaware Species Conservation & Research Program)

Description

A hardwood forest largely dominated by oaks, often mixed with pine. White, red, chestnut, black, and scarlet oaks are typical, and American holly is sometimes present. Sassafras, birch, aspen, and hazelnut are common.

Associated Herbs & Shrubs

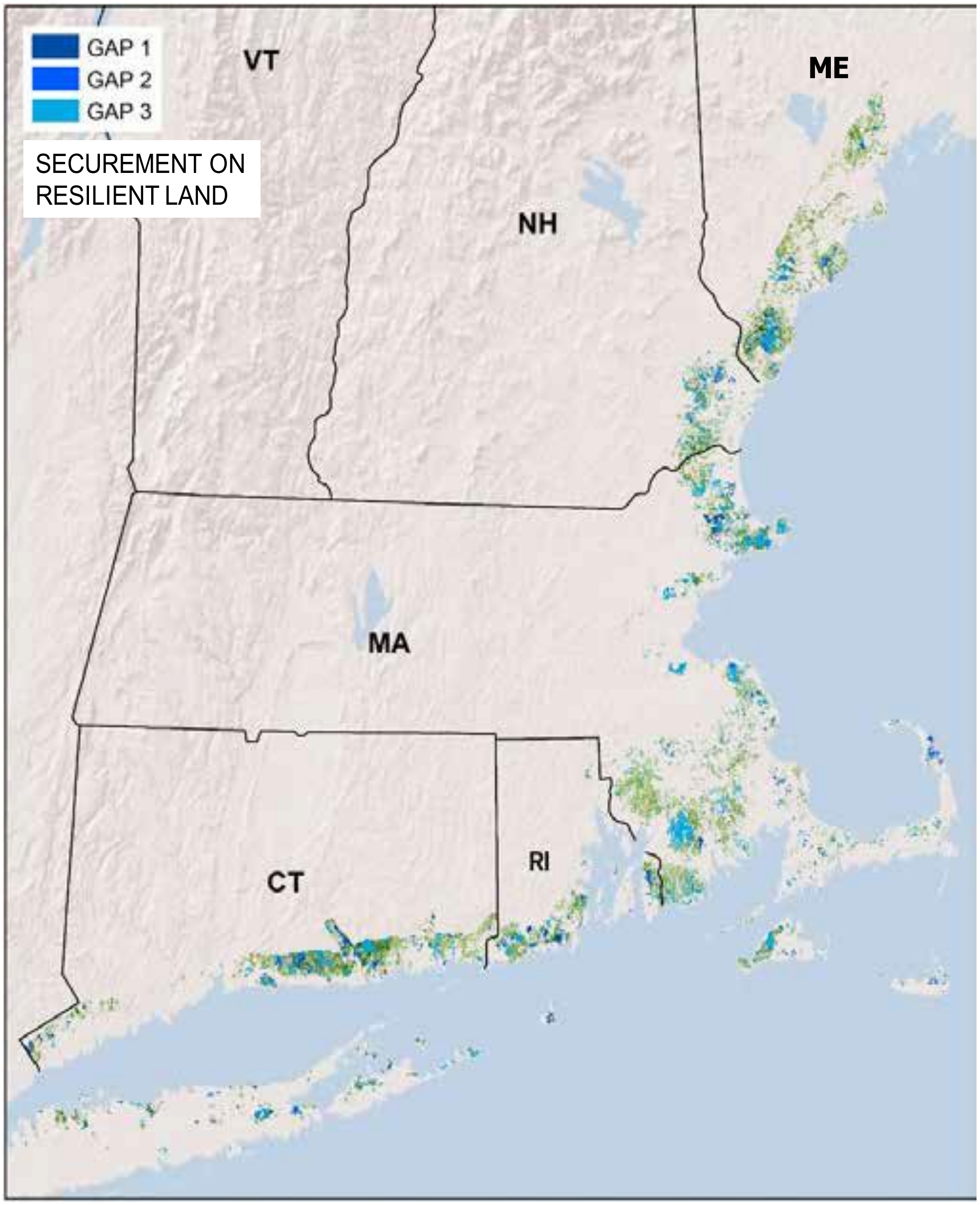
lion's-foot rattlesnake-root (*Nabalus serpentarius*), northern blazingstar (*Liatris novae-angliae*), arrow-feather threeawn (*Aristida purpurascens*), northern tubercled bog-orchid (*Platanthera flava* var. *herbiola*), large whorled pogonia (*Isotria verticillata*)

Predicted Loss to Development by 2050

High 18%

This community is one of New England's most threatened by development, with 112,063 acres (18%) likely to be lost over the next 30 years.

North Atlantic Coastal Plain Hardwood Forest



LOCATION	TOTAL ACRES	% SECURED
New England	634,467	19%
CT	193,633	14%
MA	263,497	26%
ME	76,292	13%
NH	35,815	22%
RI	65,230	18%
VT		

LOCATION	RESILIENT ACRES	% SECURED
New England	198,749	27%
CT	62,255	21%
MA	72,484	35%
ME	33,566	21%
NH	10,853	27%
RI	19,591	27%
VT		

Rare or Uncommon Plants Associated with this Habitat

purple milkweed (*Asclepias purpurascens*)

Carolina few-flowered nutsedge (*Scleria pauciflora* var. *caroliniana*)

few-flowered nutsedge (*Scleria pauciflora* var. *pauciflora*)

eastern silver American-aster (*Symphyotrichum concolor* ssp. *concolor*)

cranefly orchid (*Tipularia discolor*)

© Robert Coxe (Delaware Species Conservation & Research Program)

North Atlantic Coastal Plain Maritime Forest

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	4%	3,147	0%	25%	15%	41%	59%
Above average	16%	12,374	1%	15%	15%	31%	69%
Slightly above average	17%	13,530	1%	13%	12%	25%	75%
Average	34%	27,055	2%	9%	12%	23%	77%
Slightly below average	8%	6,592	1%	7%	12%	20%	80%
Below average	4%	3,557	3%	5%	12%	20%	80%
Far below average	1%	456	1%	2%	13%	16%	84%
Developed	16%	12,339	0%	5%	6%	11%	89%
TOTAL	**100%**	**79,051**	**1%**	**10%**	**12%**	**23%**	**77%**

Resilience & Securement

37% of this habitat scores high for resilience, and 23% of the total acreage is secured against conversion, with the resilient areas having the highest proportion of securement.

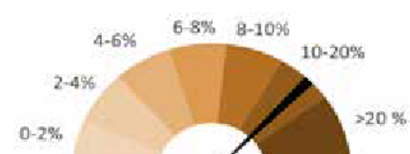
© Robert Coxe (Delaware Species Conservation & Research Program)

Description

A forest-shrubland mosaic encompassinga range of woody vegetation on barrier islands, near-coastal strands, and bluffs at the outer edge of the coastal plain. Defined by its proximity to maritime environments, the stunted vegetation includes pines (pitch, white) and oaks (scarlet, black, scrub, post) as well as eastern redcedar, black cherry, American holly, and sassafras.

Associated Herbs & Shrubs

northern blazing star (*Liatris novae-angliae*), lion's-foot rattlesnake-root (*Nabalus serpentarius*), sundial lupine (*Lupinus perennis*), butterfly milkweed (*Asclepias tuberosa*), eastern silver American-aster (*Symphyotrichum concolor* var. *concolor*), ramps (*Allium tricoccum*), coastal plain blue-eyed-grass (*Sisyrinchium fuscatum*), yellow thistle (*Cirsium horridulum* var. *horridulum*)



Predicted Loss to Development by 2050

High 16%

This is one of New England's mostthreatened communities, with 12,622 acres (16%) likely to be lost over the next 30 years.

North Atlantic Coastal Plain Maritime Forest

LOCATION	TOTAL ACRES	% SECURED
New England	79,051	23%
CT	5,489	26%
MA	32,901	30%
ME	31,930	15%
NH	774	21%
RI	7,957	26%
VT		

LOCATION	RESILIENT ACRES	% SECURED
New England	29,051	29%
CT	1,065	41%
MA	11,352	43%
ME	15,060	18%
NH	170	43%
RI	1,404	33%
VT		

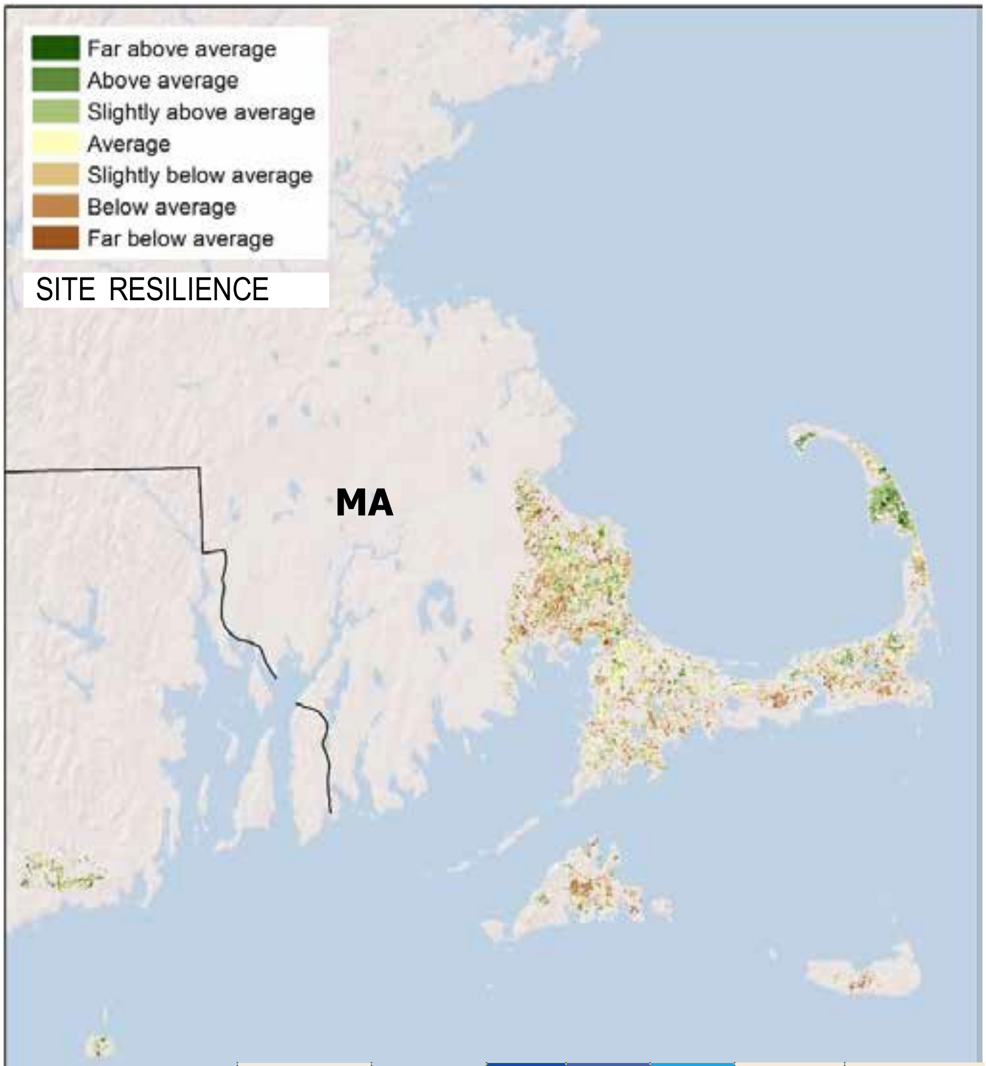
Rare or Uncommon Plants Associated with this Habitat

southern fragile fern (*Cystopteris protrusa*)

herbaceous seablight (*Suaeda maritima* ssp. *richii*)

Macoun's rabbit-tobacco (*Pseudognaphalium macounii*)

North Atlantic Coastal Plain Pitch Pine Barrens



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	0%	315	0%	69%	5%	75%	25%
Above average	5%	5,095	5%	33%	19%	57%	43%
Slightly above average	11%	11,395	7%	19%	26%	52%	48%
Average	36%	38,212	8%	4%	36%	48%	52%
Slightly below average	16%	16,892	11%	5%	31%	48%	52%
Below average	15%	15,622	13%	3%	27%	42%	58%
Far below average	3%	2,720	14%	1%	24%	38%	62%
Developed	14%	14,550	4%	4%	18%	25%	75%
TOTAL	**100%**	**104,801**	**8%**	**7%**	**29%**	**44%**	**56%**

Resilience & Securement

Only16% of this habitat scores high for resilience, but 44% of the total acreage is securedagainst conversion. Long-term management is likely needed to sustain this habitat.

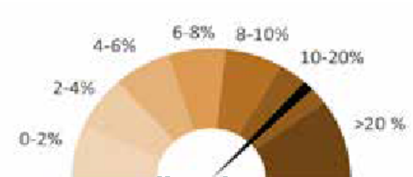
© Kathleen Strakosch Walz
(New Jersey Natural Heritage Program)

Description

A dry, fire-adapted forest with a variable canopy of pitch pine, a tall-shrub layer dominated by scrub oak, and a low-shrub layer of blueberry and other heaths. Otheroaks (scarlet, black, chestnut, white) are usually present. Composition and structure vary with fire frequency.

Associated Herbs & Shrubs

few-flowered nutsedge (*Scleria pauciflora* var. *pauciflora*), post oak (*Quercus stellata*), little ladies'-tresses (*Spiranthes tuberosa*), northern blazing star (*Liatris novae-angliae*), butterfly milkweed (*Asclepias tuberosa*), arrow-feather threeawn (*Aristida purpurascens*), Nuttall's milkwort (*Polygala nuttallii*)



Predicted Loss to Development by 2050

High 15%

This rare community has a high development threat, with 15,826acres (15%) likely to be lost overthe next 30 years.

North Atlantic Coastal Plain Pitch Pine Barrens

LOCATION	TOTAL ACRES	% SECURED
New England	104,801	45%
CT		
MA	101,027	46%
ME		
NH		
RI	3,774	25%
VT		

LOCATION	RESILIENT ACRES	% SECURED
New England	16,804	54%
CT		
MA	15,061	57%
ME		
NH		
RI	1,743	30%
VT		

Rare or Uncommon Plants Associated with this Habitat

bushy frostweed
(*Crocanthemum dumosum*)

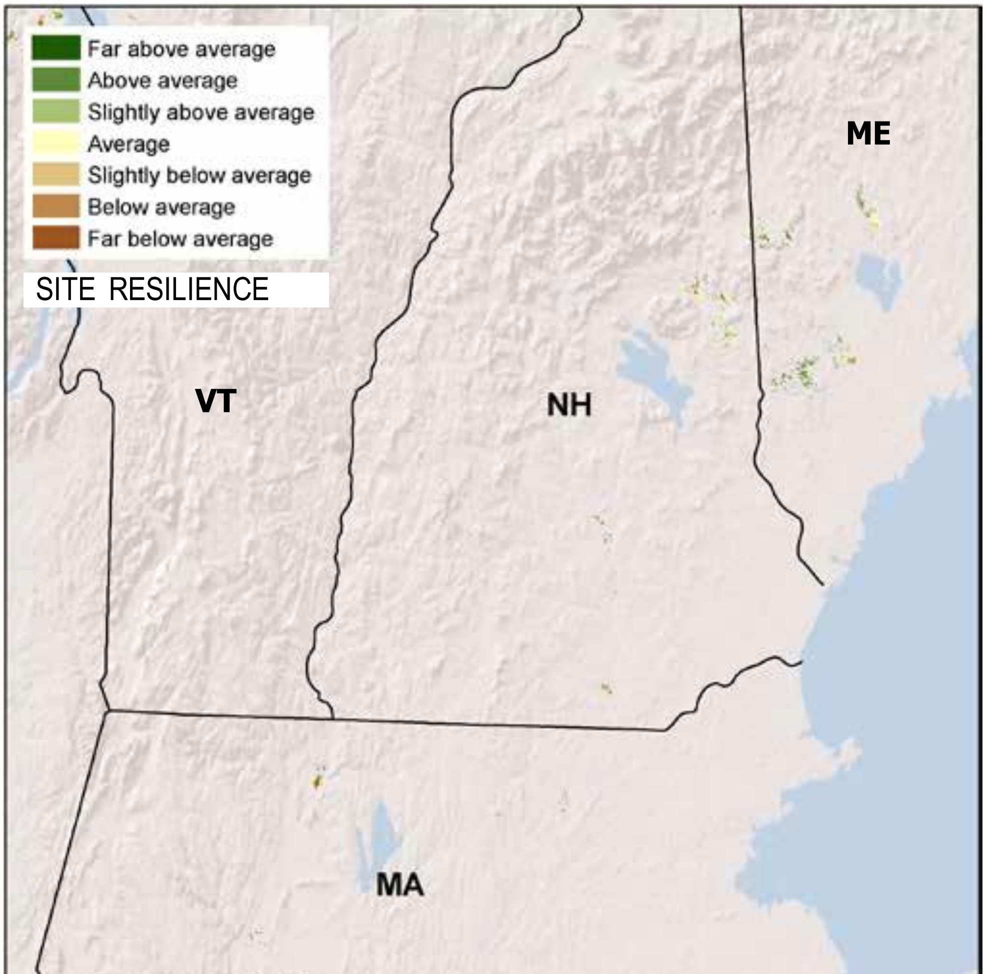
Bayard's adder's-mouth
(*Malaxis bayardii*)

Bicknell's hawthorn
(*Crataegus bicknellii*)

Carolina few-flowered nutsedge
(*Scleria pauciflora* var. *caroliniana*)

eastern silver American-aster
(*Symphyotrichum concolor* ssp. *concolor*)

Northeastern Interior Pine Barrens



© Jennifer Case (The Nature Conservancy, Pennsylvania)

Description

A fire-adapted system of Northeast glacial sandplains, typically an open woodland but sometimes including patches of closed-canopy forest and herbaceous openings. Pitch pine is the usual dominant;red oak, white pine, and gray birch are common associates. A tall-shrub layer
of scrub oak or dwarf chinkapin oak ischaracteristic, as is a low-shrub layer ofheath and sweetfern.

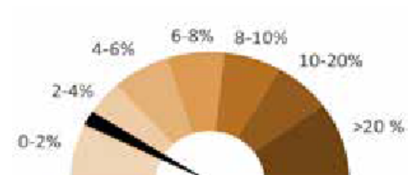
Associated Herbs & Shrubs

Canada frostweed (*Crocanthemum canadense*), tall hairy lettuce (*Lactuca hirsuta*), large whorled pogonia (*Isotria verticillata*), hoary frostweed (*Crocanthemum bicknellii*), racemed milkwort (*Polygala polygama*), sundial lupine (*Lupinus perennis*)

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	0%	53	13%	0%	17%	30%	70%
Above average	13%	2,642	18%	4%	21%	44%	56%
Slightly above average	20%	4,043	4%	3%	31%	37%	63%
Average	40%	7,997	4%	4%	41%	49%	51%
Slightly below average	10%	2,018	3%	3%	26%	32%	68%
Below average	7%	1,422	7%	0%	17%	24%	76%
Far below average	2%	493	0%	0%	58%	58%	42%
Developed	6%	1,162	1%	3%	22%	26%	74%
TOTAL	**100%**	**19,829**	**6%**	**3%**	**32%**	**41%**	**59%**

Resilience & Securement

33% of this habitat scores high for resilience, and 41% of the total acreage is secured against conversion.Long-term management is likely needed to sustain this habitat, especially on vulnerable lands.

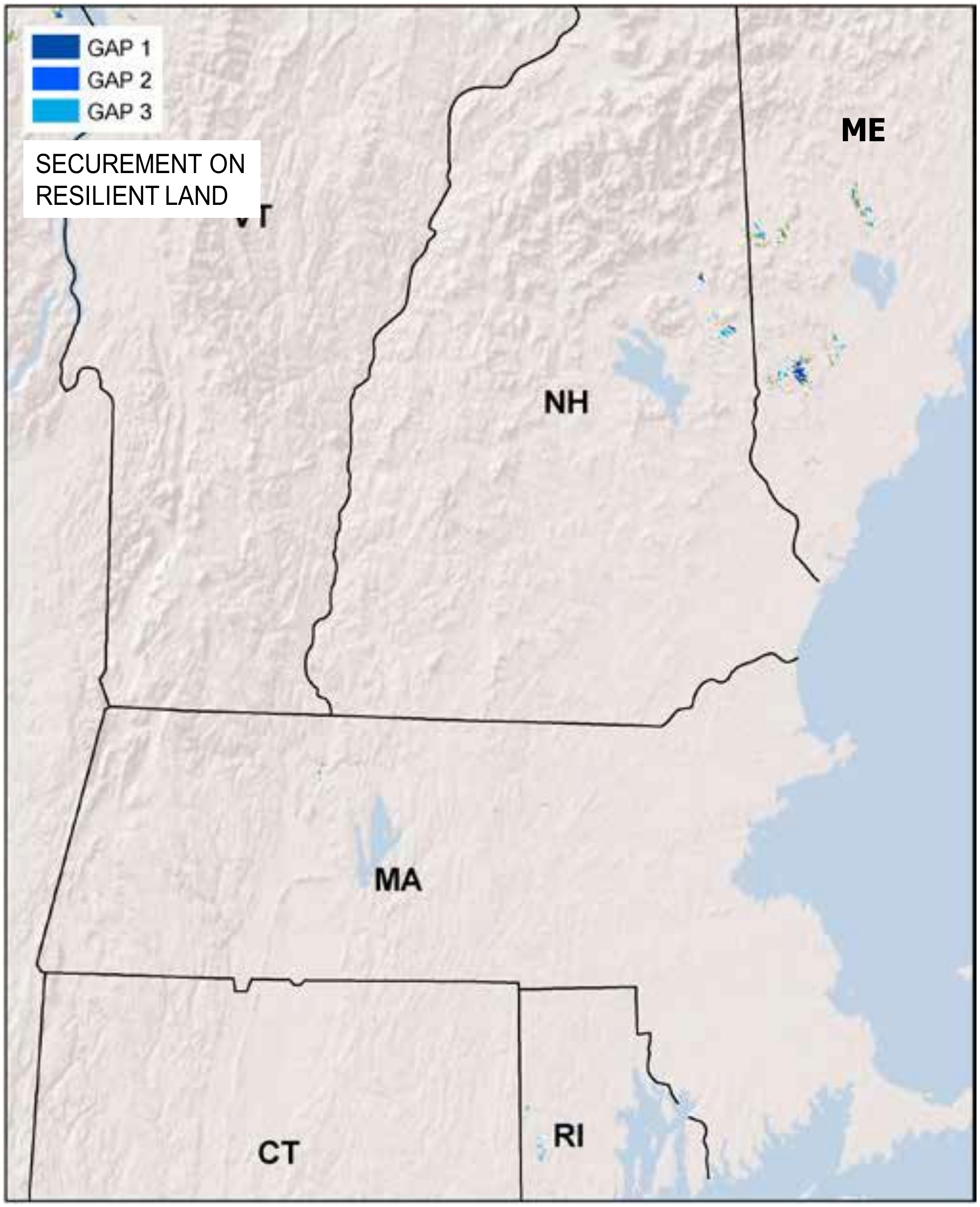


Predicted Loss to Development by 2050

Low 3%

This rare community has a low development threat, with 569 acres(3%) likely to be lost over the next 30 years.

Northeastern Interior Pine Barrens



LOCATION	TOTAL ACRES	% SECURED
New England	19,829	41%
CT	147	55%
MA	2,049	43%
ME	9,150	39%
NH	5,721	35%
RI	2,228	69%
VT	534	0

LOCATION	RESILIENT ACRES	% SECURED
New England	6,738	40%
CT	22	60%
MA	97	40%
ME	5,214	35%
NH	870	53%
RI	395	80%
VT	140	24%

Rare or Uncommon Plants Associated with this Habitat

rattlesnake hawkweed (*Hieracium venosum*)

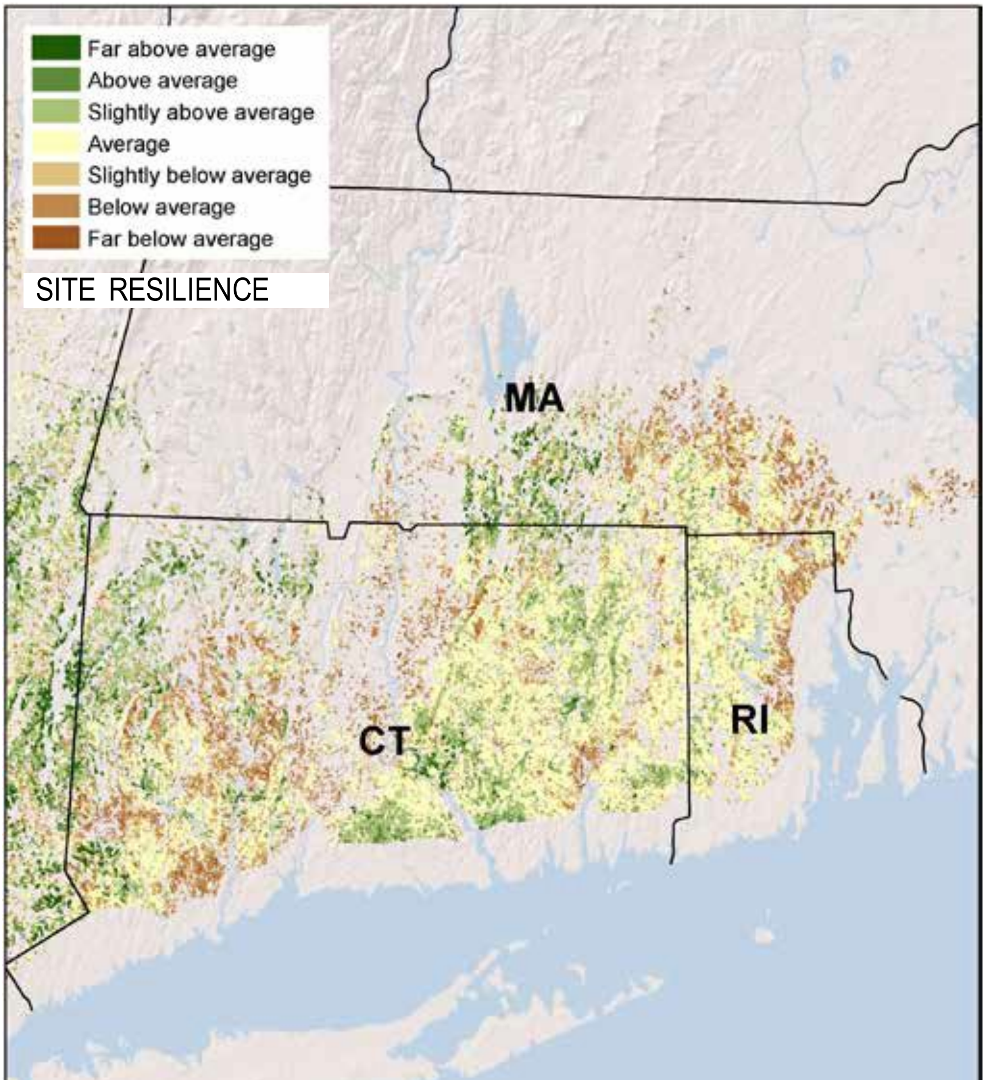
mountain and wild honeysuckle (*Lonicera villosa* and *Lonicera dioica*)

hairy rosette-panicgrass (*Dichanthelium acuminatum* ssp. *columbianum*)

ground-cedar hybrid (*Diphasiastrum xsabinifolium*)

© Robert Popp (Vermont Fish & Wildlife)

Northeastern Interior Dry-Mesic Oak Forest



© Gary P. Fleming (Virginia Department of Conservation & Recreation Natural Heritage Program)

Description

An oak-dominated, mostly closed-canopy forest that occurs in southern New England. Oak species characteristic of dry to mesic conditions (e.g., red, white, black, scarlet,and occasionally chestnut oak) and hickories are typical.

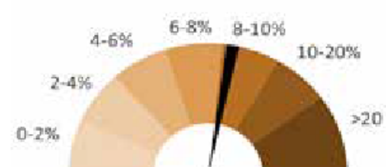
Associated Herbs & Shrubs

American wintergreen (*Pyrola americana*), blunt-lobed cliff fern (*Woodsia obtusa*), eastern bottle-brush grass (*Elymus hystrix*), common golden Alexanders (*Zizia aurea*), early buttercup (*Ranunculus fascicularis*), elliptic-leaved shinleaf (*Pyrola elliptica*), sicklepod rockcress (*Boechera canadensis*)

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	13,178	4%	10%	21%	35%	65%
Above average	6%	87,590	3%	6%	22%	31%	69%
Slightly above average	19%	261,867	3%	4%	20%	28%	72%
Average	45%	630,713	1%	3%	13%	17%	83%
Slightly below average	12%	172,782	1%	2%	9%	12%	88%
Below average	8%	108,357	0%	2%	7%	9%	91%
Far below average	1%	13,734	0%	1%	5%	5%	95%
Developed	7%	98,956	0%	1%	5%	7%	93%
TOTAL	**100%**	**1,387,176**	**1%**	**3%**	**14%**	**18%**	**82%**

Resilience & Securement

26% of this habitat scores high for resilience, and 18% of the total acreage is secured against conversion, with the resilient areas having the highest proportion of securement.

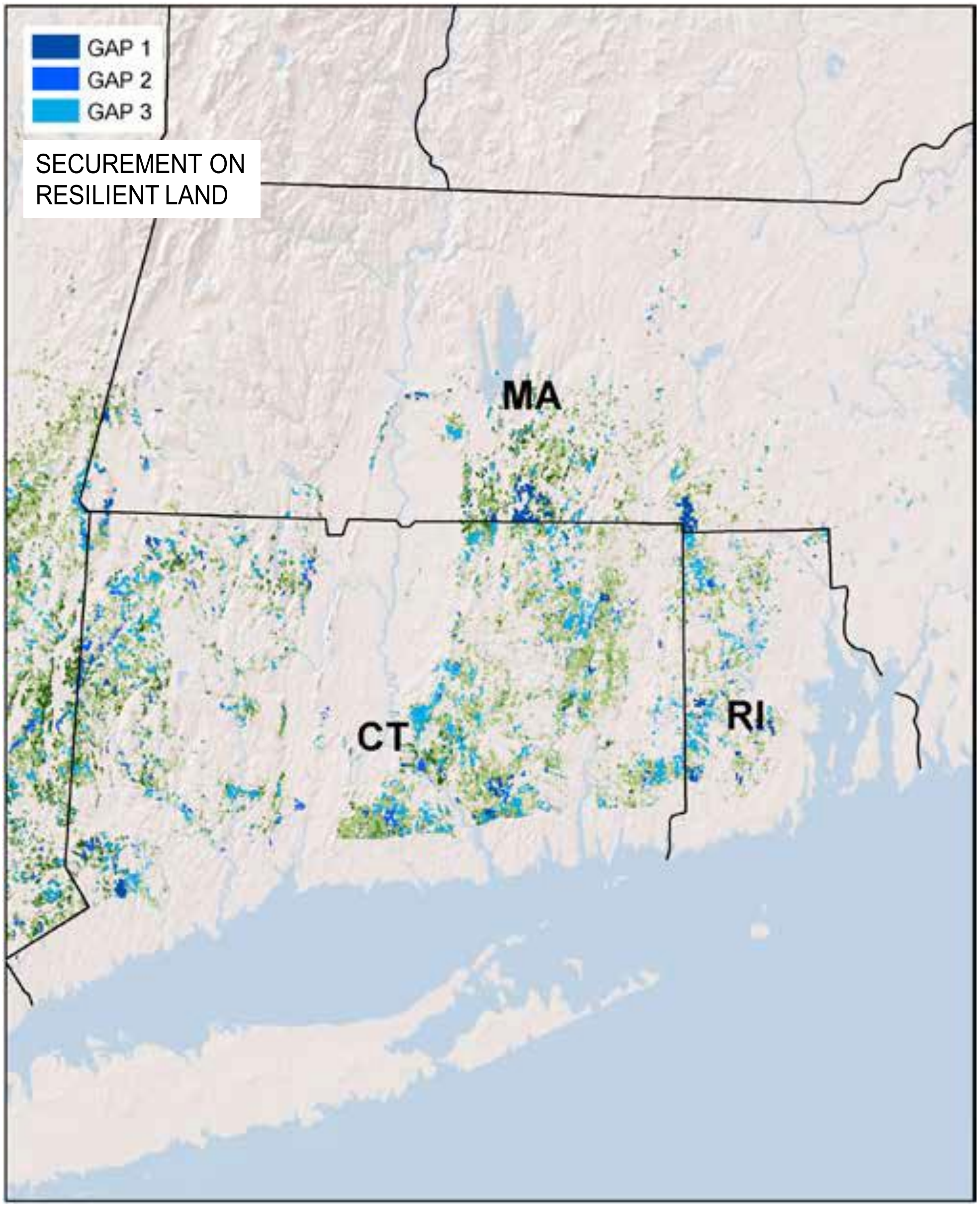


Predicted Loss to Development by 2050

Moderate 8%

This community is threatened by development, with 104,180 acres(8%) likely to be lost over the next30 years.

Northeastern Interior Dry-Mesic Oak Forest



LOCATION	TOTAL ACRES	% SECURED
New England	1,387,176	18%
CT	965,078	18%
MA	242,723	17%
ME		
NH		
RI	179,375	21%
VT		

LOCATION	RESILIENT ACRES	% SECURED
New England	362,635	29%
CT	272,306	28%
MA	60,869	28%
ME		
NH		
RI	29,459	39%
VT		

Rare or Uncommon Plants Associated with this Habitat

small whorled pogonia (*Isotria medeoloides*)

devil's bit (*Chamaelirium luteum*)

goldenseal (*Hydrastis canadensis*)

two-flowered dwarf-dandelion (*Krigia biflora* var. *biflora*)

creeping bush-clover (*Lespedeza repens*)

common yellow flax (*Linum medium* ssp. *texanum*)

lily-leaved wide-lipped orchid (*Liparis liliifolia*)

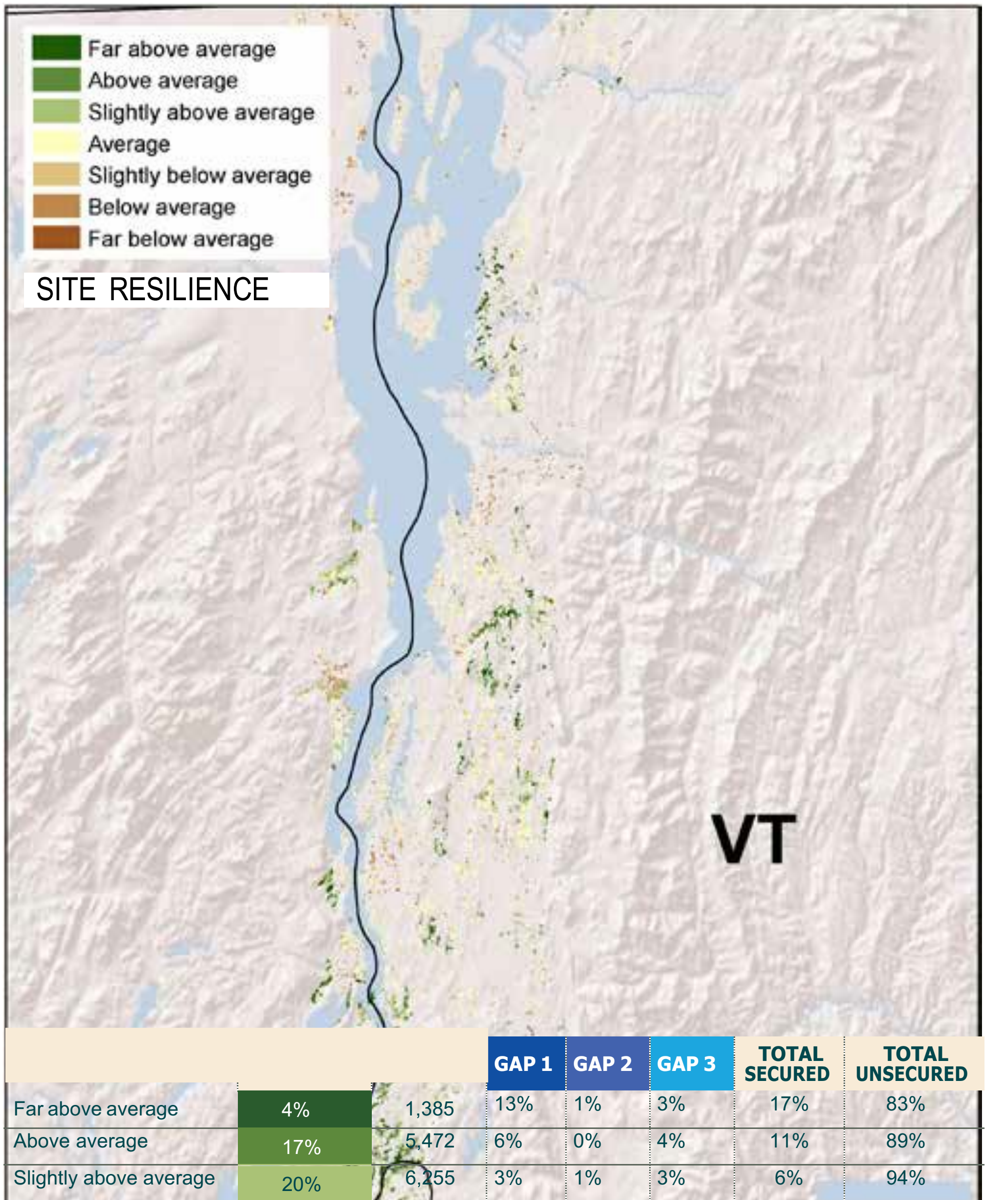
trumpet honeysuckle (*Lonicera sempervirens* var. *sempervirens*)

whip nutsedge (*Scleria triglomerata*)

shiny wedgescale (*Sphenopholis nitida*)

© Gary P. Fleming (Virginia Department of Conservation & Recreation Natural Heritage Program)

Glacial Marine & Lake Mesic Clayplain Forest



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	4%	1,385	13%	1%	3%	17%	83%
Above average	17%	5,472	6%	0%	4%	11%	89%
Slightly above average	20%	6,255	3%	1%	3%	6%	94%
Average	42%	13,610	1%	1%	4%	5%	95%
Slightly below average	9%	2,928	0%	1%	4%	4%	96%
Below average	4%	1,261	0%	0%	3%	3%	97%
Far below average	0%	74	0%	0%	0%	0%	100%
Developed	3%	1,082	0%	0%	6%	6%	94%
TOTAL	**100%**	**32,066**	**3%**	**1%**	**4%**	**7%**	**93%**

Resilience & Securement

41% of this habitat scores high for resilience, but only 7% of the total acreage is securedagainst conversion.

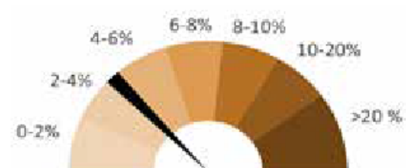
© Eric Sorenson (Vermont Fish & Wildlife)

Description

A hardwood forest of northern clayplains dominated by a shifting balance of oaks (white, red, swamp white, bur), maples (red and sugar), hemlock, white pine, ash, shagbark hickory, and other associates. The understory herb layer is distinctive and rich, and native/non-native shrubs canbe dense.

Associated Herbs & Shrubs

American hazelnut (*Corylus americana*), broad beech fern (*Phegopteris hexagonoptera*), old pasture bluegrass (*Poa saltuensis* ssp. *languida*), leafy bulrush (*Scirpus polyphyllus*), Canada sanicle (*Sanicula canadensis*)

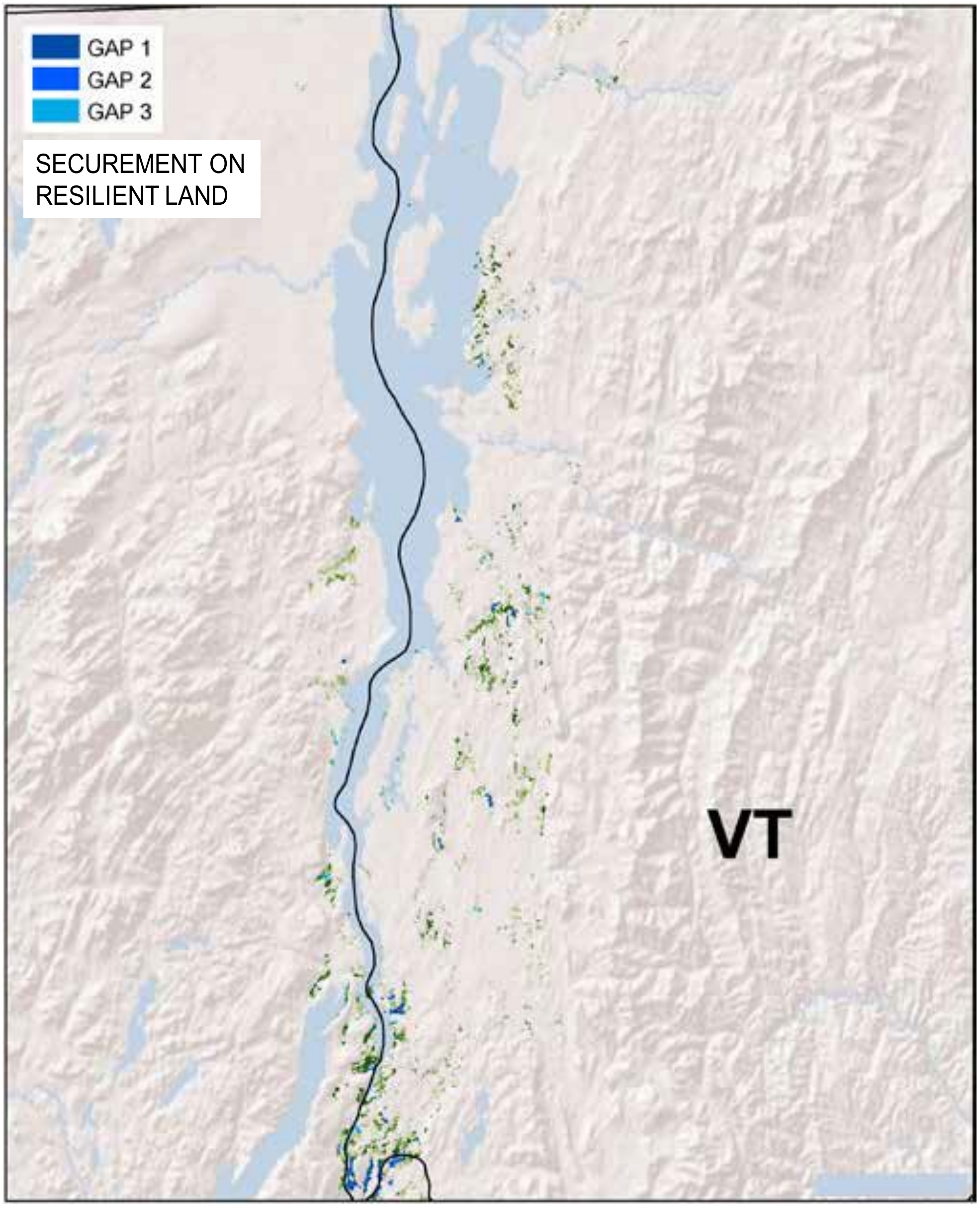


Predicted Loss to Development by 2050

Moderately low 4%

This community is somewhat threatened by development, with1,237 acres (4%) likely to be lostoverthenext 30years.

Glacial Marine & Lake Mesic Clayplain Forest



LOCATION	TOTAL ACRES	% SECURED
New England	32,066	7%
CT		
MA		
ME		
NH		
RI		
VT	32,066	7%

LOCATION	RESILIENT ACRES	% SECURED
New England	13,112	9%
CT		
MA		
ME		
NH		
RI		
VT	13,112	9%

Rare or Uncommon Plants Associated with this Habitat

floodplain avens
(*Geum laciniatum*)

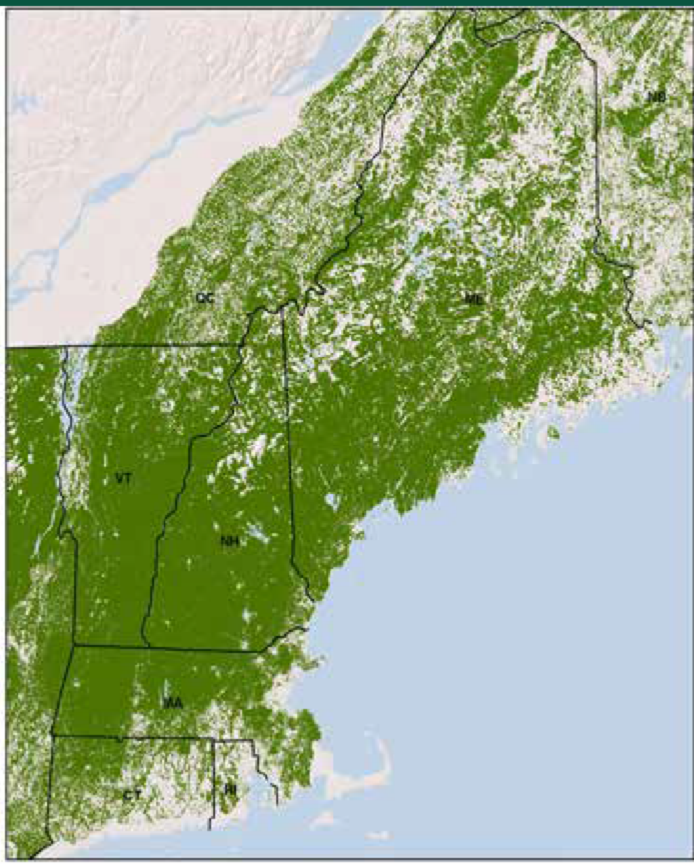
field thistle
(*Cirsium discolor*)

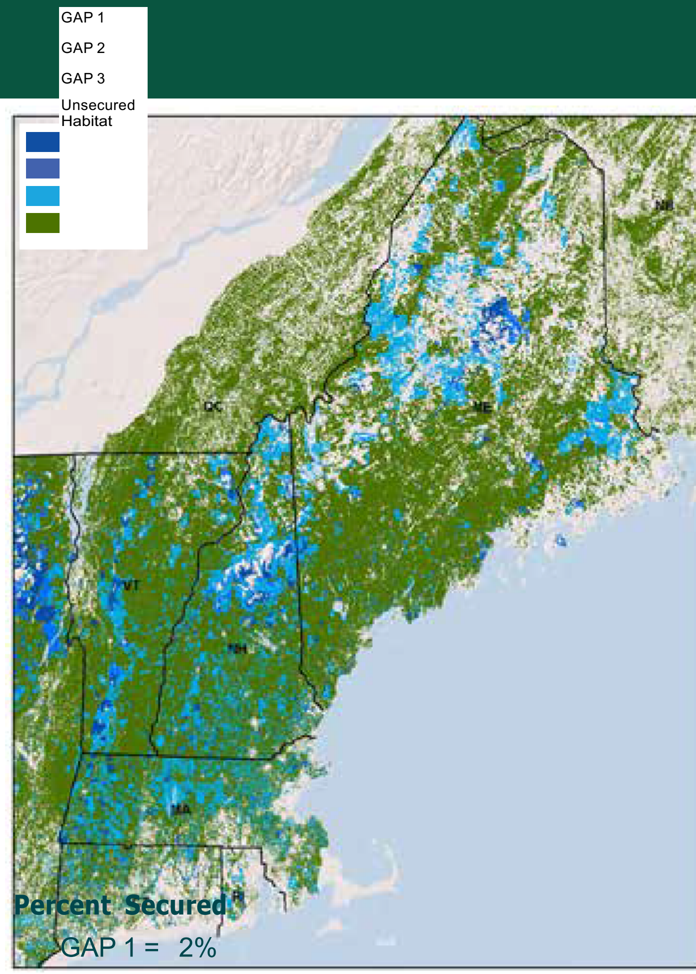
narrow-leaved blue-eyed-grass
(*Sisyrinchium angustifolium*)

© Eric Sorenson (Vermont Fish & Wildlife)

MACROGROUP

NORTHERN HARDWOOD & CONIFER FOREST





Northern Hardwood & Conifer Forest

Mixed hardwood-conifer forest of northern New England dominated by maple, beech, and birch, with Eastern hemlock and/or white pine.

Acres in New England

19.4 million

Percent Secured

GAP 1 = 2%

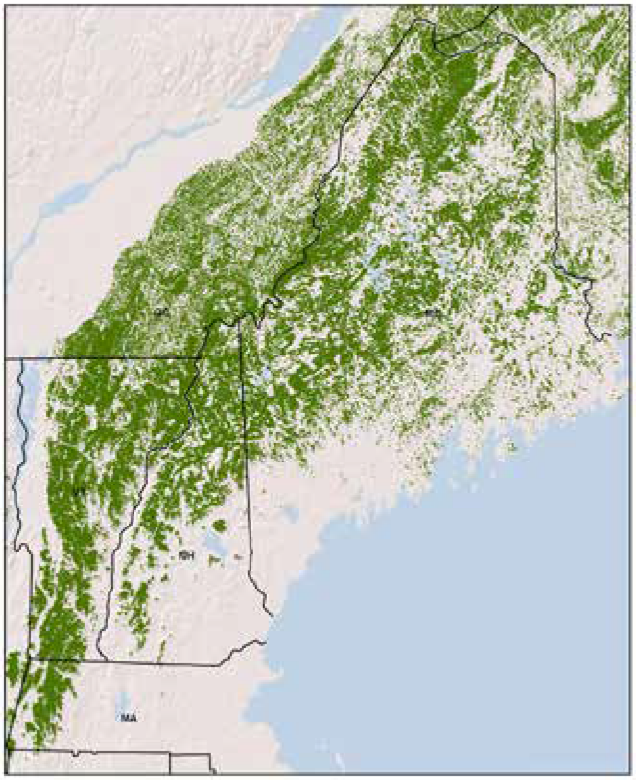
GAP 2 = 2%

GAP 3 = 18%

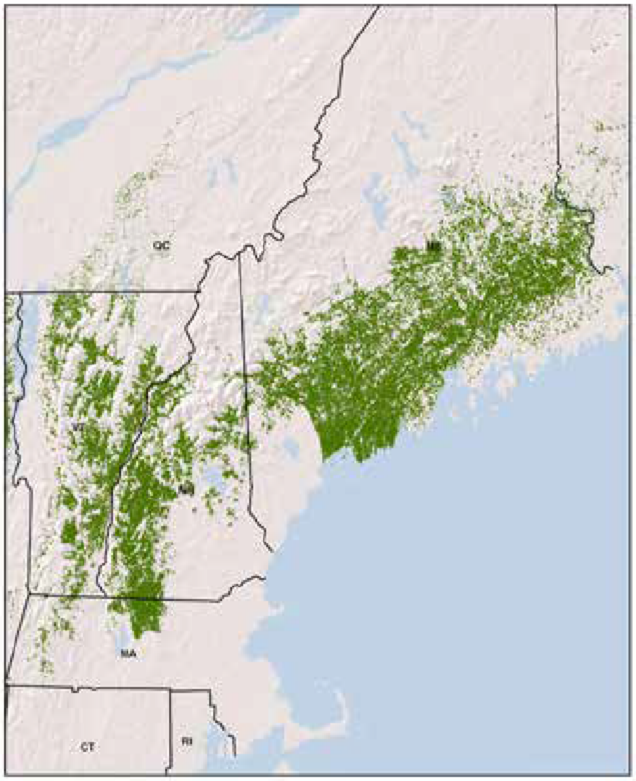
	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS TOTAL	P	S	U
Northern Hardwood & Conifer Forest	**19,364,435**	**2%**	**2%**	**18%**	**78%**	**126**	**3**	**17**	**106**
Connecticut	627,338	1%	5%	15%	79%	10	1		9
Massachusetts	2,017,572	4%	1%	27%	68%	42		8	34
Maine	8,795,168	2%	2%	15%	82%	28	1	3	24
New Hampshire	3,960,144	3%	4%	22%	71%	9		2	7
Rhode Island	61,931	2%	4%	32%	63%				
Vermont	3,902,283	3%	1%	15%	81%	37	1	4	32
New England	**19,364,435**	**467,619**	**418,688**	**3,408,800**	**15,069,328**				

U = Unsecured

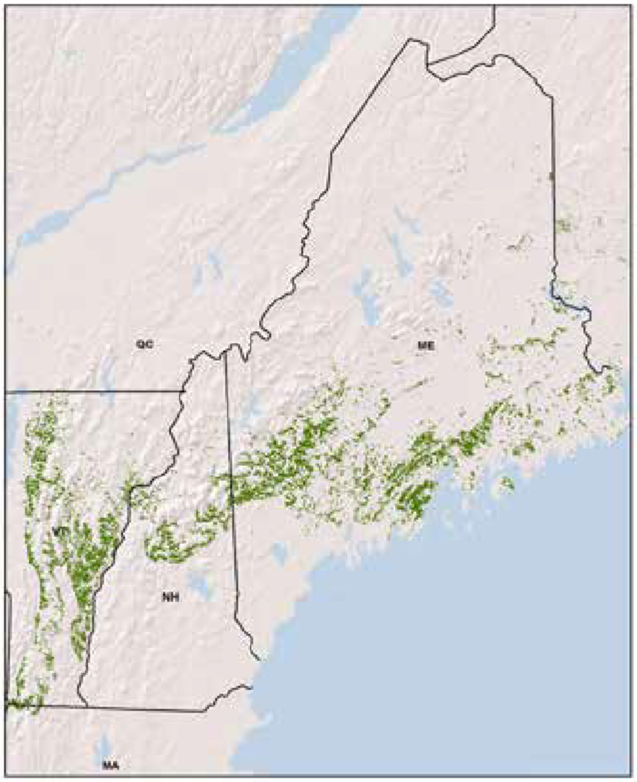
DISTRIBUTION OF HABITATS



NORTHERN | **Laurentian-Acadian Northern Hardwood Forest**

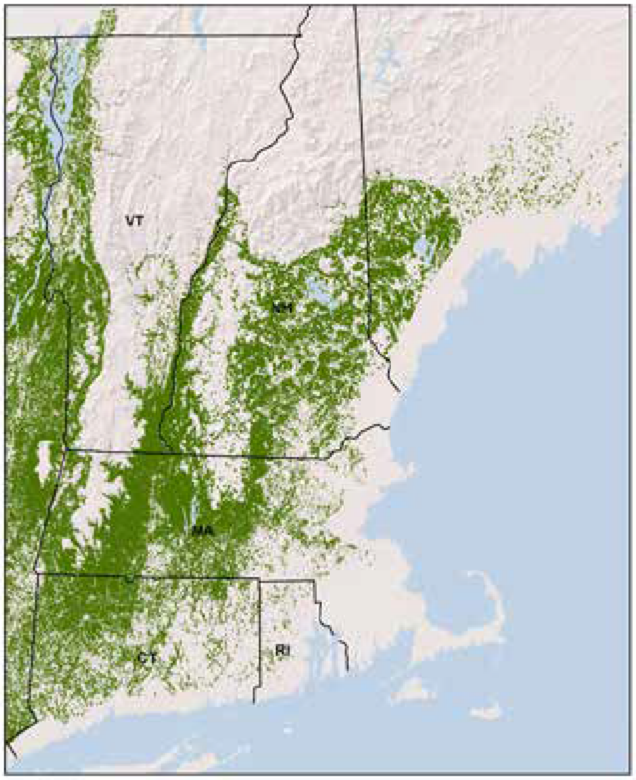


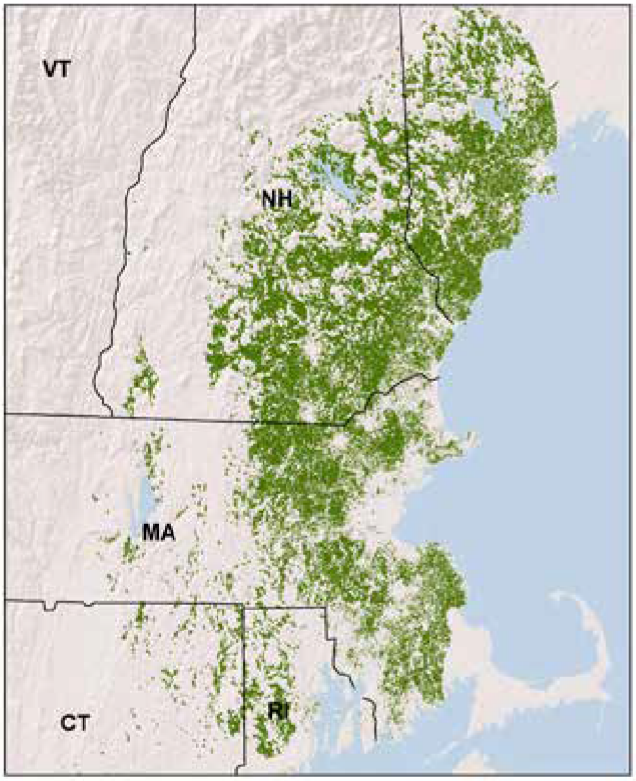
NORTHERN | **Laurentian-Acadian Pine-Hemlock-Hardwood Forest**



NORTHERN | **Laurentian-Acadian Red Oak-Northern Hardwood Forest**

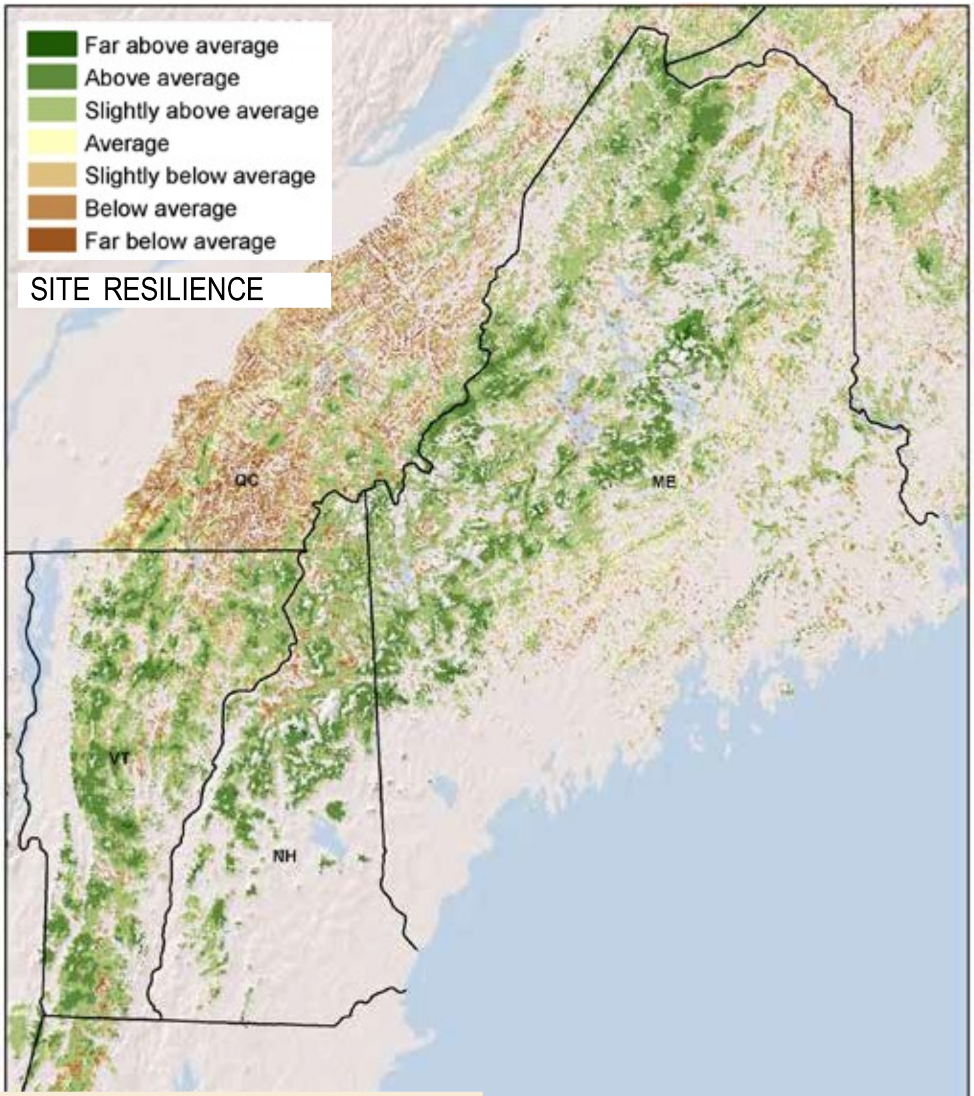
DISTRIBUTION OF HABITATS





SOUTHERN | **Appalachian (Hemlock)-Northern Hardwood Forest**

Laurentian-Acadian Northern Hardwood Forest



© Elizabeth Thompson (Vermont Land Trust)

Description

A hardwood forest dominated by sugar maple, American beech, and yellow birch.White ash, hemlock, and red spruce are frequent but minor canopy associates.
Paperbirch,redmaple,andaspenarecommon.

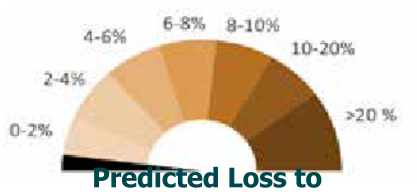
Associated Herbs & Shrubs

bristly swamp currant (*Ribes lacustre*), broad beech fern (*Phegopteris hexagonoptera*), mountain wood fern (*Dryopteris campyloptera*), pale jewelweed (*Impatiens pallida*), squirrel-corn (*Dicentra canadensis*), swamp red currant (*Ribes triste*), American twinflower (*Linnaea borealis* ssp. *americana*)

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	121,505	13%	6%	24%	43%	57%
Above average	28%	2,325,747	9%	6%	29%	44%	56%
Slightly above average	50%	4,102,761	2%	2%	24%	28%	72%
Average	8%	621,970	0%	0%	11%	12%	88%
Slightly below average	6%	509,620	0%	1%	15%	16%	84%
Below average	5%	388,551	1%	2%	17%	19%	81%
Far below average	0%	36,950	1%	2%	15%	18%	82%
Developed	2%	172,987	1%	1%	18%	21%	79%
TOTAL	**100%**	**8,280,091**	**4%**	**3%**	**23%**	**30%**	**70%**

Resilience & Securement

79% of this habitat scores high for resilience, 30% of the total acreage is secured against conversion, and 7% is protected.

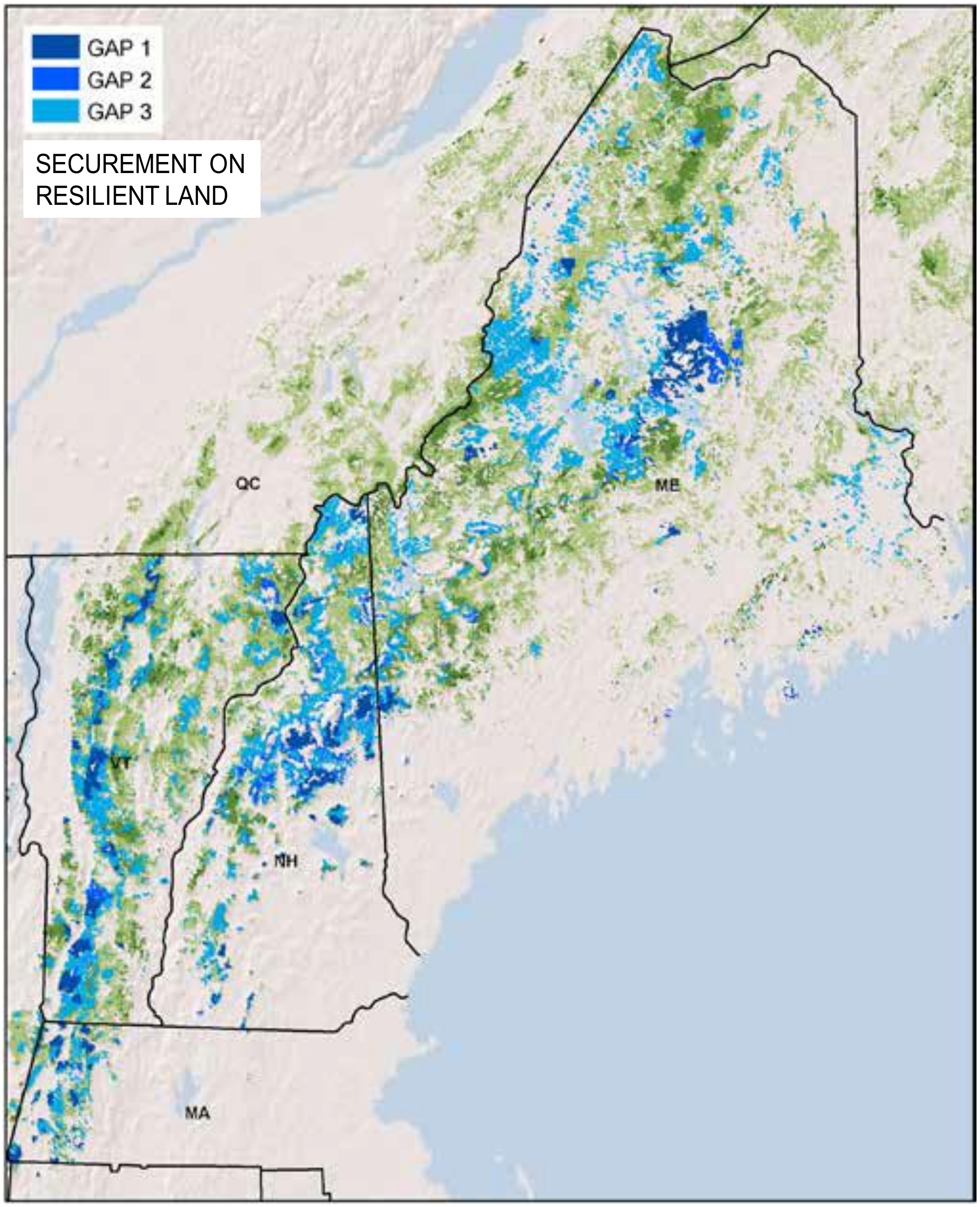


Predicted Loss to Development by 2050

Very low 1%

This community is little threatened by development, with 42,894 acres (<1%) likely to be lost over the next 30 years.

Laurentian-Acadian Northern Hardwood Forest



LOCATION	TOTAL ACRES	% SECURED
New England	8,280,091	30%
CT	4,922	22%
MA	304,911	46%
ME	4,660,932	25%
NH	1,148,942	53%
RI		
VT	2,160,384	28%

LOCATION	RESILIENT ACRES	% SECURED
New England	6,550,013	34%
CT	4,376	24%
MA	210,563	53%
ME	3,562,565	27%
NH	989,577	58%
RI		
VT	1,782,933	32%

Rare or Uncommon Plants Associated with this Habitat

American ginseng (*Panax quinquefolius*)

three-birds orchid (*Triphora trianthophora* ssp. *trianthophora*)

hairy wood-mint (*Blephilia hirsuta* var. *hirsuta*)

zigzag hawthorn (*Crataegus irrasa* var. *blanchardii*)

grove hawthorn (*Crataegus lucorum*)

Oakes' hawthorn (*Crataegus oakesiana*)

poplar hawthorn (*Crataegus populnea*)

wild hound's-tongue (*Cynoglossum virginianum* ssp. *boreale*)

male wood fern (*Dryopteris filix-mas* ssp. *brittonii*)

early wild rye (*Elymus macgregorii*)

giant rattlesnake-plantain (*Goodyera oblongifolia*)

narrow-leaved hawkweed (*Hieracium umbellatum*)

green-violet (*Hybanthus concolor*)

goldenseal (*Hydrastis canadensis*)

Vasey's rush (*Juncus vaseyi*)

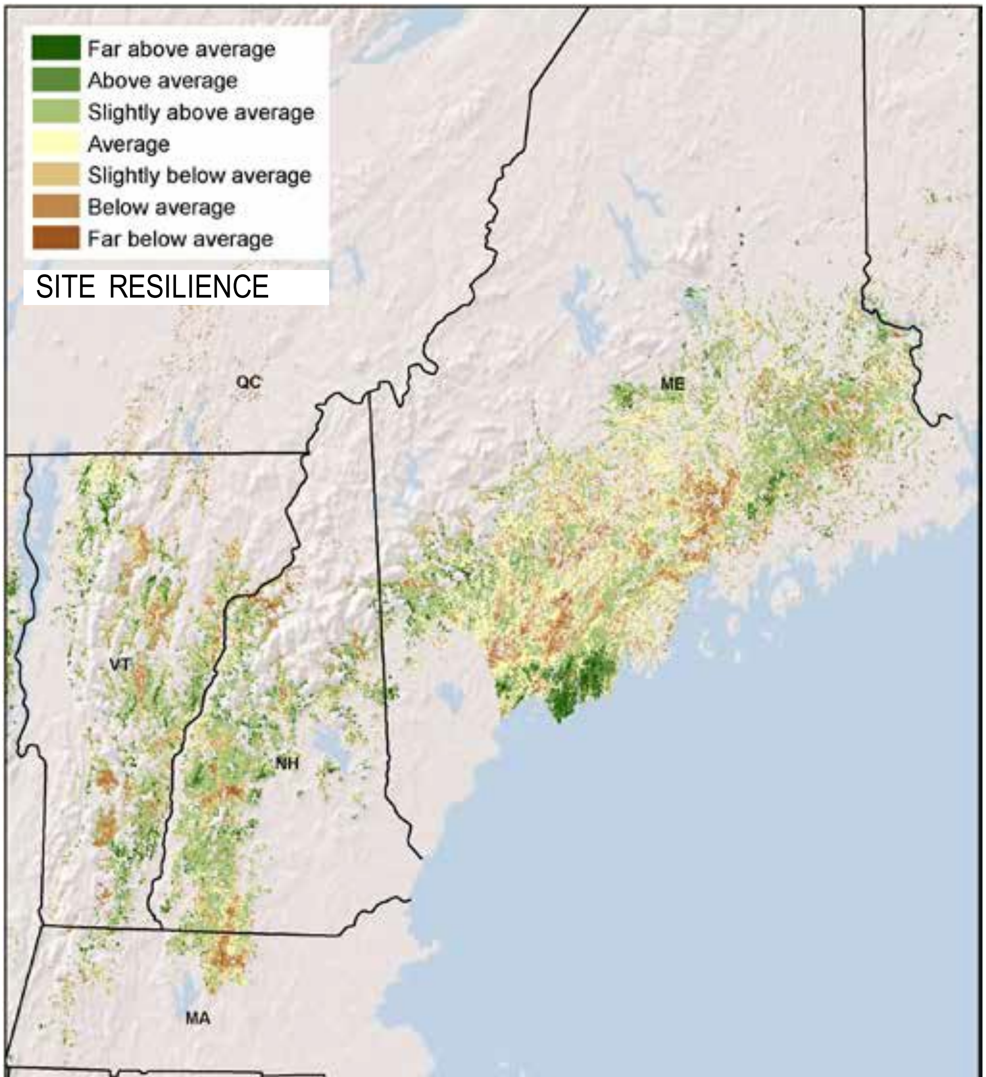
lily-leaved wide-lipped orchid (*Liparis liliifolia*)

old-pasture blue grass (*Poa saltuensis* ssp. *languida*)

white-flowered leaf-cup (*Polymnia canadensis*)

green rockcress (*Boechera missouriensis*)

Laurentian-Acadian Pine-Hemlock-Hardwood Forest



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	60,050	3%	3%	13%	20%	80%
Above average	9%	413,972	2%	3%	16%	21%	79%
Slightly above average	39%	1,720,390	1%	1%	15%	18%	82%
Average	23%	1,038,767	0%	1%	8%	9%	91%
Slightly below average	14%	628,410	0%	1%	8%	9%	91%
Below average	9%	390,676	0%	1%	6%	7%	93%
Far below average	1%	30,814	0%	0%	3%	4%	96%
Developed	4%	177,154	0%	1%	9%	10%	90%
TOTAL	**100%**	**4,460,233**	**1%**	**1%**	**11%**	**13%**	**87%**

Resilience & Securement

49% of this habitat scores high for resilience, but only 13% of the total acreage issecured against conversion, and 2% is protected.

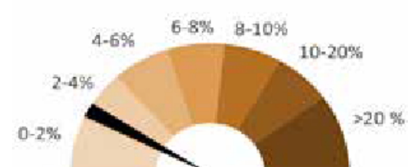
© Josh Royte (The Nature Conservancy, Maine)

Description

A coniferous or mixed forest of foothills and lowlands. White pine, hemlock, andred oak are typical canopy dominants. Red maple, sugar maple, beech, and birch also occur. Red spruce and balsamfir are infrequent.

Associated Herbs & Shrubs

Appalachian barren-strawberry (*Geum fragarioides*), pine-drops (*Pterospora andromedea*), green adder's-mouth (*Malaxis unifolia*), Loesel's wide-lipped orchid (*Liparis loeselii*), hook-spurred violet (*Viola adunca*), short-awned mountain-rice grass (*Piptatherum pungens*), spotted wintergreen (*Chimaphila maculata*), Graham's rockcress (*Boechera grahamii*)

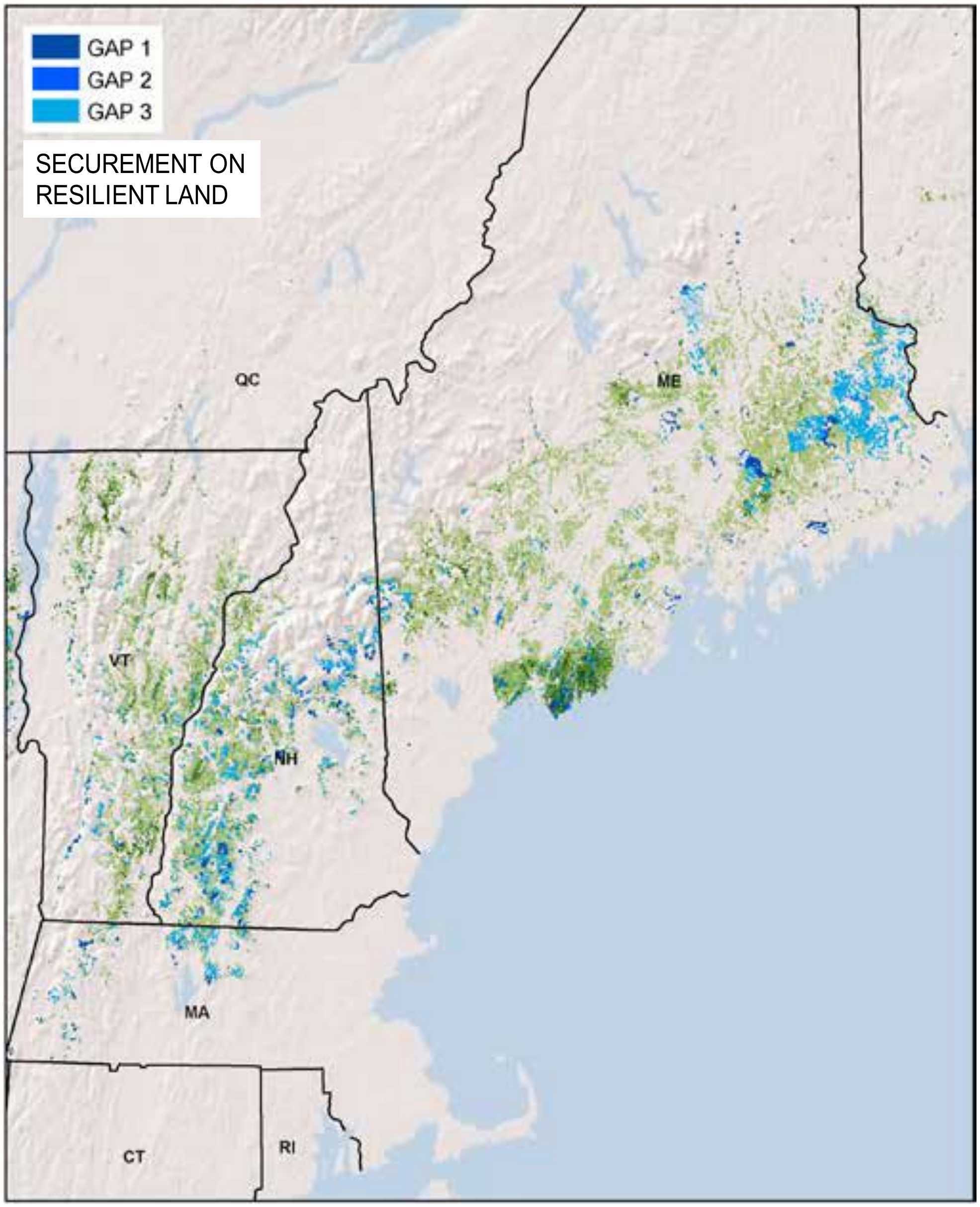


Predicted Loss to Development by 2050

Low 2%

This community is little threatenedby development, with 94,112 acres(2%) likely to be lost over the next 30 years.

Laurentian-Acadian Pine-Hemlock-Hardwood Forest



LOCATION	TOTAL ACRES	% SECURED
New England	4,460,233	14%
CT	4	0%
MA	158,090	36%
ME	2,683,041	12%
NH	845,774	22%
RI		
VT	773,325	6%

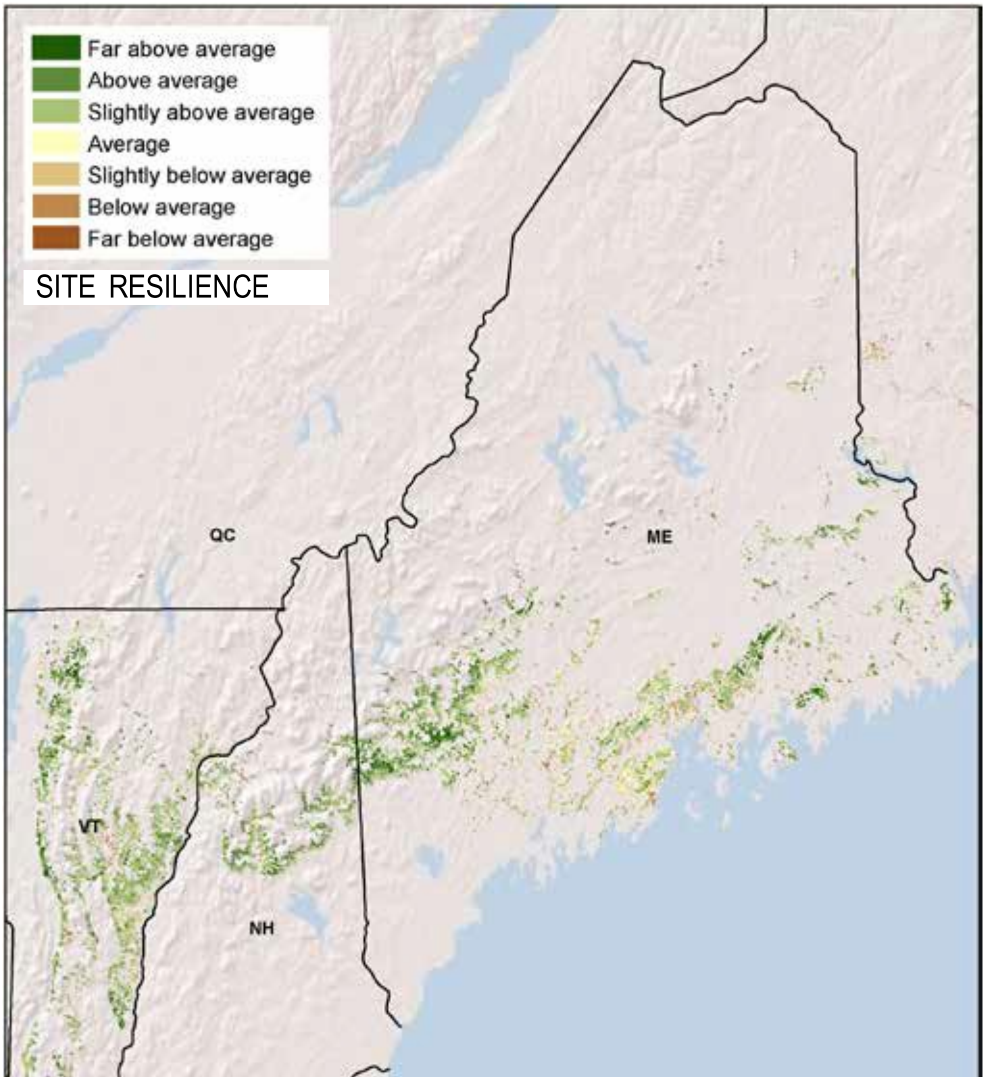
LOCATION	RESILIENT ACRES	% SECURED
New England	2,194,412	18%
CT	2	0%
MA	52,481	47%
ME	1,215,410	17%
NH	520,186	27%
RI		
VT	406,333	8%

Rare or Uncommon Plants Associated with this Habitat

swarthy sedge
(*Carex adusta*)

pine-drops
(*Pterospora andromedea*)

Laurentian-Acadian Red Oak-Northern Hardwood Forest



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	2%	24,337	3%	6%	16%	25%	75%
Above average	24%	253,653	3%	6%	21%	31%	69%
Slightly above average	50%	531,348	1%	3%	13%	17%	83%
Average	12%	129,123	0%	1%	4%	5%	95%
Slightly below average	6%	69,476	1%	1%	3%	5%	95%
Below average	3%	34,030	1%	1%	5%	7%	93%
Far below average	0%	2,691	4%	0%	6%	10%	90%
Developed	3%	27,202	0%	1%	8%	9%	91%
TOTAL	**100%**	**1,071,860**	**2%**	**3%**	**13%**	**18%**	**82%**

Resilience & Securement

76% of this habitat scores high for resilience, and 18% of the total acreage is secured against conversion, with the resilient areas having the highest proportion of securement.

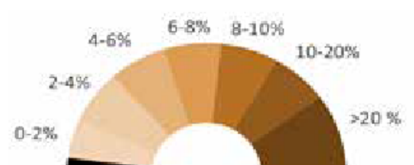
© Eric Sorenson (Vermont Fish & Wildlife)

Description

A closed canopy forest where a significant component of red oak is present along with the suite of northern hardwoods, primarily sugar maple, beech, and yellow birch. Red maple, hemlock, and white pine are common associates.

Associated Herbs & Shrubs

American squaw-root (*Conopholis americana*), broad beech fern (*Phegopteris hexagonoptera*), flowering big-bracted dogwood (*Benthamidia florida*), perfoliate bellwort (*Uvularia perfoliata*), slender loose-flowered sedge (*Carex gracilescens*), leathery grapefern (*Botrychium multifidum*), sharp-fruited rush (*Juncus acuminatus*)

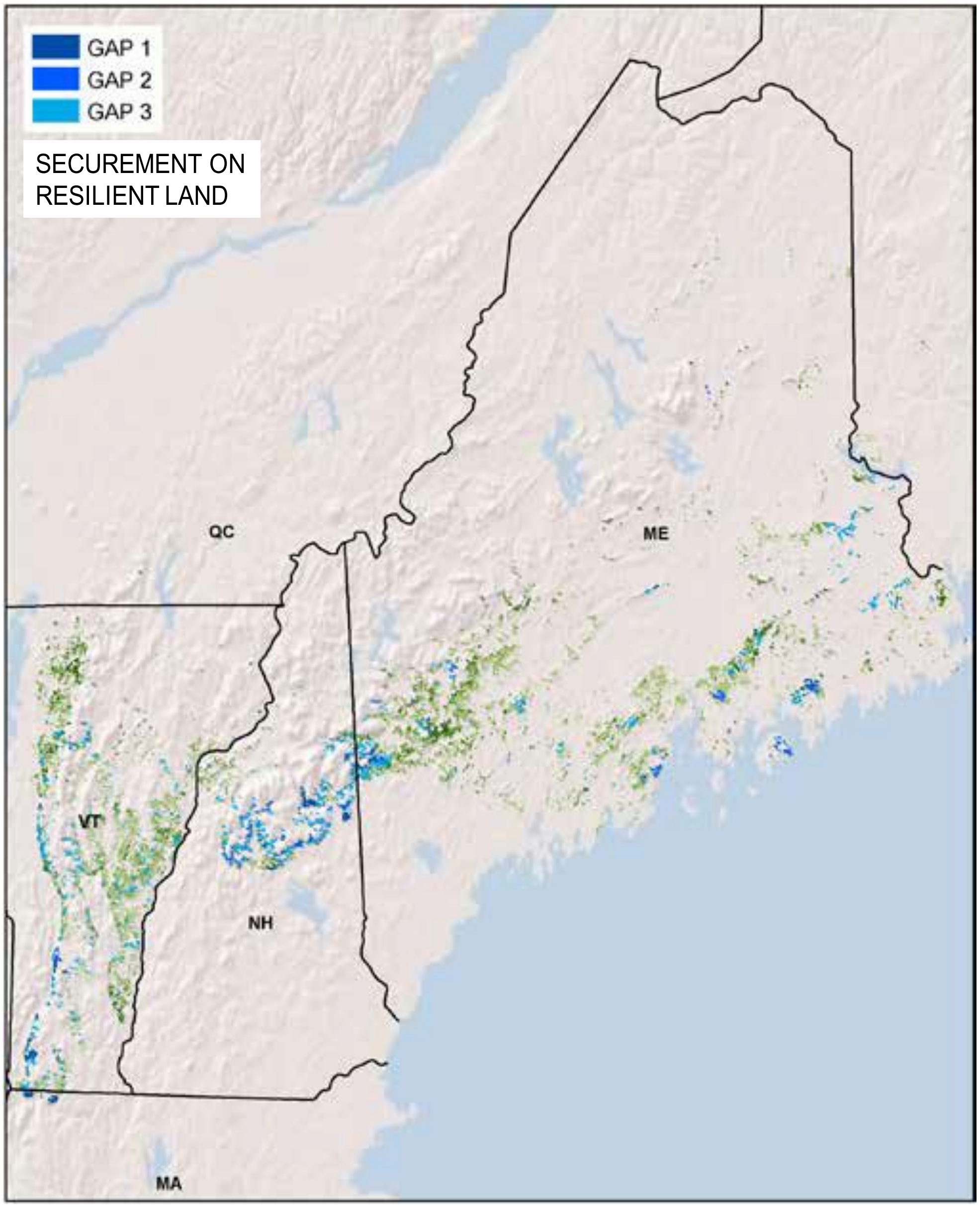


Predicted Loss to Development by 2050

Very low 1%

This community is not threatened by development, with 13,201 acres (1%) likely to be lost over the next 30 years.

Laurentian-Acadian Red Oak-Northern Hardwood Forest




© Eric Sorenson (Vermont Fish & Wildlife)

LOCATION	TOTAL ACRES	% SECURED
New England	1,071,860	18%
CT		
MA	6,566	46%
ME	601,479	12%
NH	114,383	54%
RI		
VT	349,432	15%

LOCATION	RESILIENT ACRES	% SECURED
New England	809,338	22%
CT		
MA	4,911	48%
ME	417,248	15%
NH	102,967	58%
RI		
VT	284,213	17%

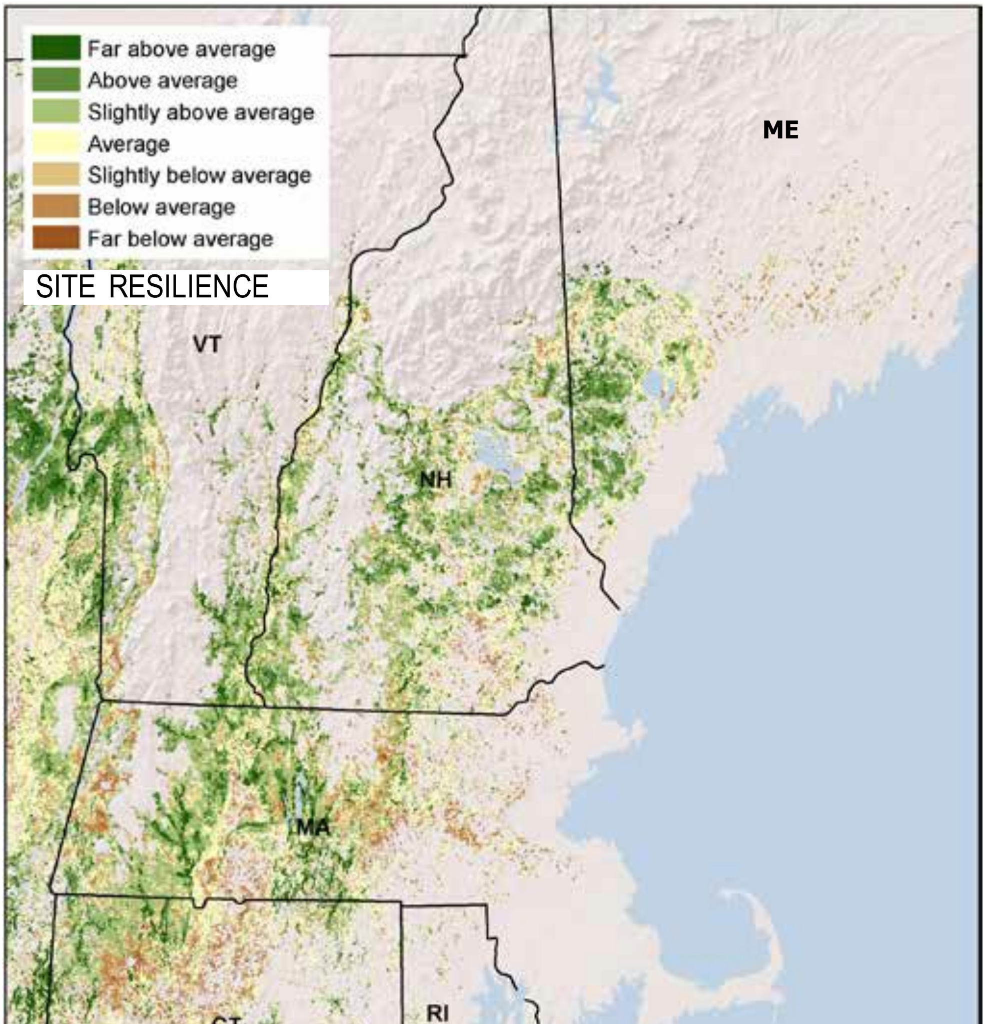
Rare or Uncommon Plants Associated with this Habitat

American ginseng
(*Panax quinquefolius*)

large whorled pogonia
(*Isotria verticillata*)

summer sedge
(*Carex aestivalis*)

Appalachian (Hemlock)-Northern Hardwood Forest



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	4%	154,153	3%	2%	25%	31%	69%
Above average	18%	736,753	2%	2%	19%	23%	77%
Slightly above average	33%	1,339,229	2%	2%	17%	21%	79%
Average	25%	1,016,503	1%	1%	12%	15%	85%
Slightly below average	9%	349,797	1%	1%	13%	15%	85%
Below average	5%	188,029	1%	1%	10%	11%	89%
Far below average	0%	19,345	0%	0%	6%	7%	93%
Developed	5%	212,785	1%	1%	8%	10%	90%
TOTAL	**100%**	**4,016,594**	**1%**	**2%**	**15%**	**18%**	**82%**

Resilience & Securement

55% of this habitat scores high for resilience, and 18% of the total acreage is secured against conversion, with the resilient areas having the highest proportion of securement.

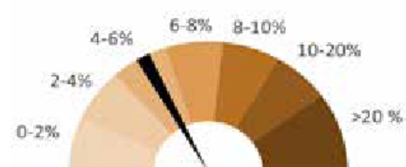
© Maine Natural Areas Program

Description

A hardwood forest of sugar maple, American beech, and yellow birch, sometimes mixed with, and sometimes dominated by, eastern hemlock. Northernred oak and white oak occur commonly, but do not dominate. Black cherry, black birch, white pine, and tuliptree are typicalon nutrientrich sites.

Associated Herbs & Shrubs

broad beech fern (*Phegopteris hexagonoptera*), four-leaved milkweed (*Asclepias quadrifolia*), perfoliate bellwort (*Uvularia perfoliata*), round-leaved trailing tick-trefoil (*Desmodium rotundifolium*), northern spicebush (*Lindera benzoin*)

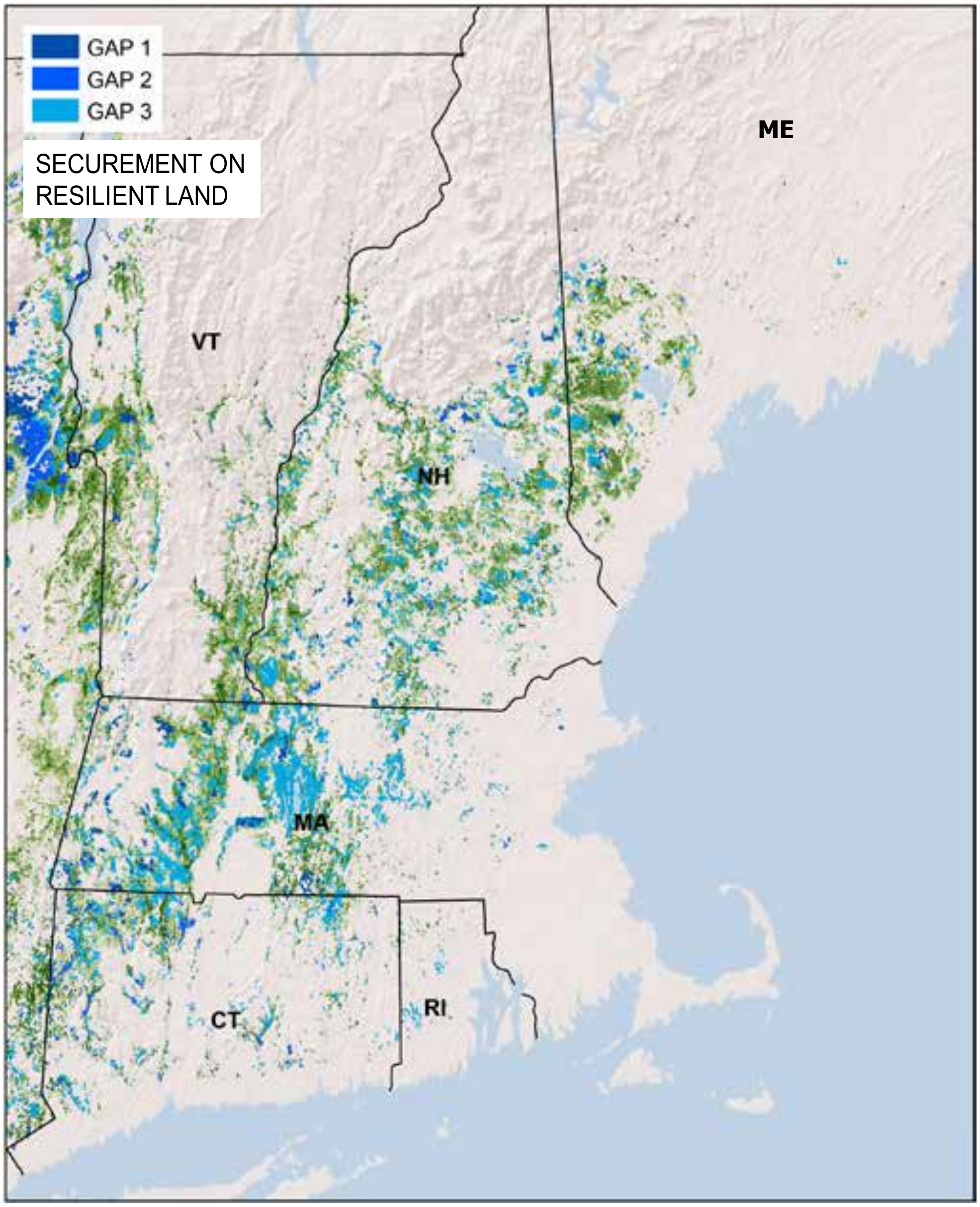


Predicted Loss to Development by 2050

Moderately low 5%

This community is threatened by development, with 195,274 acres(5%) likely to be lost over the next30 years.

Appalachian (Hemlock)-Northern Hardwood Forest



LOCATION	RESILIENT ACRES	% SECURED
New England	4,016,594	18%
CT	584,064	20%
MA	1,145,701	30%
ME	458,126	8%
NH	1,197,641	16%
RI	11,920	42%
VT	619,141	8%

LOCATION	RESILIENT ACRES	% SECURED
New England	2,230,135	22%
CT	224,222	29%
MA	588,283	38%
ME	265,563	10%
NH	751,166	19%
RI	4,271	57%
VT	396,630	10%

Rare or Uncommon Plants Associated with this Habitat

ram's-head lady's-slippers (*Cypripedium arietinum*)

small whorled pogonia (*Isotria medeoloides*)

southern lady fern (*Athyrium asplenioides*)

downywood mint (*Blephilia ciliata*)

Reznicek's sedge (*Carex reznicekii*)

devil's bit (*Chamaelirium luteum*)

Appalachian white-aster (*Doellingeria infirma*)

southeastern wild-rye (*Elymus glabriflorus*)

green-violet (*Hybanthus concolor*)

big-leaved holly (*Ilex montana*)

hairy honeysuckle (*Lonicera hirsuta*)

lion's-foot rattlesnake-root (*Nabalus serpentarius*)

stiff flat-topped-goldenrod (*Oligoneuron rigidum*)

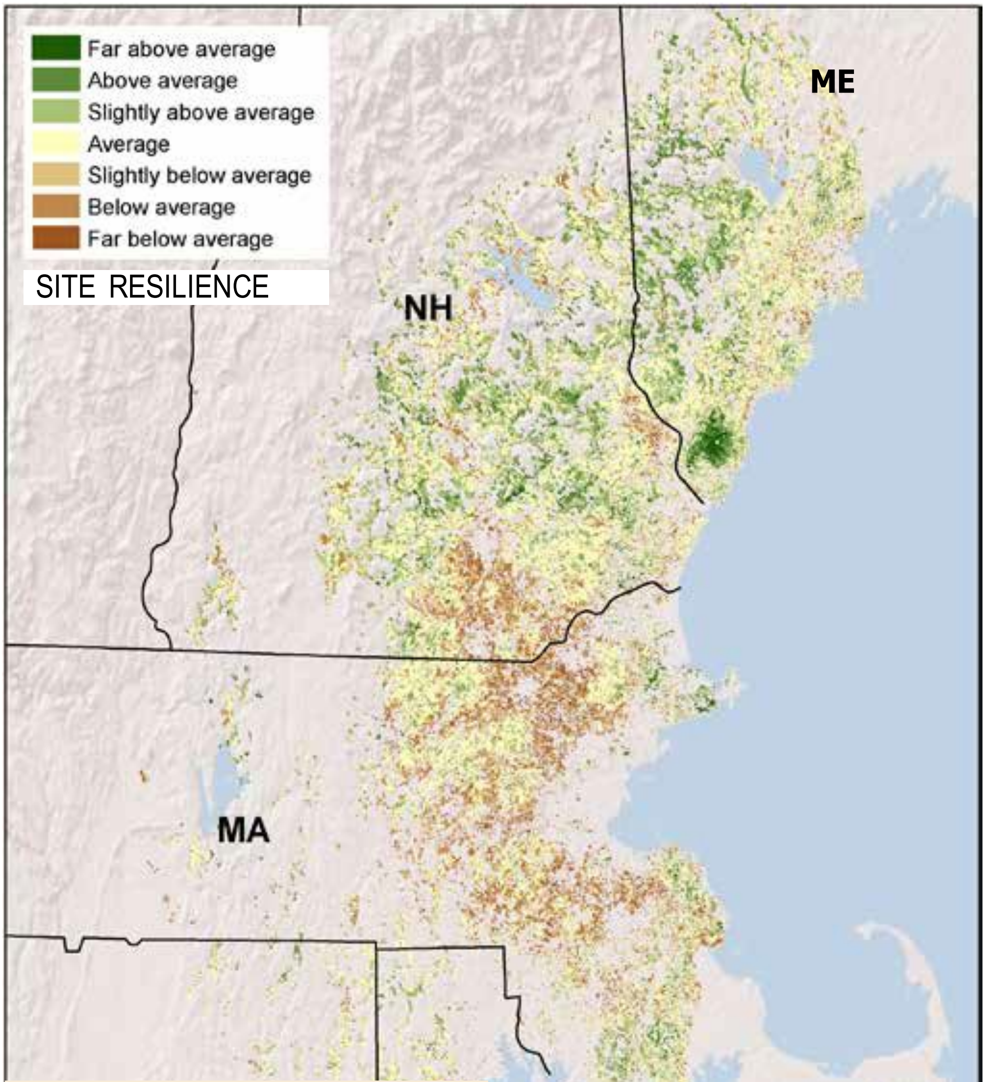
Appalachian gooseberry (*Ribes rotundifolium*)

Case's ladies'-tresses (*Spiranthes casei*)

hidden dropseed (*Sporobolus clandestinus*)

smooth blackhaw (*Viburnum prunifolium*)

Northeastern Coastal & Interior Pine-Oak Forest



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	0%	6,159	2%	4%	39%	44%	56%
Above average	9%	138,368	2%	2%	21%	25%	75%
Slightly above average	21%	320,941	1%	2%	17%	19%	81%
Average	43%	662,069	1%	2%	15%	18%	82%
Slightly below average	11%	161,484	1%	1%	13%	15%	85%
Below average	6%	98,241	1%	1%	12%	13%	87%
Far below average	1%	12,097	0%	1%	7%	8%	92%
Developed	9%	136,299	0%	1%	7%	8%	92%
TOTAL	**100%**	**1,535,658**	**1%**	**2%**	**15%**	**18%**	**82%**

Resilience & Securement

30% of this habitat scores high for resilience, and 18% of the total acreage is secured against conversion, with the resilient areas having the highest proportion of securement.

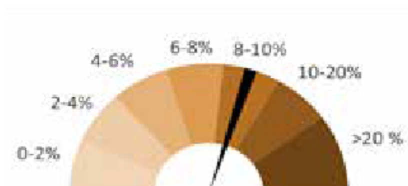
© Patricia Swain (Massachusetts Division of Fisheries & Wildlife/Natural Heritage & Endangered Species Program)

Description

A mixed forest dominated by white pine, red oak, and hemlock in varying proportions. Red maple and white oak are common associates, as are northern hardwoods like white ash and American beech.

Associated Herbs & Shrubs

sundial lupine (*Lupinus perennis*), large whorled pogonia (*Isotria verticillata*), northern blazing star (*Liatris novae-angliae*), Philadelphia panicgrass (*Panicum philadelphicum*), sassafras (*Sassafras albidum*), swamp small-flowered-saxifrage (*Micranthes pensylvanica*), hook-spurred violet (*Viola adunca*), northern tuberculed bog-orchid (*Platanthera flava* var. *herbiola*)

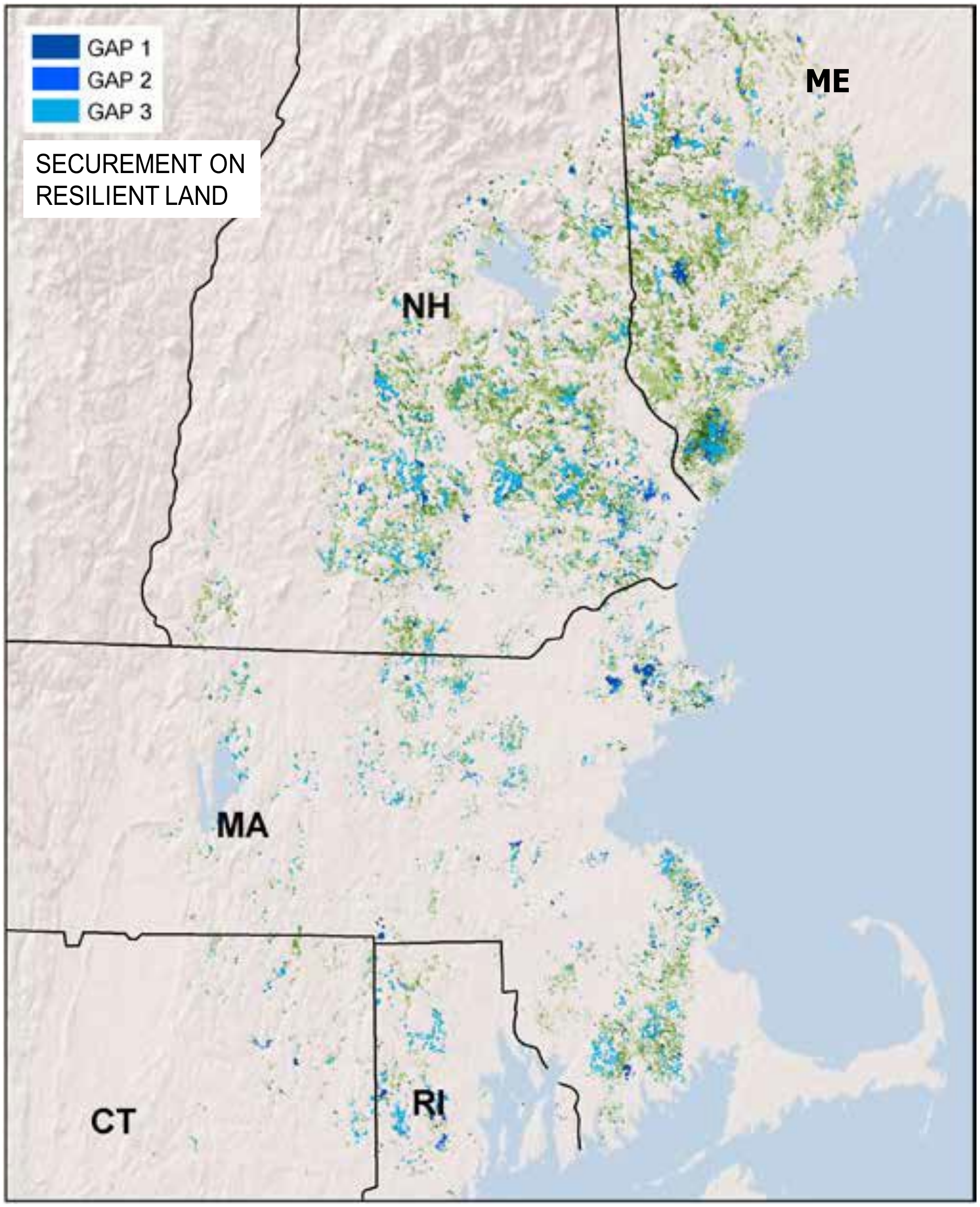


Predicted Loss to Development by 2050

Moderate 9%

This community is threatened by development, with 134,828 acres (9%) likely to be lost over the next 30 years.

Northeastern Coastal & Interior Pine-Oak Forest



LOCATION	TOTAL ACRES	% SECURED
New England	1,535,658	17%
CT	38,349	23%
MA	402,304	24%
ME	391,590	9%
NH	653,405	16%
RI	50,011	36%
VT		

LOCATION	RESILIENT ACRES	% SECURED
New England	465,468	21%
CT	8,888	29%
MA	54,656	38%
ME	168,507	13%
NH	220,752	22%
RI	12,664	48%
VT		

Rare or Uncommon Plants Associated with this Habitat

Torrey's mountain-mint (*Pycnanthemum torrei*)

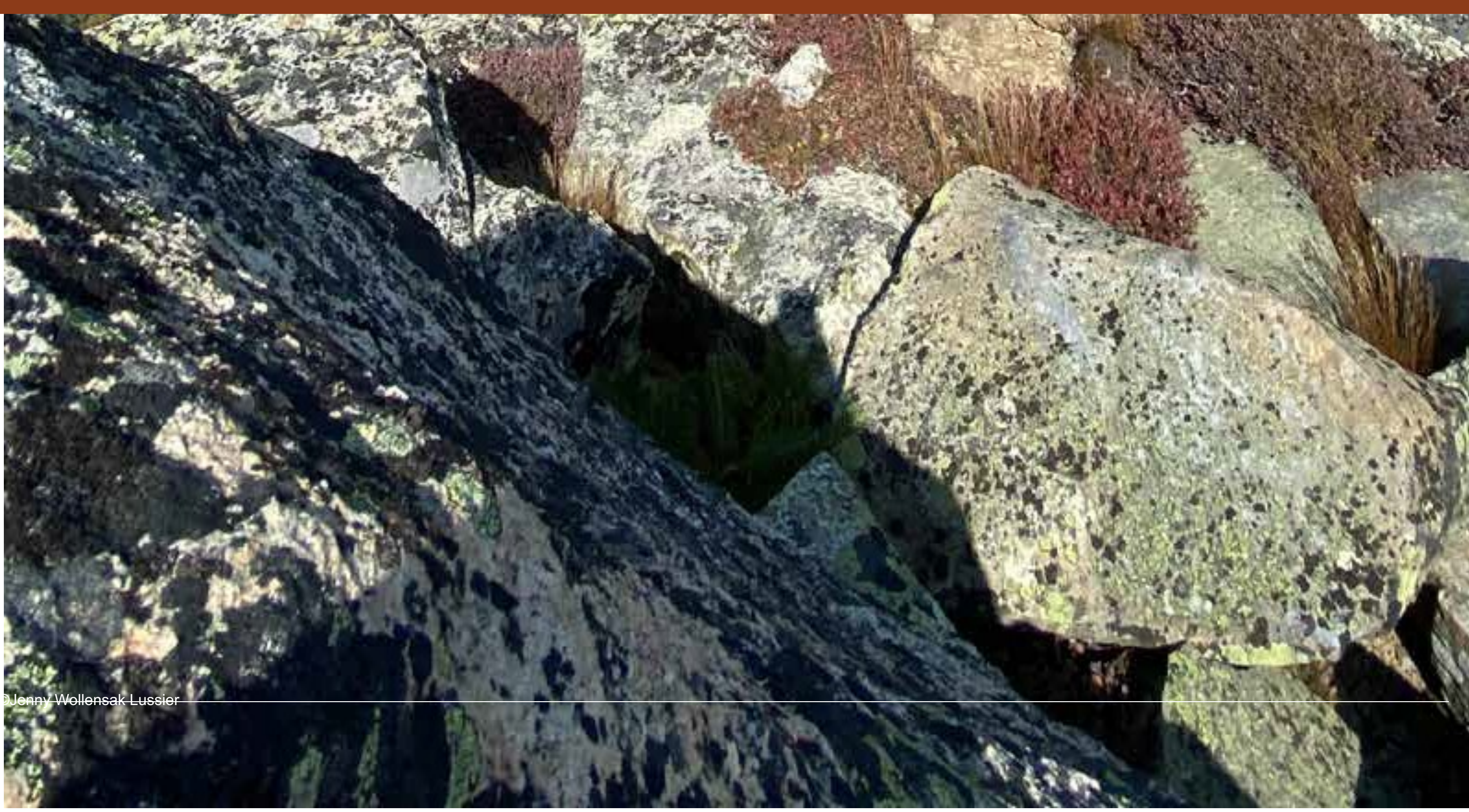
lesser snakeroot (*Ageratina aromatica*)

Appalachian white-aster (*Doellingeria infirma*)

willow-leaved American-aster (*Symphyotrichum praealtum* ssp. *angustior*)

Jpland HabItats

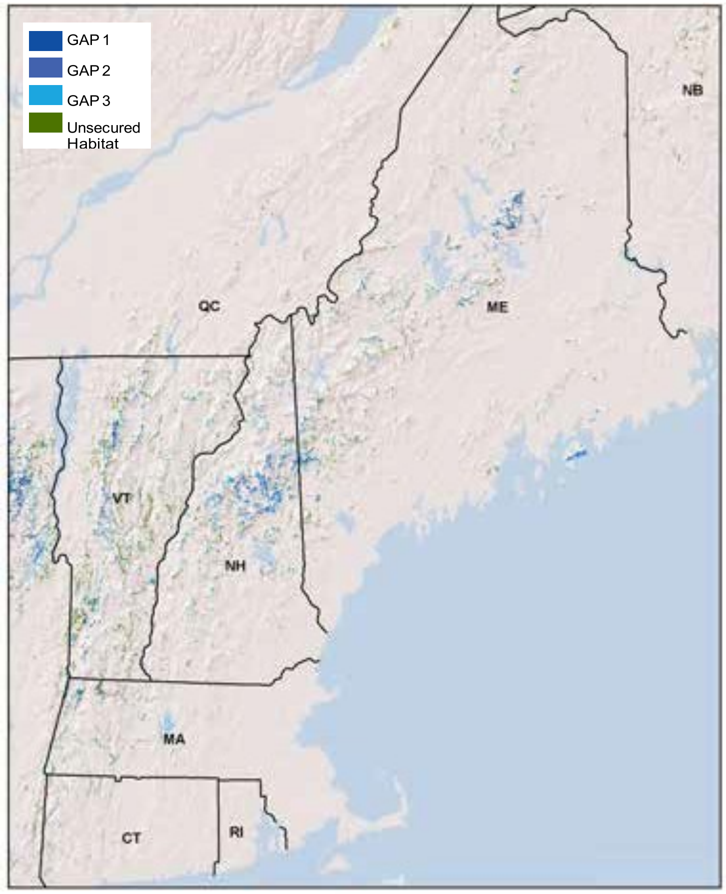
atch-forming habitats



©Jenny Wollensak Lussier

MACROGROUP

CLIFF & TALUS



Cliff & Talus

A sparsely vegetated cliff or talus slope formed on bedrock. The lack of soil limits the vegetation to mosses, lichens, and herbs growing on bare rock or in crevices.

Acres in New England

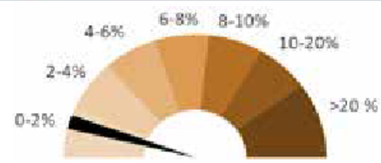
156,031

Percent Secured

GAP 1 = 16%

GAP 2 = 14%

GAP 3 = 19%



Predicted Loss to Development by 2050

3,433 acres (2%)

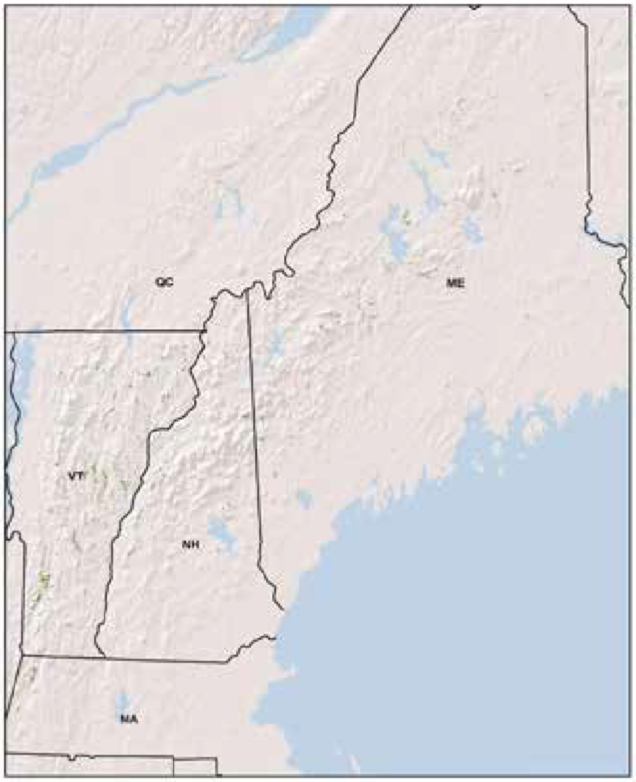
	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS TOTAL	P	S	U
Cliff & Talus	**156,190**	**16%**	**14%**	**19%**	**51%**				
Connecticut	3,901	2%	14%	19%	66%				
Massachusetts	11,700	22%	1%	28%	49%				
Maine	43,935	19%	19%	15%	48%				
New Hampshire	39,892	16%	32%	21%	32%				
Rhode Island	3	0%	0%	0%	100%				
Vermont	56,758	13%	1%	20%	66%				

New England	**156,190**	**24,283**	**22,266**	**30,254**	**79,387**

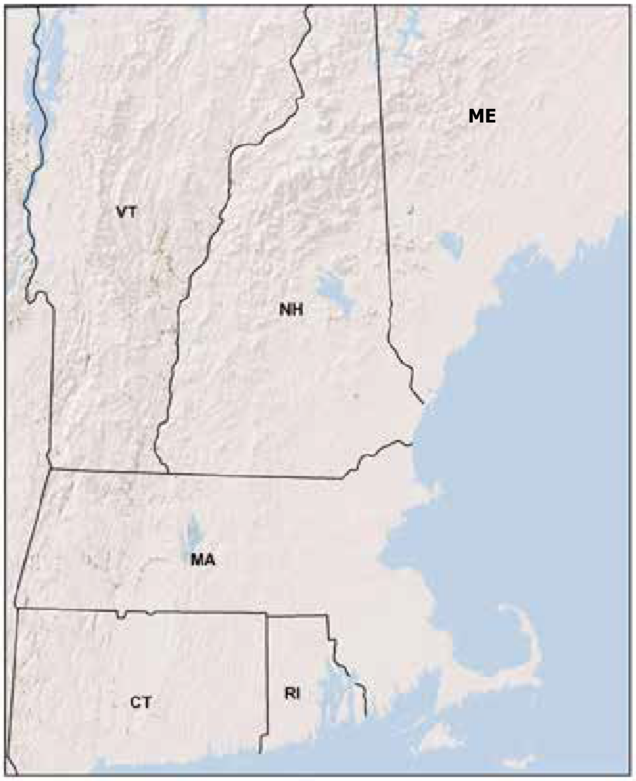
P = Protected S = Secured
U = Unsecured

DISTRIBUTION OF HABITATS

Acidic Cliff & Talus

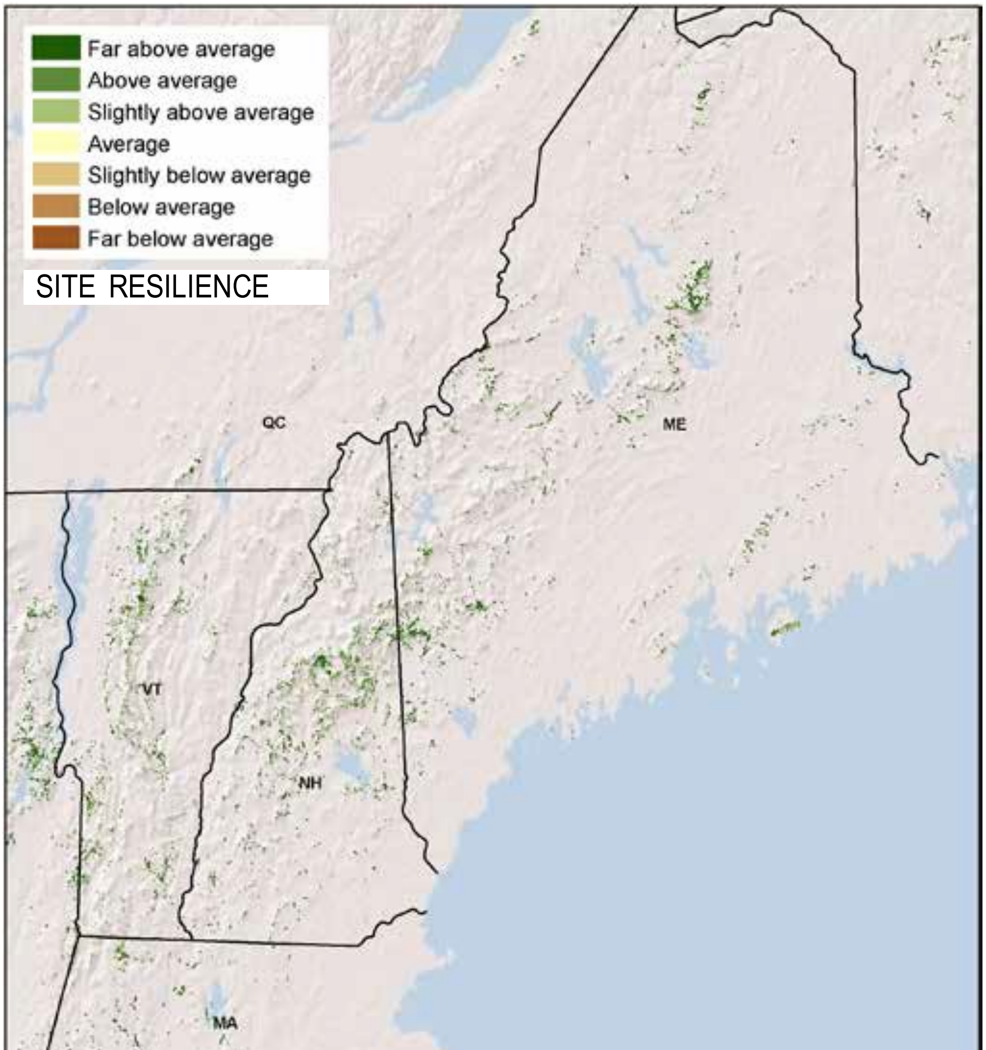


Calcareous Cliff & Talus



Circumneutral Cliff & Talus

Acidic Cliff & Talus



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	13%	14,837	22%	12%	18%	52%	48%
Above average	68%	76,522	21%	21%	19%	61%	39%
Slightly above average	18%	20,365	7%	10%	19%	37%	63%
Average	0%	404	5%	6%	8%	19%	81%
Slightly below average	0%	169	2%	4%	11%	16%	84%
Below average	0%	143	1%	9%	32%	42%	58%
Far below average	0%	6	0%	4%	23%	27%	73%
Developed	1%	767	9%	11%	17%	37%	63%
TOTAL	**100%**	**113,213**	**19%**	**17%**	**19%**	**55%**	**45%**

Resilience & Securement

99% of this habitat scores high for resilience, 55% of the total acreage is secured againstconversion, and 36% is protected.

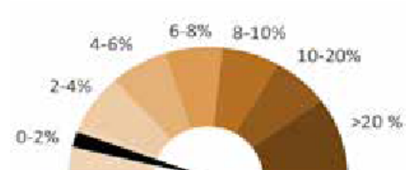
© Maine Natural Areas Program

Description

A sparsely vegetated cliff or talus slope formed on granitic, sandstone, or other acidic bedrock. The lack of soil, highly acidic bedrock, and constant erosion limit the vegetation to mosses, lichens, herbs, and stunted trees growing in rockycrevices.

Associated Herbs & Shrubs

violet butterwort (*Pinguicula vulgaris*), fragrant wood fern (*Dryopteris fragrans*), Goldie's wood fern (*Dryopteris goldiana*) canescent whitlow-mustard (*Draba cana*), Blake's milk-vetch (*Astragalus robbinsii* var. *minor*), Michaux's sandplant (*Minuartia michauxii*), small-flower bittercress (*Cardamine parviflora*), smooth false foxglove (*Aureolaria flava*), summer grape (*Vitis gestivalis* var. *bicolor*), white mountain saxifrage (*Saxifraga paniculata*)

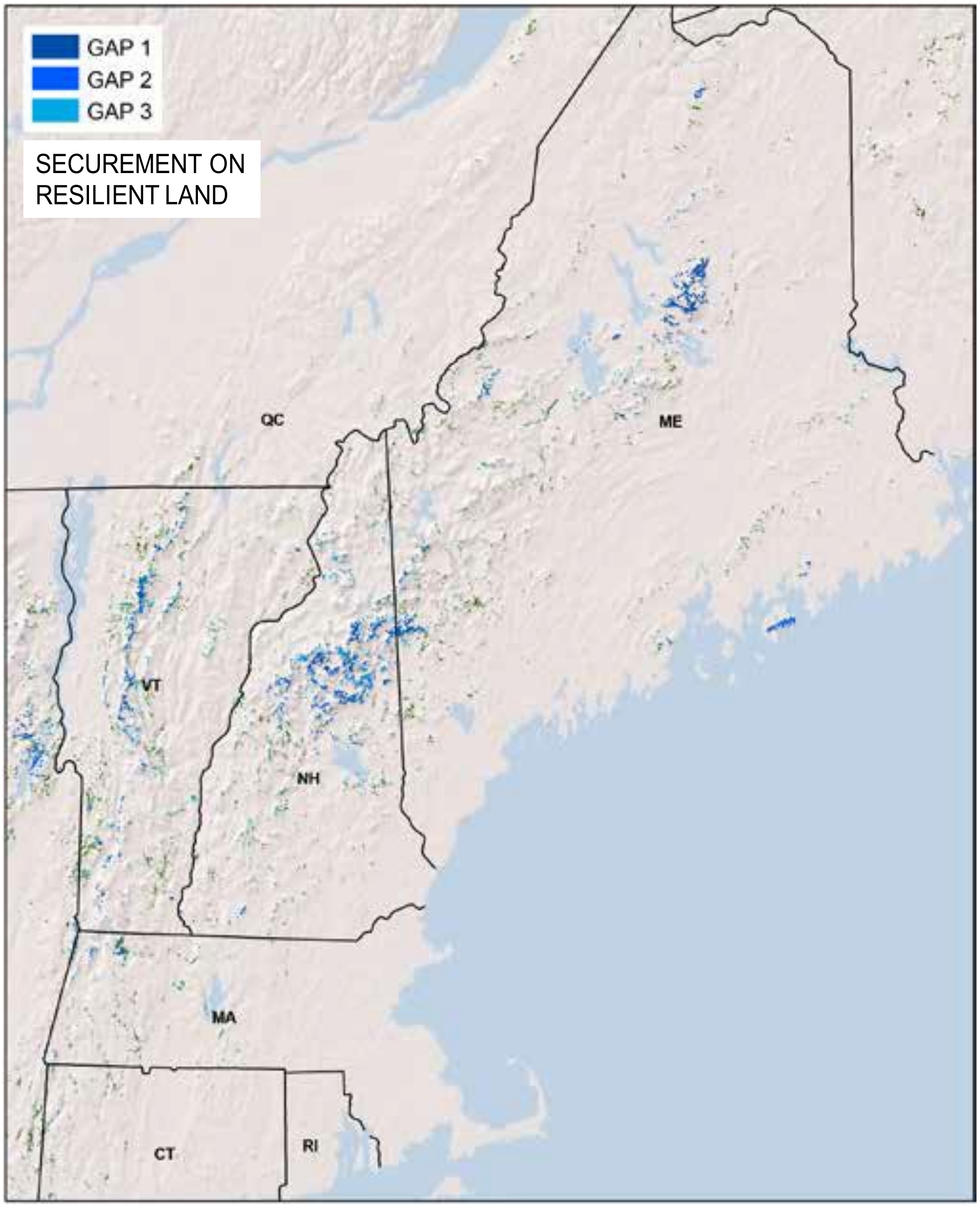


Predicted Loss to Development by 2050

Low 2%

This community is not threatenedby development, with 2,054 acres(2%) likely to be lost over the next30 years.

Acidic Cliff & Talus



© Eric Sorenson (Vermont Fish & Wildlife)

LOCATION	TOTAL ACRES	% SECURED
New England	113,213	55%
CT	2,059	39%
MA	6,149	49%
ME	35,209	56%
NH	35,125	73%
RI	3	0%
VT	34,668	39%

LOCATION	RESILIENT ACRES	% SECURED
New England	111,724	56%
CT	1,962	41%
MA	6,009	50%
ME	34,896	56%
NH	34,833	73%
RI	3	0%
VT	34,021	39%

Rare or Uncommon Plants Associated with this Habitat

mountain spleenwort
(*Asplenium montanum*)

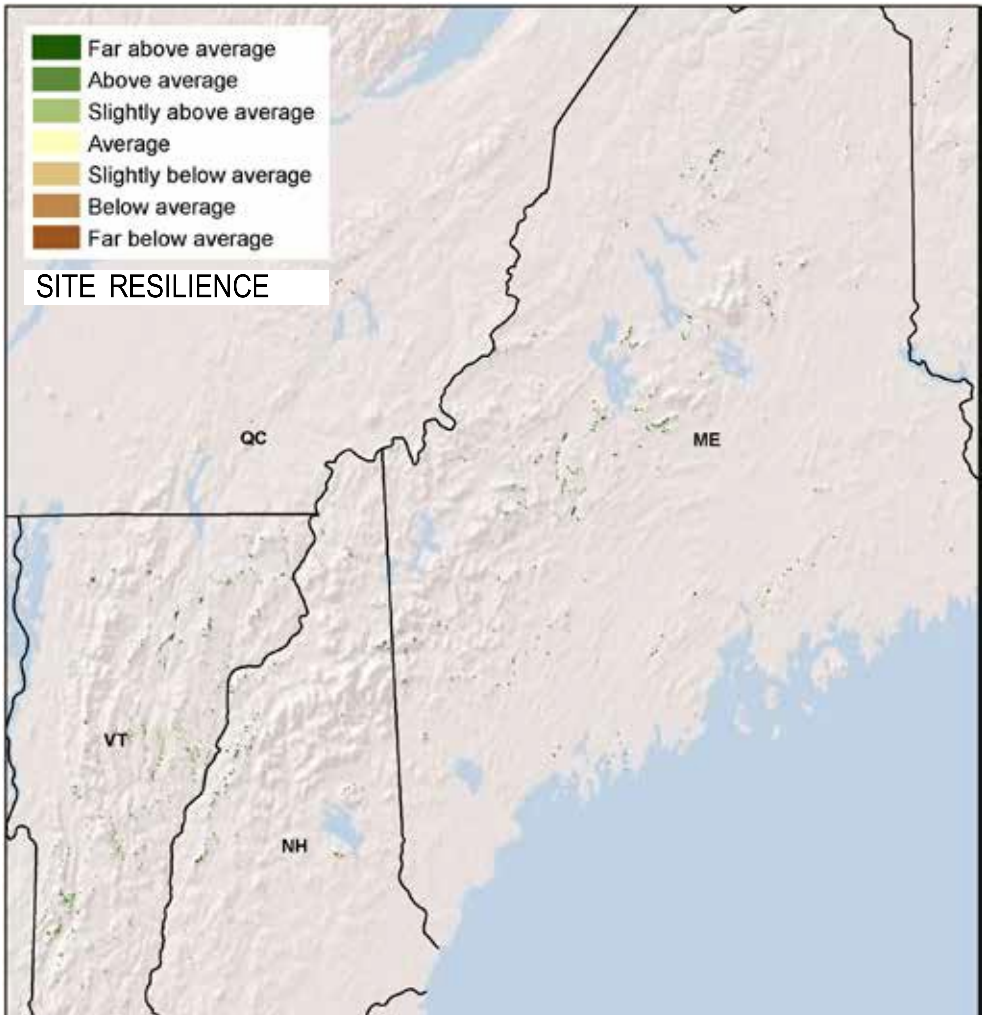
violet butterwort
(*Pinguicula vulgaris*)

Canada mountain-rice grass
(*Piptatherum canadense*)

neglected reed-grass
(*Calamagrostis stricta* ssp. *inexpansa*)

silvery whitlow-wort
(*Paronychia argyrocoma*)

Calcareous Cliff & Talus



SITE RESILIENCE	RESILIENT	ACRES	GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	7%	1,975	2%	10%	19%	31%	69%
Above average	64%	18,810	9%	9%	22%	40%	60%
Slightly above average	27%	7,782	8%	3%	18%	29%	71%
Average	1%	182	0%	0%	3%	3%	97%
Slightly below average	0%	89	0%	1%	6%	7%	93%
Below average	0%	102	5%	0%	3%	7%	93%
Far below average	0%	6	7%	0%	19%	26%	74%
Developed	1%	279	5%	1%	19%	25%	75%
TOTAL	**100%**	**29,225**	**8%**	**7%**	**21%**	**36%**	**64%**

Resilience & Securement

98% of this habitat scores high for resilience, 36% of the total acreage is secured against conversion, and 15% is protected.

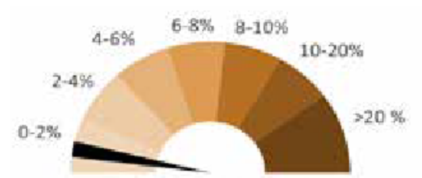
© Elizabeth Thompson (Vermont Land Trust)

Description

A sparsely vegetated talus slope formed on limestone, dolomite, dolostone, or other calcareous bedrock. Edaphic conditions limit vegetation to herbs, ferns, and sparse trees growing in rock crevices. Northern white cedar is characteristic. Ash, basswood, and bladdernut are other indicators.

Associated Herbs & Shrubs

Lake Mistassini primrose (*Primula mistassinica*), Blake's milk-vetch (*Astragalus robbinsii* var. *minor*), alpine northern-rockcress (*Braya humilis* ssp. *humilis*), Canadian single-spike sedge (*Carex scirpoidea*), few-flowered spikesedge (*Eleocharis quinqueflora* ssp. *fernaldii*), slender rock-brake (*Cryptogramma stelleri*), fragrant wood fern (*Dryopteris fragrans*), hyssop-leaved fleabane (*Erigeron hyssopifolius*), thale-cress (*Arabidopsis lyrata*), roseroot (*Rhodiola rosea*), slender cliff-brake (*Pellaea glabella*), smooth rockcress (*Boechera laevigata*), smooth cliff fern (*Woodsia glabella*), boreal sandplant (*Minuartia rubella*)

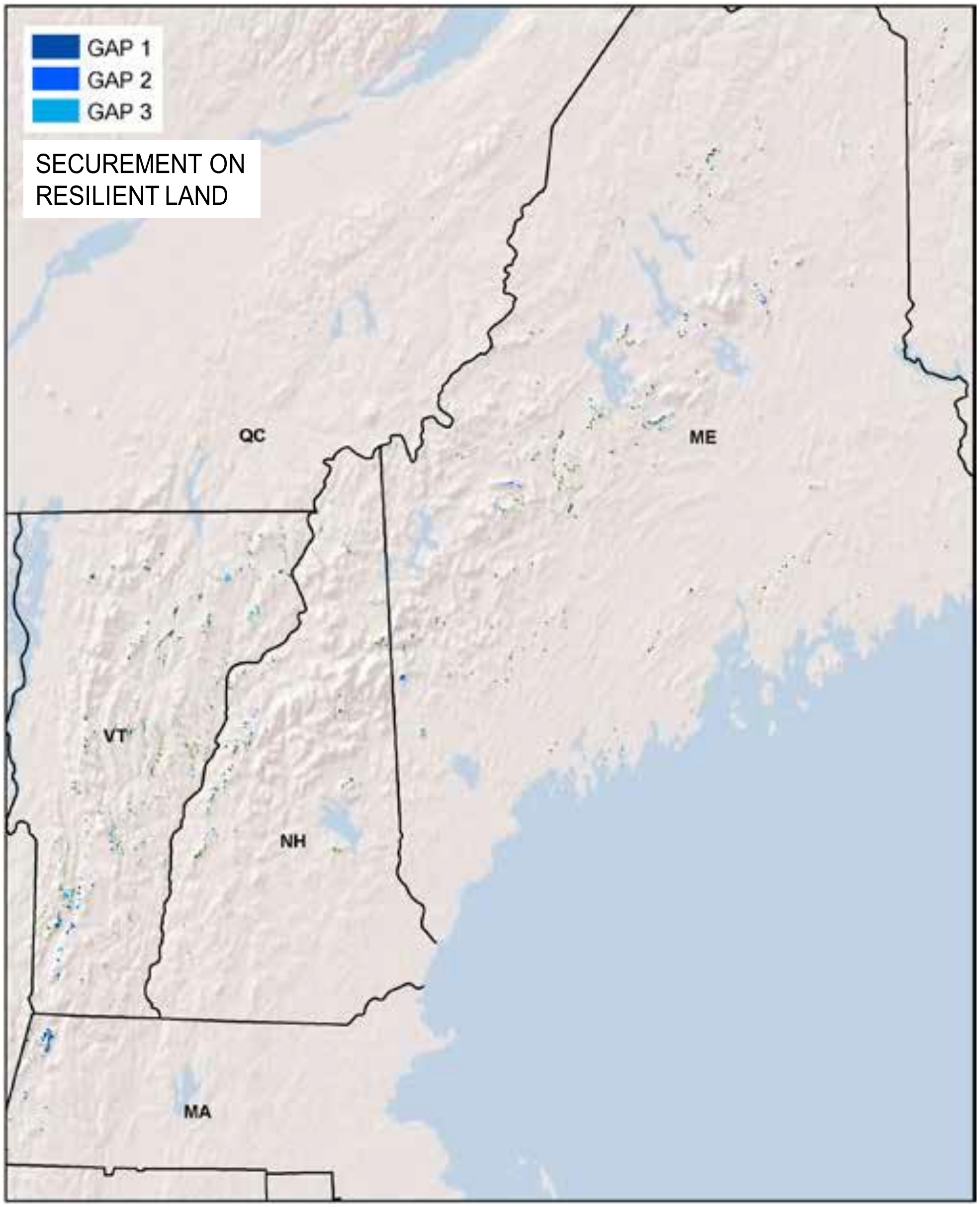


Predicted Loss to Development by 2050

Very low 1%

This community is not threatened by development, with only 428 acres (<1%) likely to be lost over the next 30 years.

Calcareous Cliff & Talus



LOCATION	TOTAL ACRES	% SECURED
New England	29,225	36%
CT		
MA	1,868	63%
ME	7,868	38%
NH	3,757	35%
RI		
VT	15,732	31%

LOCATION	RESILIENT ACRES	% SECURED
New England	28,567	36%
CT		
MA	1,834	63%
ME	7,804	38%
NH	3,732	36%
RI		
VT	15,198	32%

Rare or Uncommon Plants Associated with this Habitat

mountain death camas (*Anticlea elegans* ssp. *glauca*)

green spleenwort (*Asplenium viride*)

Crave's sedge (*Carex crawei*)

slender rock-brake (*Cryptogramma stelleri*)

wiry panicgrass (*Panicum flexile*)

northern cliff fern (*Woodsia alpina*)

violet butterwort (*Pinguicula vulgaris*)

glaucous blue grass (*Poa glauca* ssp. *glauca*)

yellow mountain saxifrage (*Saxifraga aizoides*)

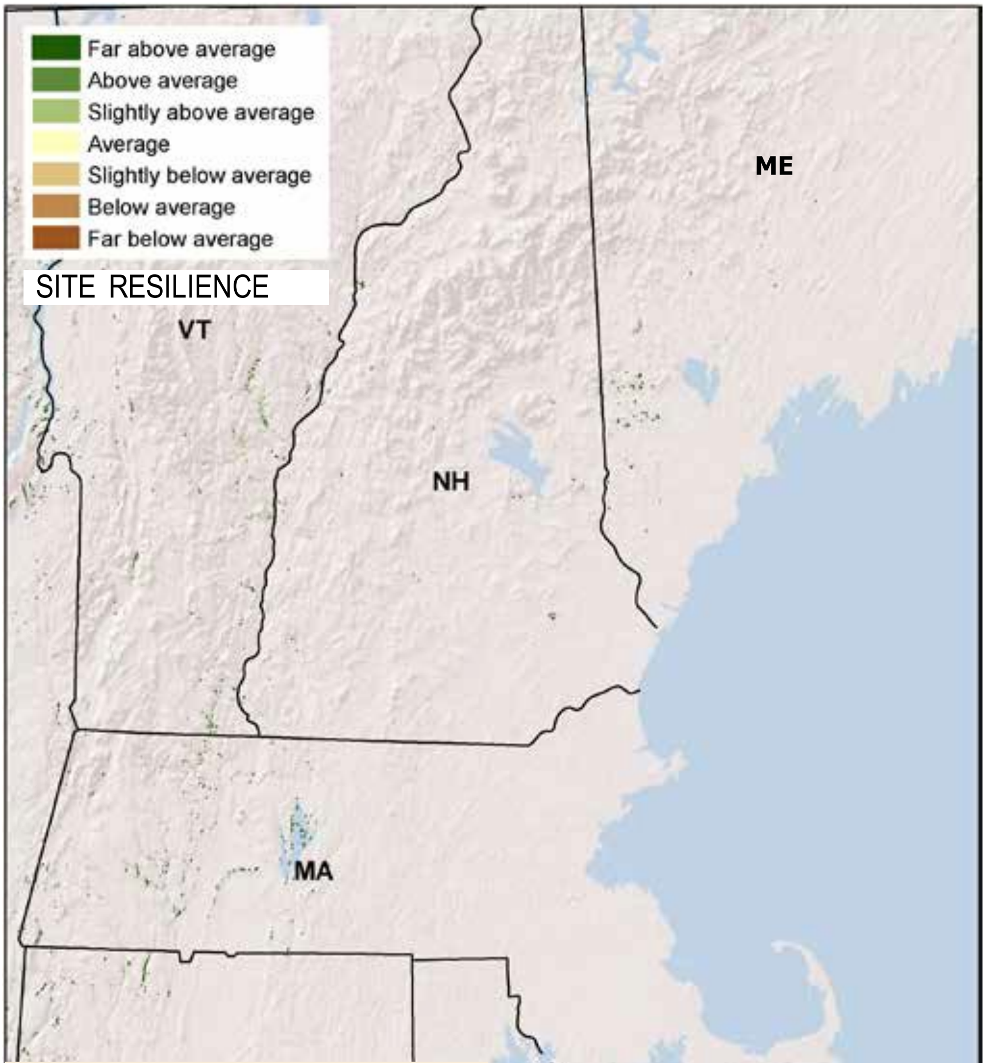
purple mountain saxifrage (*Saxifraga oppositifolia*)

little skullcap (*Scutellaria parvula* var. *parvula*)

small dropseed (*Sporobolus neglectus*)

pennyroyal bluecurls (*Trichostema brachiatum*)

Circumneutral Cliff & Talus



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	19%	2,632	11%	3%	21%	35%	65%
Above average	45%	6,204	6%	5%	19%	29%	71%
Slightly above average	30%	4,083	1%	5%	17%	23%	77%
Average	3%	367	3%	6%	17%	25%	75%
Slightly below average	1%	118	2%	0%	29%	31%	69%
Below average	0%	50	0%	0%	42%	42%	58%
Far below average	0%	1	0%	0%	0%	0%	100%
Developed	2%	298	2%	1%	12%	15%	85%
TOTAL	**100%**	**13,752**	**5%**	**4%**	**19%**	**28%**	**72%**

Resilience & Securement

94% of this habitat scores high for resilience, 28% of the total acreage is secured against conversion, and 9% is protected.

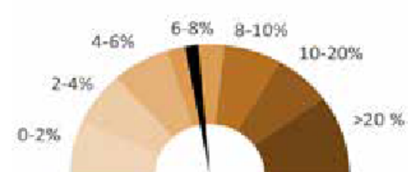
© West Virginia Division of Natural Resources

Description

A sparsely vegetated cliff or talus slope formed on moderately calcareous substrates such as calcareous shales or sandstones mixed with limestone. Edaphic conditions limit vegetation to herbs, ferns, and sparse trees growing in rock crevices.

Associated Herbs & Shrubs

rock muhly (*Muhlenbergia sobolifera*), Allegheny-vine (*Adlumia fungosa*), downy arrowwood (*Viburnum rafinesquianum*), narrow-leaved glade fern (*Diplazium pycnocarpon*), ledge spikemoss (*Selaginella rupestris*), whorled milkweed (*Asclepias verticillata*), Michaux's stitchwort (*Minuartia michauxii*), narrow-leaved vervain (*Verbena simplex*), nodding stickseed (*Hackelia deflexa* ssp. *americana*), purple virgin's-bower (*Clematis occidentalis*), small-flowered crowfoot (*Ranunculus micranthus*), upland boneset (*Eupatorium sessilifolium*), wall-rue spleenwort (*Asplenium ruta-muraria*)

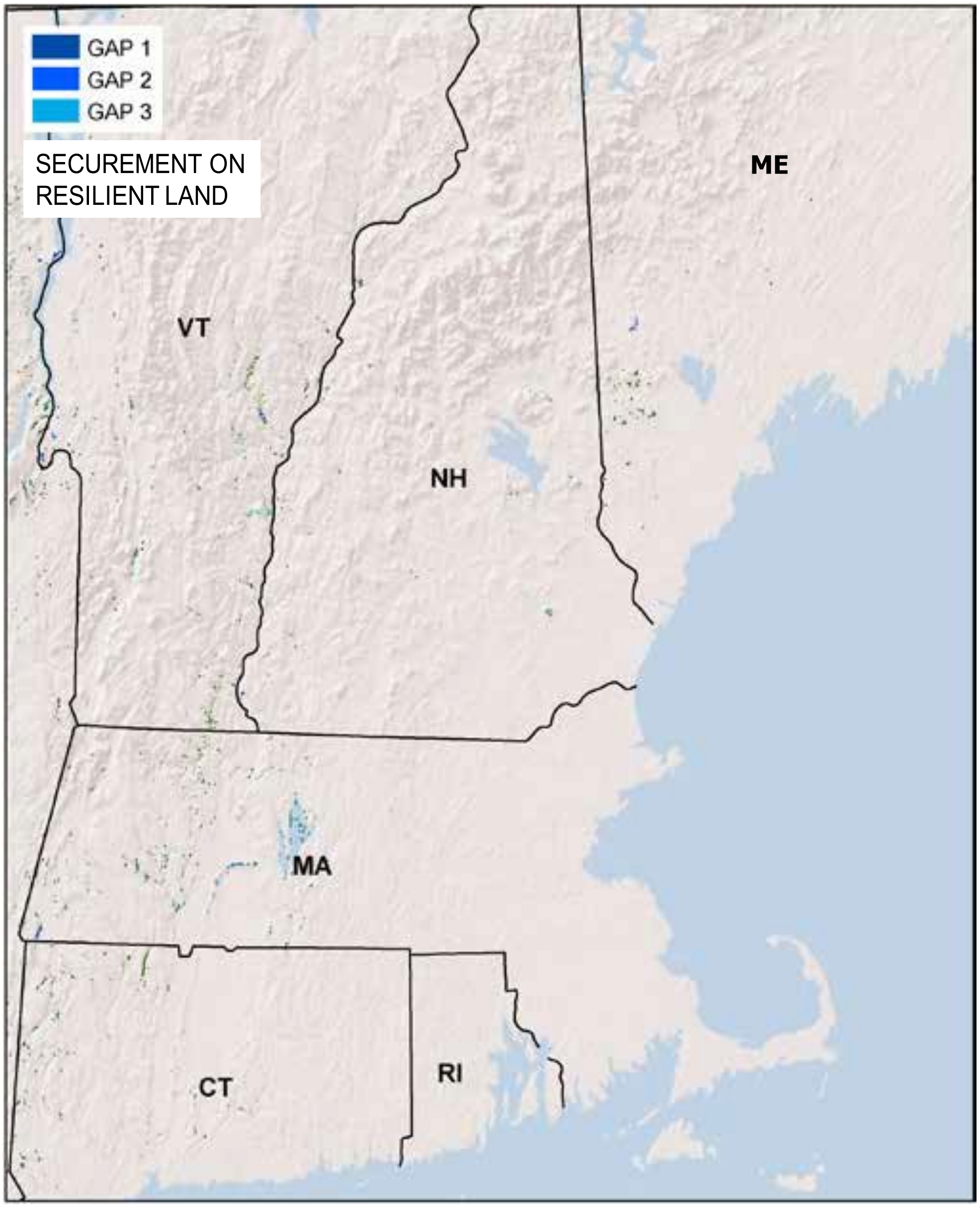


Predicted Loss to Development by 2050

Moderate 7%

This community is somewhat threatened by development, with 951 acres (7%) likely to be lost over the next 30 years.

Circumneutral Cliff & Talus



LOCATION	TOTAL ACRES	% SECURED
New England	13,752	28%
CT	1,842	29%
MA	3,683	48%
ME	858	36%
NH	1,010	32%
RI		
VT	6,358	15%

LOCATION	RESILIENT ACRES	% SECURED
New England	12,919	29%
CT	1,658	29%
MA	3,488	48%
ME	839	36%
NH	955	33%
RI		
VT	5,980	15%

Rare or Uncommon Plants Associated with this Habitat

wavy blue grass
(*Poa laxa* ssp. *fernaldiana*)

field wormwood
(*Artemisia campestris* ssp. *canadensis*)

neglected reed grass
(*Calamagrostis stricta* ssp. *stricta*)

scabrous black sedge
(*Carex atratiformis*)

hair-like sedge
(*Carex capillaris* ssp. *capillaris*)

Appalachian bristle fern
(*Crepidomanes* (*Trichomanes*) *intricatum*)

western tansy-mustard
(*Descurainia pinnata* ssp. *brachycarpa*)

canescent whitlow-mustard
(*Draba cana*)

smooth whitlow-mustard
(*Draba glabella*)

northern firmoss
(*Huperzia selago*)

glaucous blue grass
(*Poa glauca* ssp. *glauca*)

interior blue grass
(*Poa interior*)

bird's-eye primrose
(*Primula laurentiana*)

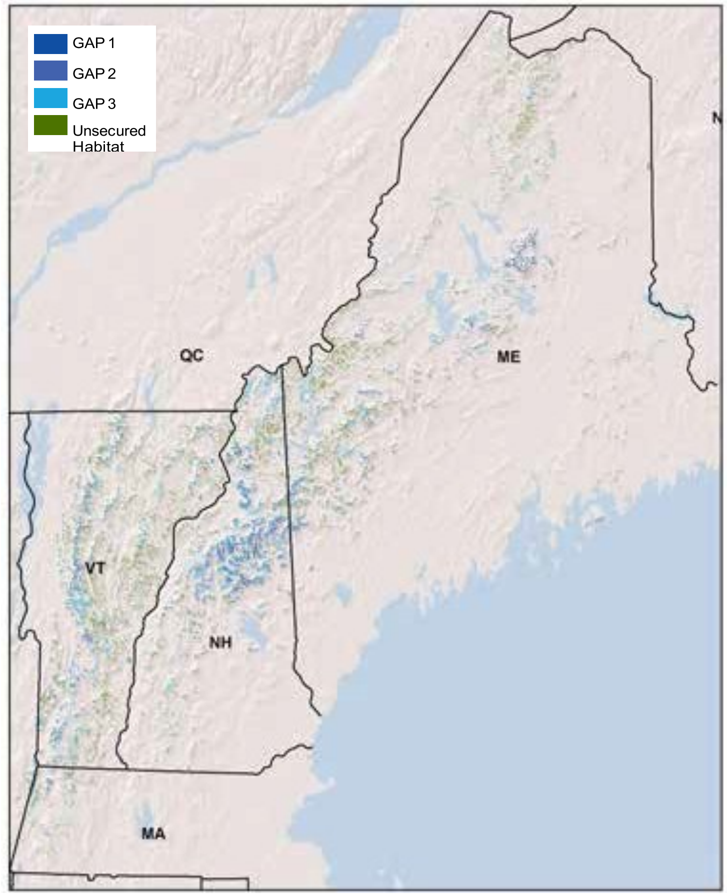
needle beaksedge
(*Rhynchospora capillacea*)

Appalachian gooseberry
(*Ribes rotundifolium*)

rough dropseed
(*Sporobolus compositus* var. *drummondii*)

MACROGROUP

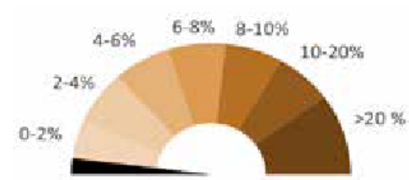
OUTCROP, SUMMIT & ALPINE



Outcrop, Summit & Alpine
An herbaceous or sparsely vegetated mountain summit with thin soils and bedrock outcrops.

Acres in New England
191,682

Percent Secured
GAP 1 = 16%
GAP 2 = 13%
GAP 3 = 20%

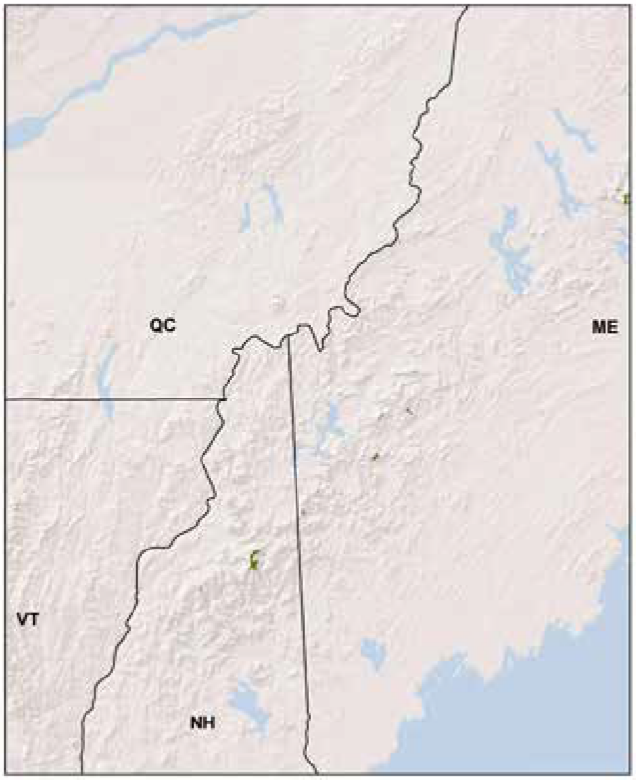


Predicted Loss to Development by 2050
658 acres (0%)

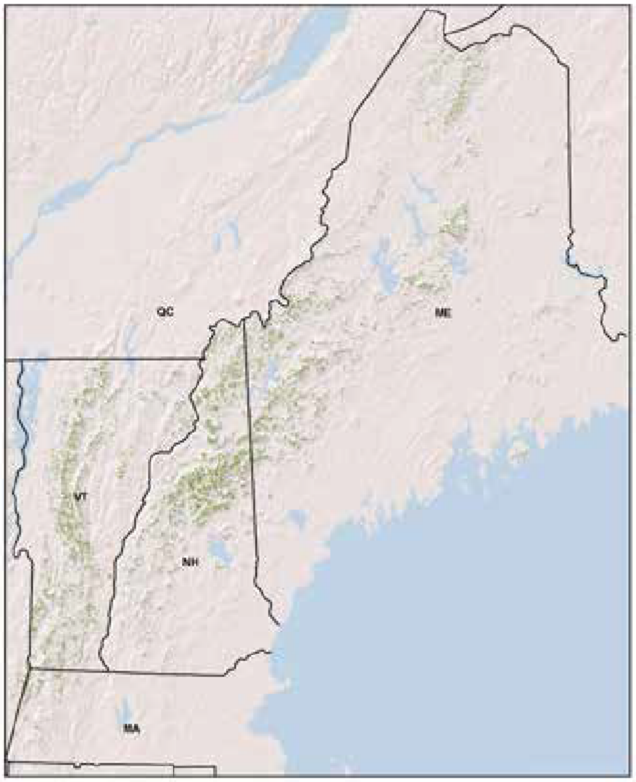
	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS			
						TOTAL	P	S	U
Outcrop, Summit & Alpine	**191,618**	**16%**	**13%**	**20%**	**51%**				
Connecticut	91	0%	0%	7%	93%				
Massachusetts	5,005	21%	2%	29%	48%				
Maine	67,998	11%	9%	19%	61%				
New Hampshire	57,488	26%	32%	18%	25%				
Vermont	61,036	12%	3%	22%	63%				
New England	**191,618**	**30,610**	**25,831**	**38,339**	**96,837**				

P = Protected S = Secured
U = Unsecured

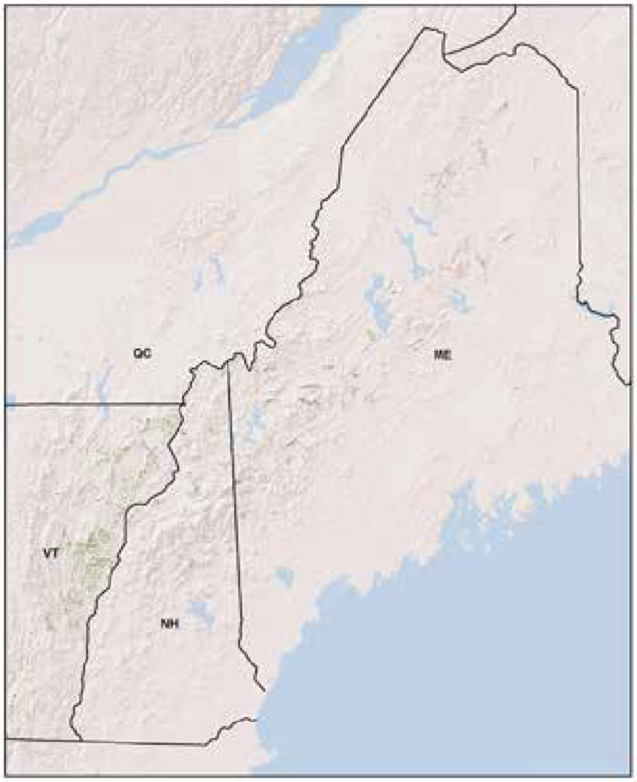
DISTRIBUTION OF HABITATS



Acadian-Appalachian Alpine Tundra

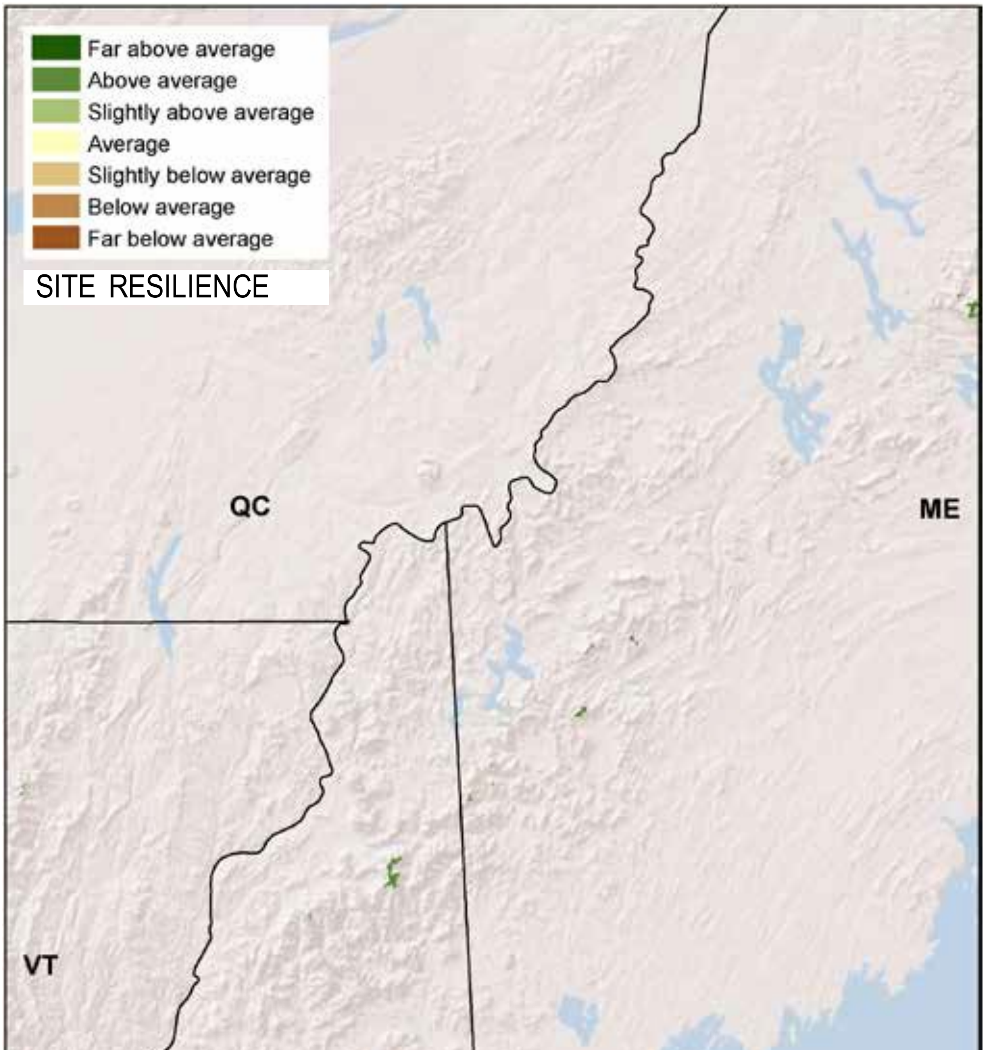


Acidic Rocky Outcrop



Calcareous Rocky Outcrop

Acadian-Appalachian Alpine Tundra



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	2%	127	76%	5%	19%	100%	0%
Above average	97%	7,647	76%	9%	14%	99%	1%
Slightly above average	1%	101	93%	5%	2%	100%	0%
Average	0%						
Slightly below average	0%						
Below average	0%						
Far below average	0%						
Developed	0%	25	68%	14%	11%	93%	7%
TOTAL	**100%**	**7,900**	**76%**	**9%**	**14%**	**99%**	**1%**

Resilience & Securement

100% of this habitat scores high for resilience, 99% of the total acreage is secured against conversion, and 85% is protected.

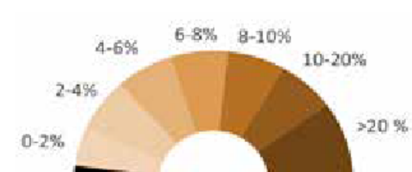
© Josh Royte (The Nature Conservancy, Maine)

Description

A sparsely vegetated system near or above treeline in the Northern Appalachian mountains, dominated by lichens, dwarf-shrubland, and sedges. At the highest elevations, the dominant plants are dwarf heaths such as alpine bilberry and cushion-plants.

Associated Herbs & Shrubs

alpine-azalea (*Loiseleuria procumbens*), alpine blueberry (*Vaccinium uliginosum*), alpine bitter-cress (*Cardamine bellidifolia*), alpine sweet grass (*Anthoxanthum monticola*), bearberry willow (*Salix uva-ursi*), Bigelow's sedge (*Carex bigelowii*), black crowberry (*Empetrum nigrum*), highland rush (*Juncus trifidus*), cushion-plant (*Diapensia lapponica*), Lapland rosebay (*Rhododendron lapponicum*), mountain cranberry (*Vaccinium vitis-idaea*), mountain sandplant (*Minuartia groenlandica*)

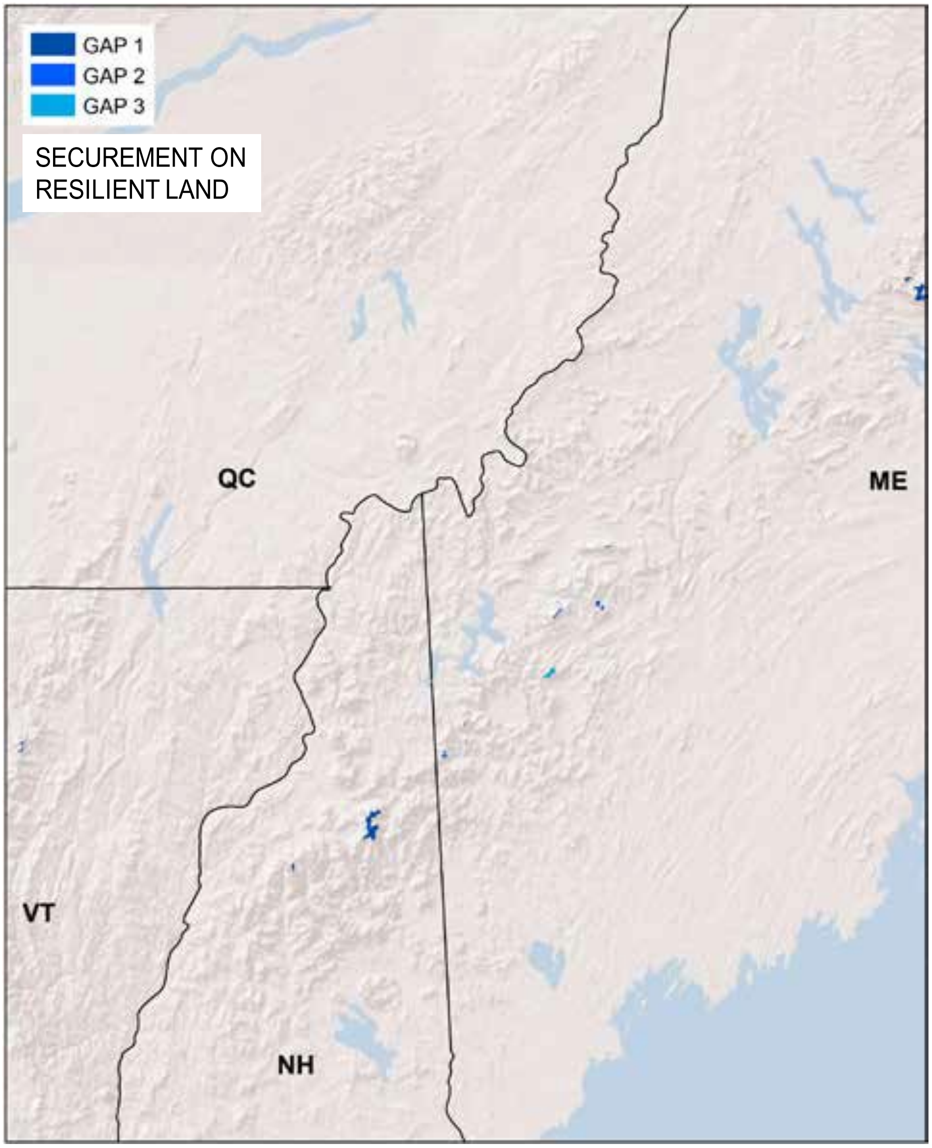


Predicted Loss to Development by 2050

Very low 0%

This community is not threatened by development.

Acadian-Appalachian Alpine Tundra



LOCATION	TOTAL ACRES	% SECURED
New England	7,900	99%
CT		
MA		
ME	3,624	99%
NH	4,160	99%
RI		
VT	115	100%

LOCATION	RESILIENT ACRES	% SECURED
New England	7,875	99%
CT		
MA		
ME	3,622	99%
NH	4,138	99%
RI		
VT	115	100%

Rare or Uncommon Plants Associated with this Habitat

lance-leaved arnica (*Arnica lanceolata* ssp. *lanceolata*)

White Mountain avens (*Geum peckii*)

Robbins' cinquefoil (*Potentilla robbinsiana*)

alpine bearberry (*Arctous alpina*)

glandular birch (*Betula glandulosa*)

alpine bistort (*Bistorta vivipara*)

capitate sedge (*Carex arctogena*)

scabrous black sedge (*Carex atratiformis*)

Sitka ground-cedar (*Diphasiastrum sitchense*)

Hornemann's willow-herb (*Epilobium hornemannii* ssp. *hornemannii*)

Oakes" eyebright (*Euphrasia oakesii*)

alpine fescue (*Festuca brachyphylla* ssp. *brachyphylla*)

moss-plant (*Harrimanella hypnoides*)

alpine azalea (*Kalmia procumbens*)

spiked wood rush (*Luzula spicata*)

leafy stemmedsaxifrage (*Micranthes foliolosa*)

alpine arctic-cudweed (*Omalotheca supina*)

mountain-sorrel (*Oxyria digyna*)

mountain Timothy (*Phleum alpinum*)

purple mountain-heath (*Phyllodoce caerulea*)

little yellow-rattle (*Rhinanthus minor* ssp. *groenlandicus*)

northern willow (*Salix arctophila*)

Labrador willow (*Salix argyrocarpa*)

nodding saxifrage (*Saxifraga cernua*)

alpine-brook saxifrage (*Saxifraga rivularis* ssp. *rivularis*)

sibbaldia (*Sibbaldia procumbens*)

moss campion (*Silene acaulis*)

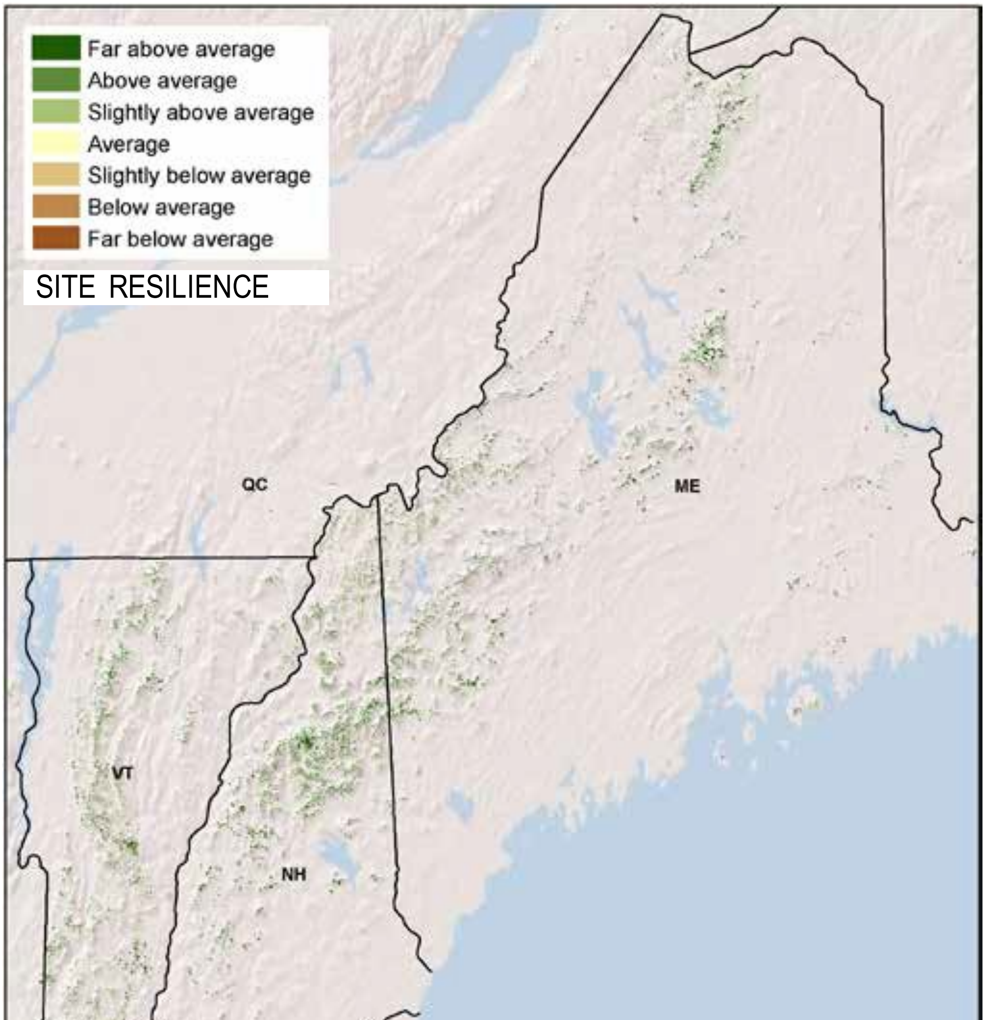
arctic hair grass (*Vahlodea atropurpurea*)

American alpine-speedwell (*Veronica wormskjoldii* var. *wormskjoldii*)

northern marshviolet (*Viola palustris* var. *palustris*)

northern painted-cup (*Castilleja septentrionalis*)

Acidic Rocky Outcrop



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	3%	4,362	25%	14%	18%	56%	44%
Above average	63%	96,467	20%	21%	20%	61%	39%
Slightly above average	32%	48,957	5%	5%	23%	33%	67%
Average	1%	781	0%	1%	10%	11%	89%
Slightly below average	0%	513	2%	1%	12%	15%	85%
Below average	1%	1,156	2%	1%	17%	21%	79%
Far below average	0%	164	3%	0%	10%	13%	87%
Developed	0%	571	1%	4%	12%	17%	83%
TOTAL	**100%**	**152,972**	**15%**	**15%**	**21%**	**51%**	**49%**

Resilience & Securement

98% of this habitat scores high for resilience, 51% of the total acreage is secured against conversion, and 30% is protected.

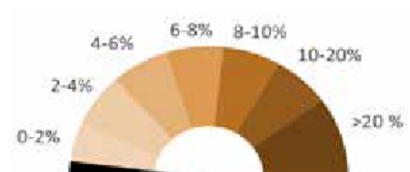
© Josh Royte (The Nature Conservancy, Maine)

Description

A sparsely vegetated system on resistant acidic bedrock such as sandstone, quartzite, or granite. The vegetation is a mosaic of woodlands and open glades, reflecting the proportion of rock surface to thin soil. Stunted trees over low heathshrubs are characteristic. Lichens and mosses dominate the ground cover.

Associated Herbs & Shrubs

variable depending upon elevation; includes alpine blueberry (*Vaccinium uliginosum*), alpine sweet-grass (*Anthoxanthum monticola*), Canada mountain-rice grass (*Piptatherum canadense*), Douglas's knotweed (*Polygonum douglasii*), mountain sandplant (*Minuartia groenlandica*)

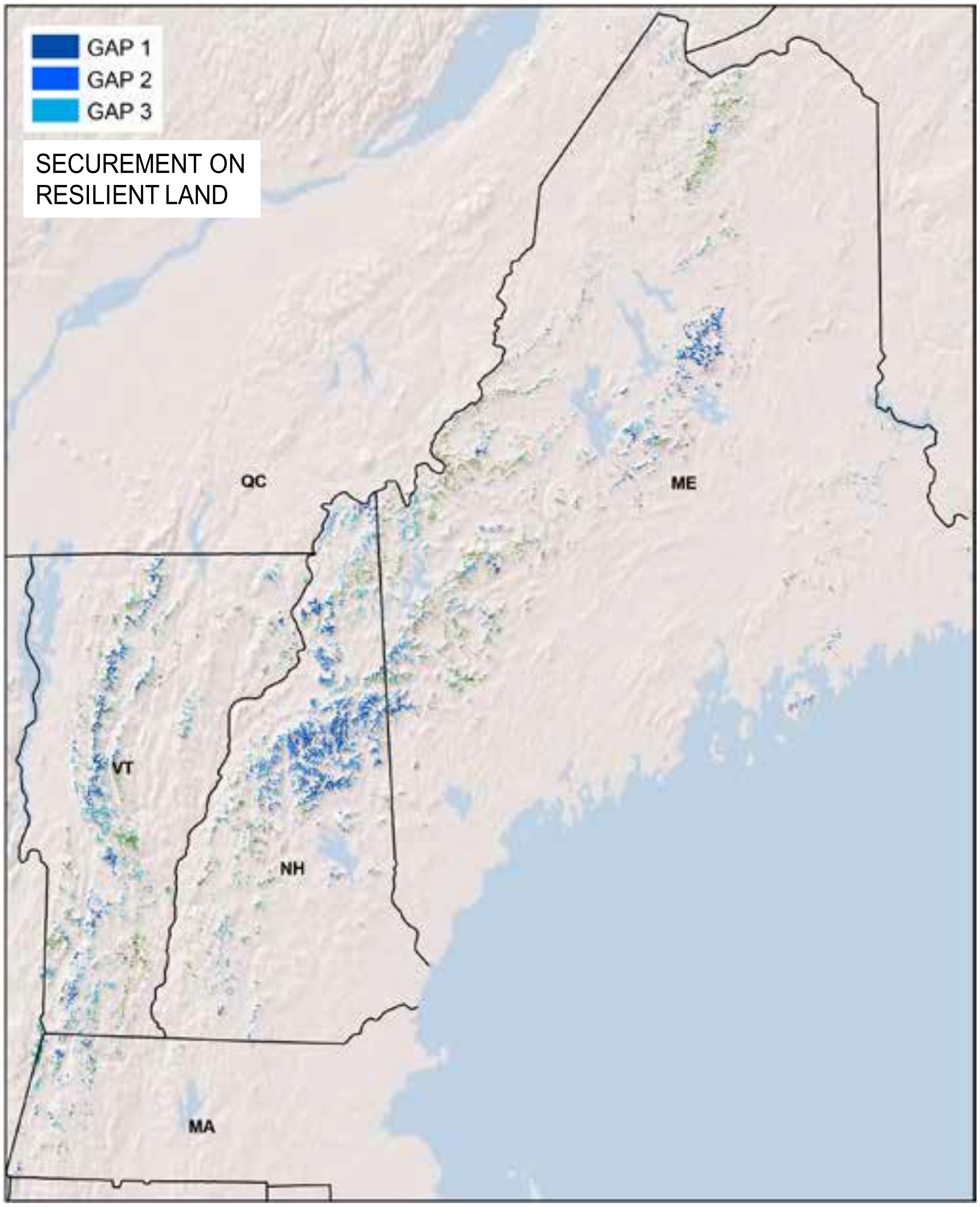


Predicted Loss to Development by 2050

Very low 0%

This community is not threatened by development, with only 560 acres (0%) likely to be lost over the next 30 years.

Acidic Rocky Outcrop



LOCATION	TOTAL ACRES	% SECURED
New England	152,972	51%
CT	91	7%
MA	5,005	52%
ME	53,631	36%
NH	50,309	74%
RI		
VT	43,936	42%

LOCATION	RESILIENT ACRES	% SECURED
New England	149,786	52%
CT	87	8%
MA	4,753	53%
ME	52,604	36%
NH	49,446	75%
RI		
VT	42,896	43%

Rare or Uncommon Plants Associated with this Habitat

Nantucket shadbush
(*Amelanchier nantucketensis*)

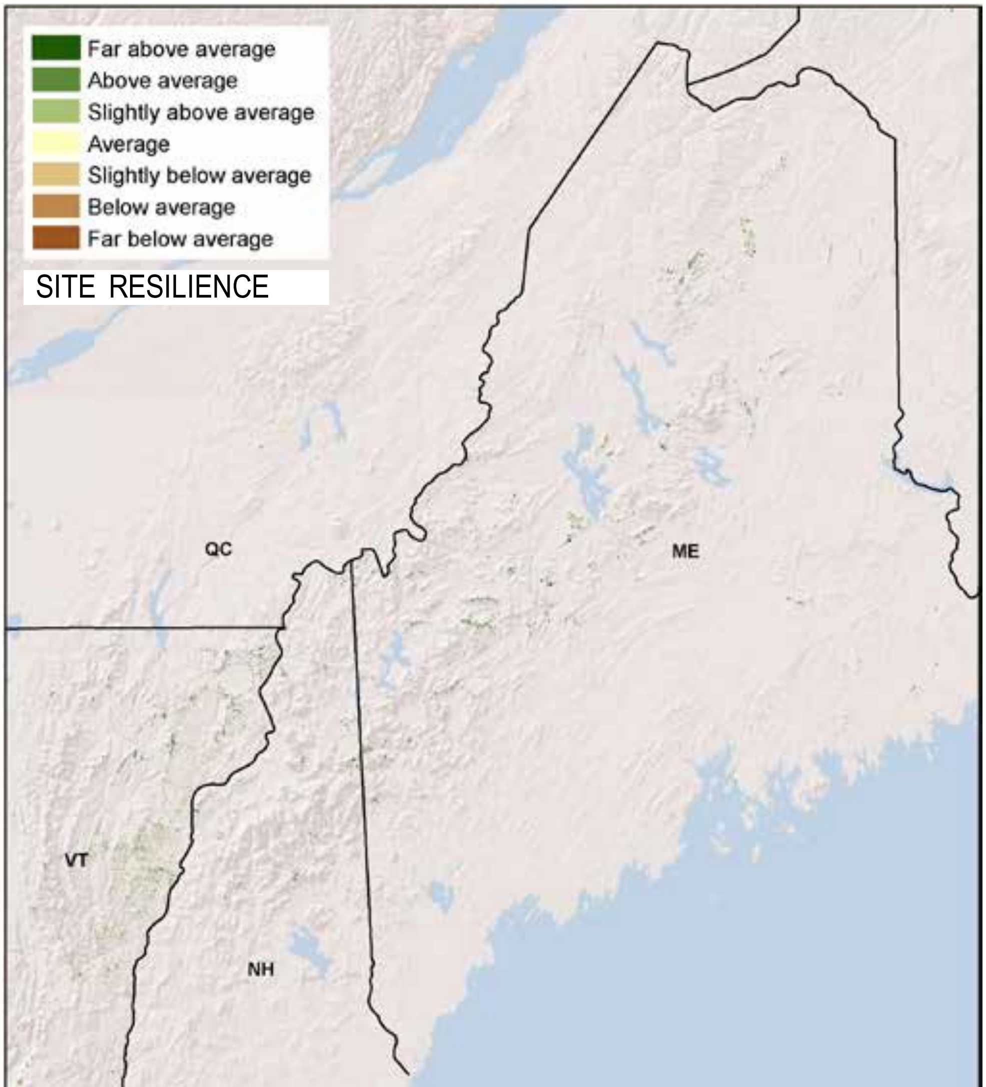
pale-seeded plantain
(*Plantago virginica*)

Agassiz's Kentucky blue grass
(*Poa pratensis* ssp. *agassizensis*)

silvery whitlow-wort
(*Paronychia argyrocoma*)

© George Gress (The Nature Conservancy, Pennsylvania)

Calcareous Rocky Outcrop



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	391	6%	5%	25%	36%	64%
Above average	50%	15,327	7%	10%	23%	40%	60%
Slightly above average	42%	12,955	3%	2%	16%	21%	79%
Average	2%	579	0%	0%	2%	2%	98%
Slightly below average	2%	594	0%	0%	5%	5%	95%
Below average	2%	719	1%	0%	3%	4%	96%
Far below average	0%	96	0%	0%	5%	6%	94%
Developed	0%	86	4%	0%	7%	11%	89%
TOTAL	**100%**	**30,746**	**5%**	**6%**	**19%**	**30%**	**70%**

Resilience & Securement

93% of this habitat scores high for resilience, 30% of the total acreage is secured against conversion, and 11% is protected.

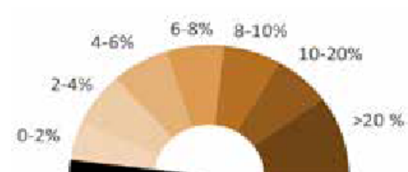
© Maine Natural Areas Program

Description

A sparsely vegetated ridge, summit, dome, or flat plain, composed of circumneutral or calcareous bedrock such as limestone or dolomite. The vegetation is a mosaic of woodlands and open glades. Northern white cedar is characteristic.

Associated Herbs & Shrubs

straw sedge (*Carex foenea*), creeping juniper (*Juniperus horizontalis*), downy arrowwood (*Viburnum rafinesquianum*), bristle-leaved sedge (*Carex eburnea*), four-leaved milkweed (*Asclepias quadrifolia*), fragrant sumac (*Rhus aromatica*), northeastern beardtongue (*Penstemon hirsutus*), hairy honeysuckle (*Lonicera hirsuta*), pale-leaved sunflower (*Helianthus strumosus*), lyre-leaved thale-cress (*Arabis lyrata*), purple virgin's-bower (*Clematis occidentalis*), Richardson's sedge (*Carex richardsonii*)

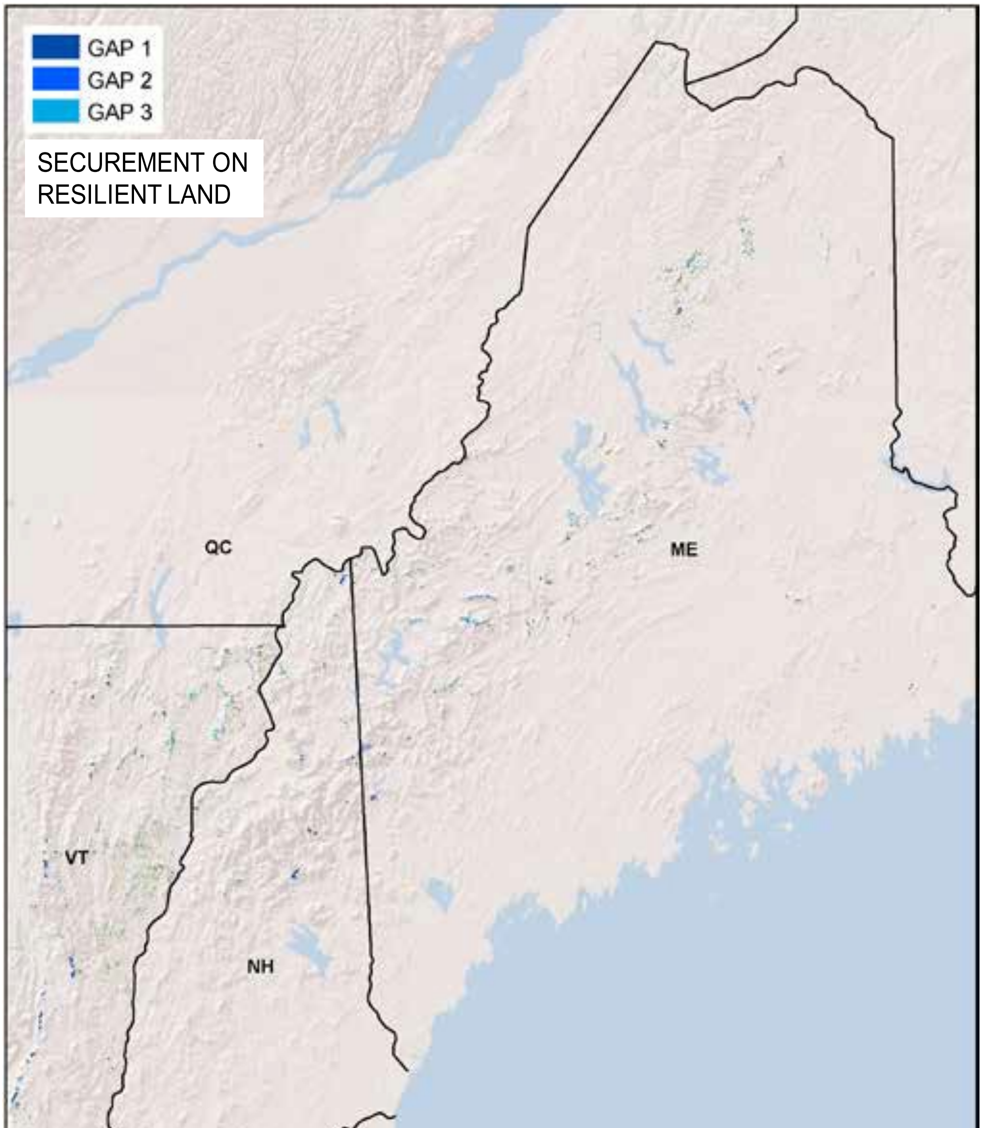


Predicted Loss to Development by 2050

Very low 0%

This community is not threatened by development, with only 98 acres (0%) likely to be lost over the next 30 years.

Calcareous Rocky Outcrop



LOCATION	TOTAL ACRES	% SECURED
New England	30,746	30%
CT		
MA		
ME	10,743	35%
NH	3,018	46%
RI		
VT	16,985	23%

LOCATION	RESILIENT ACRES	% SECURED
New England	28,673	31%
CT		
MA		
ME	10,556	35%
NH	2,856	48%
RI		
VT	15,260	26%

Rare or Uncommon Plants Associated with this Habitat

upswept moonwort
(*Botrychium ascendens*)

prairie moonwort
(*Botrychium campestre*)

Fogg's goosefoot
(*Chenopodium foggii*)

northern blazing star
(*Liatris novae-angliae* var. *novae-angliae*)

sideoats grama
(*Bouteloua curtipendula* var. *curtipendula*)

Carolina whitlow-mustard
(*Draba reptans*)

white flat-topped goldenrod
(*Oligoneuron album*)

stiff flat-topped goldenrod
(*Oligoneuron rigidum* var. *rigidum*)

old-pasture blue grass
(*Poa saltuensis* ssp. *languida*)

small-flowered crowfoot
(*Ranunculus micranthus*)

bristly rose
(*Rosa acicularis* ssp. *sayi*)

little skullcap
(*Scutellaria parvula* var. *parvula*)

pennyroyal bluecurls
(*Trichostema brachiatum*)

rock elm
(*Ulmus thomasii*)

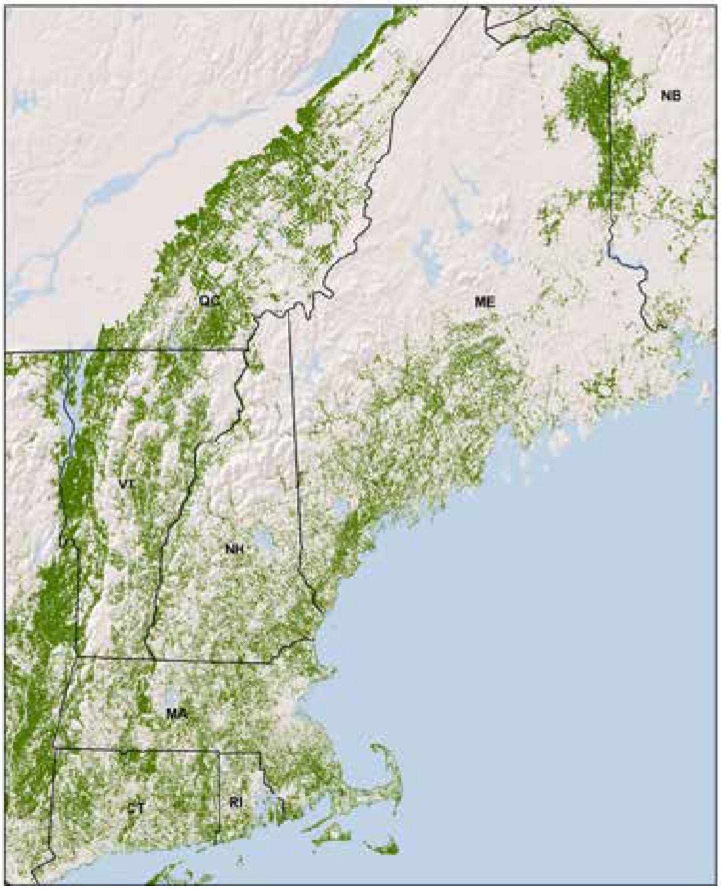
green rockcress
(*Boechera missouriensis*)

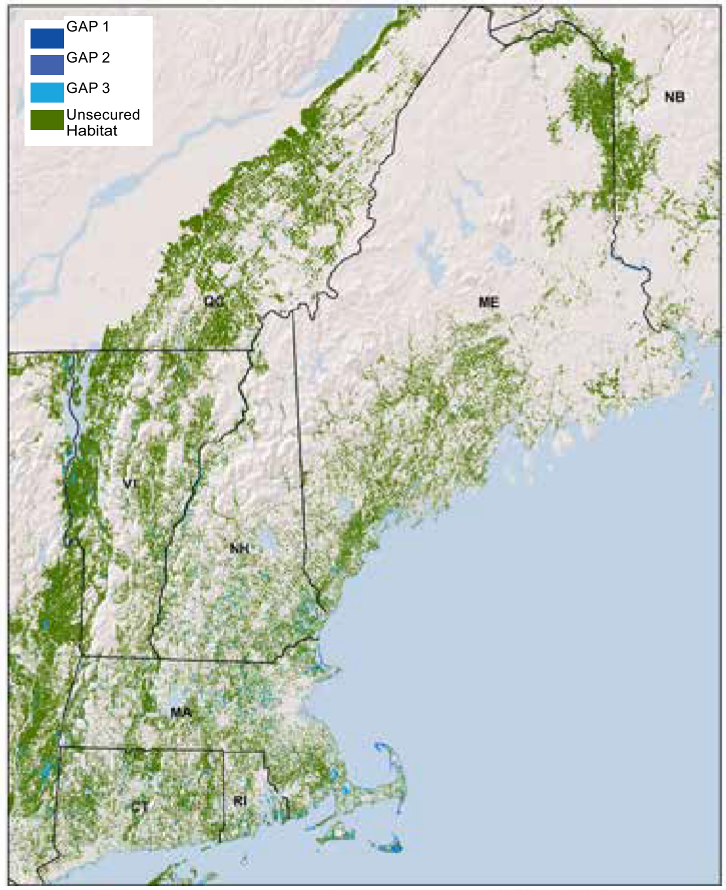
neglected reedgrass
(*Calamagrostis stricta* ssp. *inexpansa*)

Canadian single-spike sedge
(*Carex scirpoidea* ssp. *scirpoidea*)

rock whitlow-mustard
(*Draba arabisans*)

MACROGROUP
GRASSLAND & SHRUBLAND



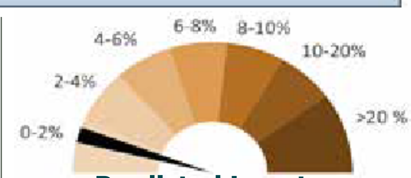


Grassland & Shrubland

Herbaceous communities dominated by grasses and sedges and sparse to dense shrubs. Naturally occurring grasslands are rare and restricted to conditions where soil, fire, or disturbance limits tree growth. This type includes farmland, old fields and agricultural edges, and coastal heathlands.

Acres in New England
2,691,236

Percent Secured
GAP 1 = 0%
GAP 2 = 0%
GAP 3 = 4%



Predicted Loss to Development by 2050
193,318 acres (7%)

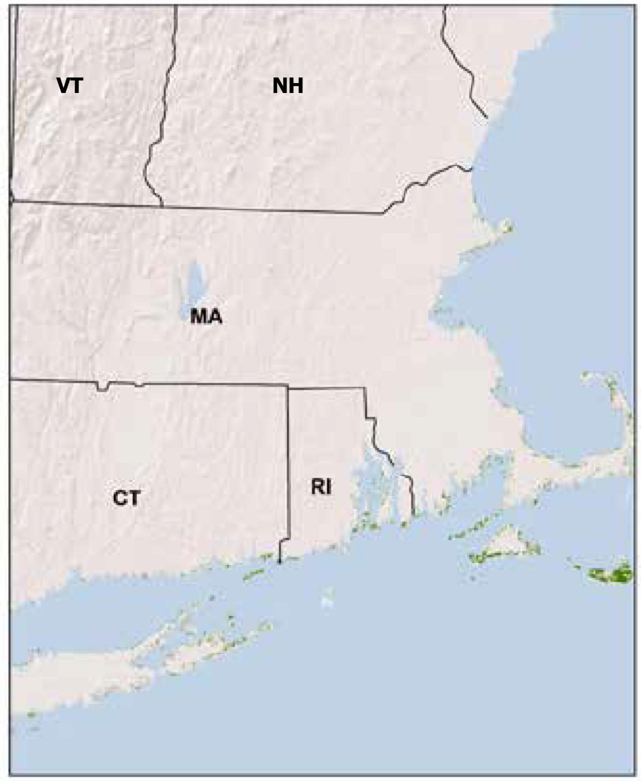
	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS TOTAL	P	S	U
Grassland & Shrubland	**2,691,236**	**0%**	**1%**	**4%**	**95%**	**13**	**1**	**1**	**11**
Connecticut	282,051	0%	2%	4%	95%				
Massachusetts	415,501	1%	3%	9%	87%	9	1	1	7
Maine	832,972	0%	0%	1%	99%	2			2
New Hampshire	261,934	0%	1%	9%	90%				
Rhode Island	51,672	1%	3%	12%	85%				
Vermont	847,105	0%	0%	2%	98%	2			2

New England	**2,691,236**	**6,094**	**26,964**	**103,037**	**2,555,140**

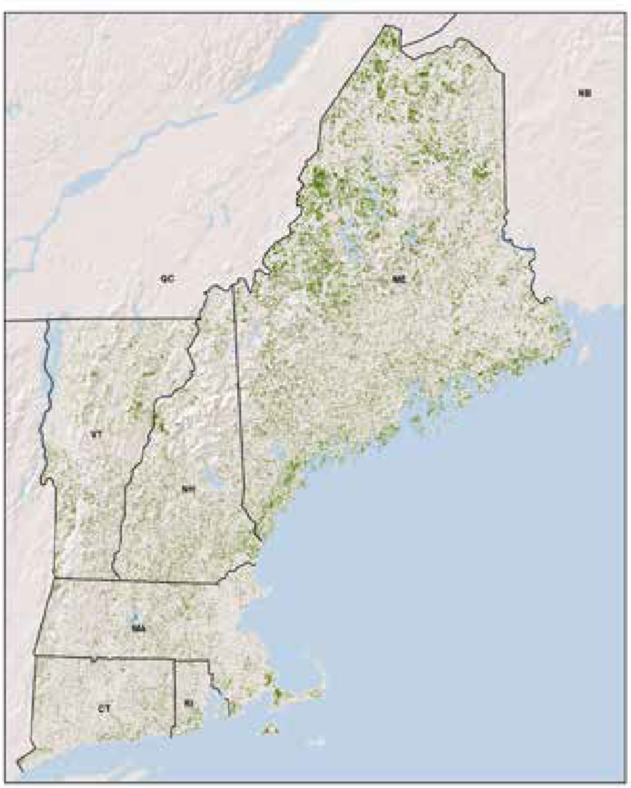
P = Protected S = Secured U = Unsecured

DISTRIBUTION OF HABITATS

Atlantic Coastal Plain Beach & Dune



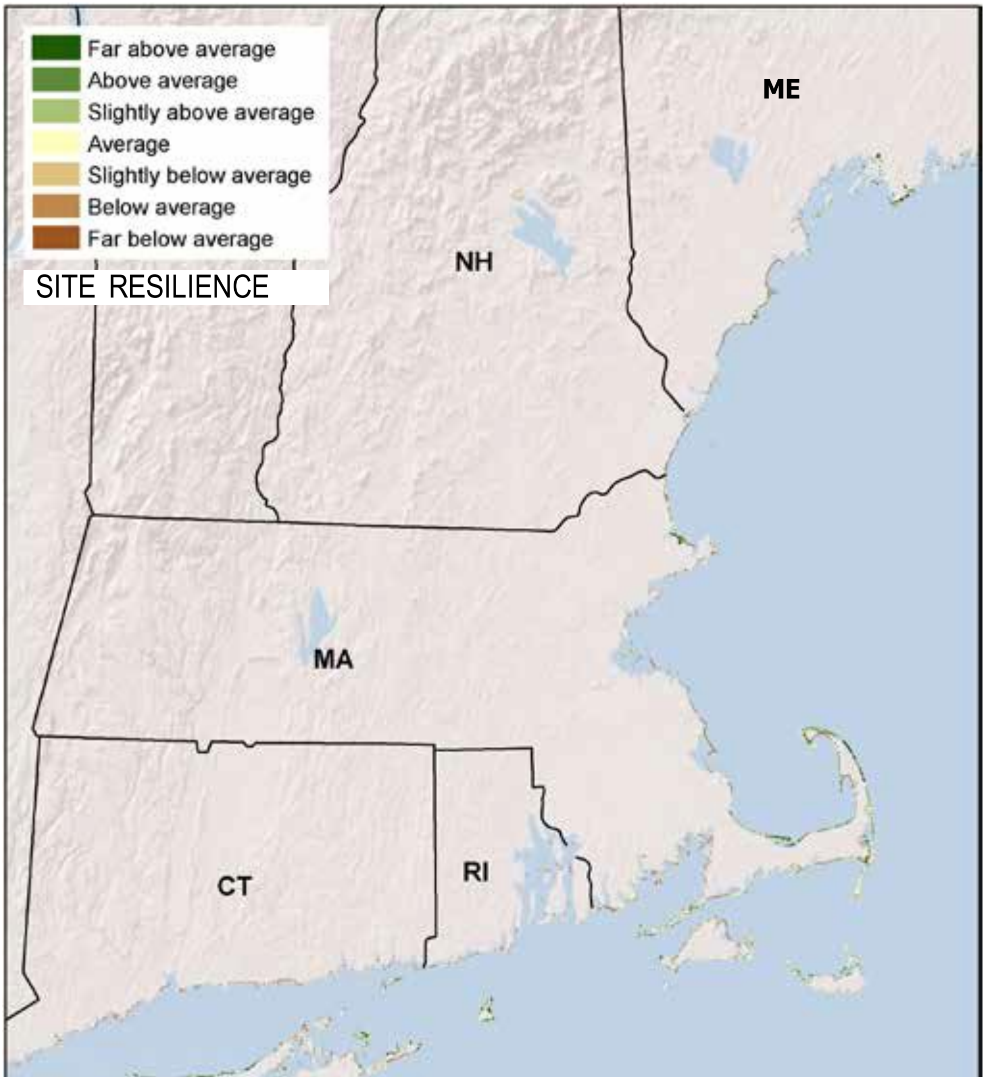
North Atlantic Coastal Plain Heathland & Grassland



Ruderal Grassland & Shrubland

Agricultural Grassland

Atlantic Coastal Plain Beach & Dune



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	3%	953	0%	48%	20%	68%	32%
Above average	16%	5,822	1%	46%	19%	65%	35%
Slightly above average	17%	6,159	1%	35%	14%	49%	51%
Average	27%	9,898	2%	28%	14%	44%	56%
Slightly below average	6%	2,144	3%	23%	13%	38%	62%
Below average	3%	1,118	1%	20%	14%	36%	64%
Far below average	0%	115	0%	16%	24%	40%	60%
Developed	28%	10,276	0%	8%	10%	18%	82%
TOTAL	**100%**	**36,484**	**1%**	**26%**	**14%**	**41%**	**59%**

Resilience & Securement

36% of this habitat scores high for resilience, 41% of the total acreage is secured against conversion, and 27% is protected.

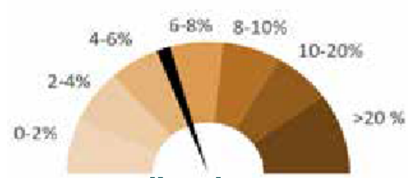
© Kathleen Strakosch Walz
(New Jersey Natural Heritage Program)

Description

A sparsely vegetated beach, dune, or barrier island on unconsolidated sand and shell sediments on the Atlantic coast. Shifting winds and floods largely limit vegetation to pioneering, salt-tolerant grasses and succulents.

Associated Herbs & Shrubs

American beach grass (*Ammophila breviligulata*), American lyme grass (*Leymus mollis* var. *mollis*), saltmarsh rush (*Juncus gerardii*), maritime marsh-elder (*Iva frutescens*), saltgrass (*Distichlis spicata*), smooth cordgrass (*Spartina alterniflora*), saltmarsh hay (*Spartina patens*), Carolina sea-lavender (*Limonium carolinianum*), American sea-rocket (*Cakile edentula*), seaside-sandwort (*Honckenya peploides*), seaside goldenrod (*Solidago sempervirens*), oysterleaf (*Mertensia maritima*), northern bayberry (*Myrica pensylvanica*), poison-ivy (*Toxicodenron radicans*)



Predicted Loss to Development by 2050

Moderate 6%

This community is moderately threatened by development, with 2,646 acres (6%) likely to be lost over the next 30 years.

Atlantic Coastal Plain Beach & Dune

LOCATION	TOTAL ACRES	% SECURED
New England	36,484	41%
CT	2,378	27%
MA	27,104	49%
ME	3,371	14%
NH	743	31%
RI	2,888	17%
VT		

LOCATION	RESILIENT ACRES	% SECURED
New England	12,934	58%
CT	93	52%
MA	11,250	63%
ME	1,021	24%
NH	73	62%
RI	497	24%
VT		

Rare or Uncommon Plants Associated with this Habitat

coastal plain blue-eyed-grass
(*Sisyrinchium fuscatum*)

yellow thistle
(*Cirsium horridulum*)

eastern prickly-pear
(*Opuntia humifusa*)

field wormwood
(*Artemisia campestris* ssp. *caudata*)

velvety rosette-panicgrass
(*Dichanthelium scoparium*)

foxtail bog-clubmoss
(*Lycopodiella alopecuroides*)

ambiguous spikesedge
(*Eleocharis ambigens*)

quill-leaved arrowhead
(*Sagittaria teres*)

bristly smartweed
(*Persicaria setacea*)

Plymouth rose-gentian
(*Sabatia kennedyana*)

Torrey's beaksedge
(*Rhynchospora torreyana*)

narrow-fruited beaksedge
(*Rhynchospora inundata*)

netted nutsedge
(*Scleria reticularis*)

Pursh's blue maidencane
(*Amphicarpum amphicarpon*)

Wright's rosette-panicgrass
(*Dichanthelium wrightianum*)

New England thoroughwort
(*Eupatorium novae-angliae*)

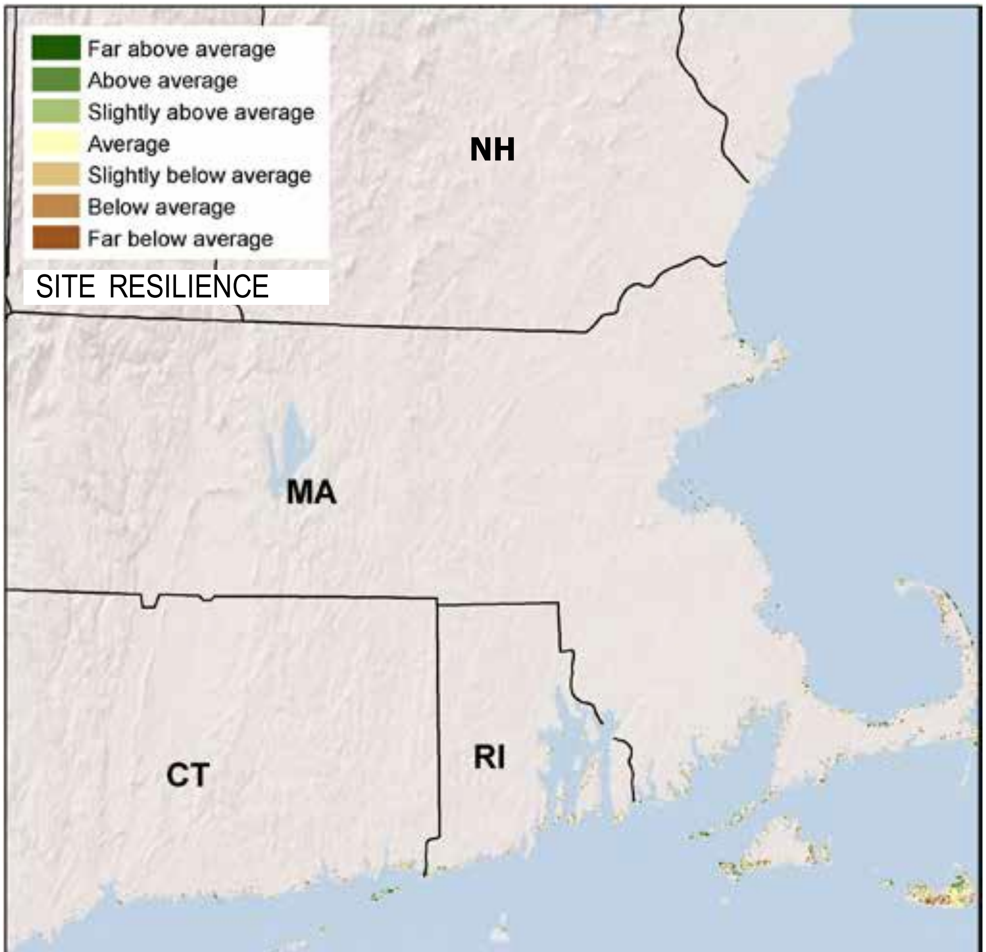
whorled marsh-pennywort
(*Hydrocotyle verticillata*)

thyme-leaved pinweed
(*Lechea minor*)

seaside knotweed
(*Polgyonum glaucum*)

seabeach amaranth
(*Amaranthus pumilus*)

North Atlantic Coastal Plain Heathland & Grassland



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	156	0%	42%	16%	59%	41%
Above average	8%	2,014	1%	17%	19%	37%	63%
Slightly above average	14%	3,491	3%	19%	15%	37%	63%
Average	38%	9,613	3%	25%	14%	42%	58%
Slightly below average	11%	2,729	3%	23%	11%	36%	64%
Below average	7%	1,721	2%	12%	12%	25%	75%
Far below average	2%	411	0%	2%	19%	21%	79%
Developed	20%	5,083	1%	8%	8%	17%	83%
TOTAL	**100%**	**25,219**	**2%**	**18%**	**13%**	**33%**	**67%**

Resilience & Securement

23% of this habitat scores high for resilience, 33% of the total acreage is secured against conversion, and 20% is protected.

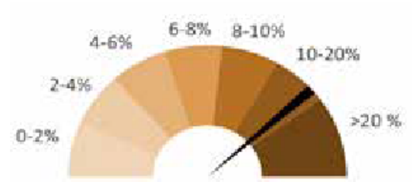
© Ben Kimball (New Hampshire Natural Heritage Bureau)

Description

A heathland/grassland complex of acidic, nutrient-poor, and very well drained soils in coastal areas. The vegetation is maintained by extreme soil conditions and periodic fire or other disturbance. Characteristic species include huckleberry, bearberry, broom crowberry, Nantucket shadbush, goldenheather, blueberry, little bluestem, and Pennsylvania sedge.

Associated Herbs & Shrubs

Abroom crowberry (*Corema conradii*), bushy rockrose (*Helianthemum dumosum*), hyssopleaf hedge-nettle (*Stachys hyssopifolia*), sandplain flax (*Linum intercursum*)



Predicted Loss to Development by 2050

High 18%

This community is highly threatened by development, with more than 4,664 acres (18%) likely to be lost over the next 30 years.

North Atlantic Coastal Plain Heathland & Grassland

LOCATION	TOTAL ACRES	% SECURED
New England	25,219	34%
CT	1,364	28%
MA	20,654	36%
ME		
NH	38	45%
RI	3,163	24%
VT		

LOCATION	RESILIENT ACRES	% SECURED
New England	5,661	38%
CT	182	13%
MA	5,182	39%
ME		
NH	1	0%
RI	296	33%
VT		

Rare or Uncommon Plants Associated with this Habitat

sandplain agalinis
(*Agalinis acuta*)

Nantucket shadbush
(*Amelanchier nantucketensis*)

arrow-feather threeawn
(*Aristida purpurascens*)

butterfly milkweed
(*Asclepias tuberosa*)

eastern silver American-aster
(*Symphyotrichum concolor*)

yellow thistle
(*Cirsium horridulum*)

bushy frowstweed
(*Crocanthemum dumosum*)

tall hairy lettuce
(*Lactuca hirsuta*)

sundial lupine
(*Lupinus perennis*)

Nuttall's milkwort
(*Polygala nuttallii*)

northern blazing star
(*Liatris novae-angliae*)

coastal plain blue-eyed-grass
(*Sisyrinchium fuscatum*)

spring ladies-tresses
(*Spiranthes vernalis*)

thyme-leaved pinweed
(*Lechea minor*)

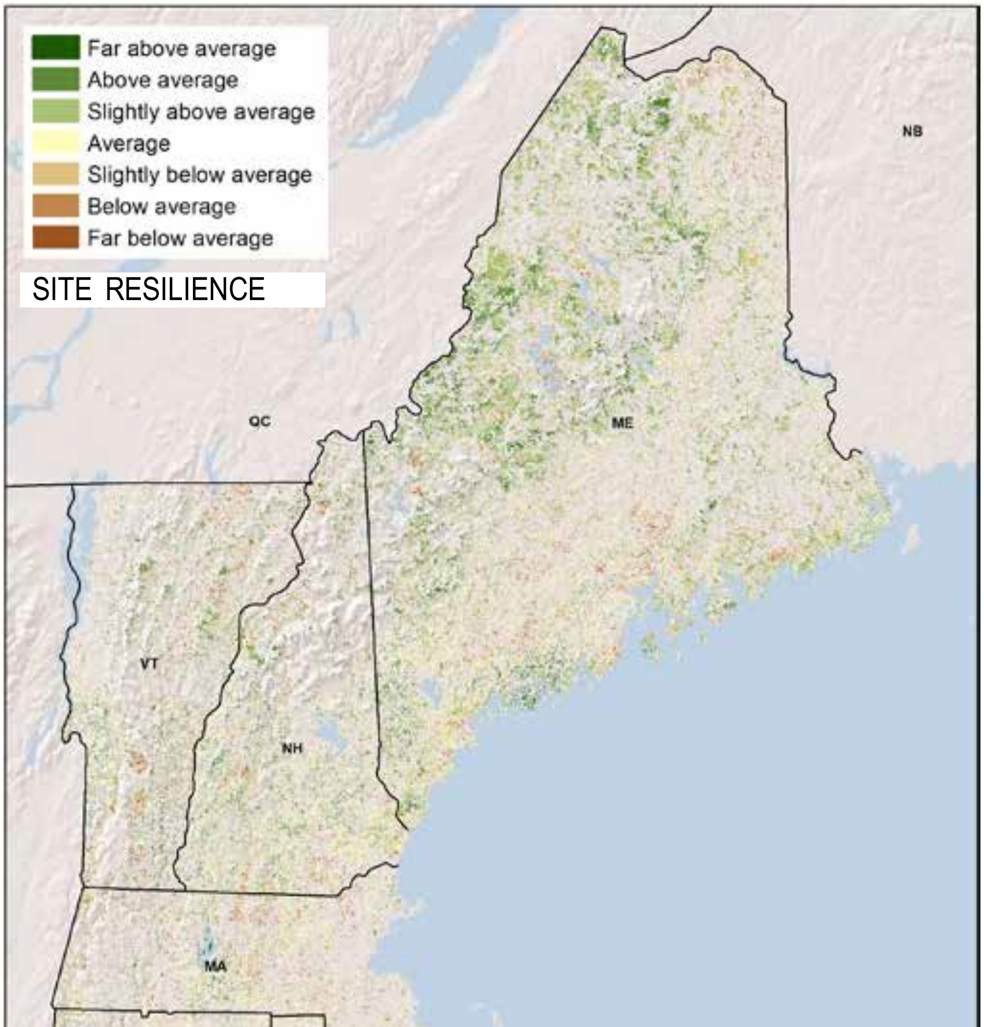
post oak
(*Quercus stellata*)

broom-crowberry
(*Corema conradii*)

multi-stemmed St. John's-wort
(*Hypericum stragulum*)

lion's-foot rattlesnake-root
(*Nabalus serpentarius*)

Ruderal Grassland & Shrubland



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	2%	941	4%	4%	10%	17%	83%
Above average	10%	5,148	2%	2%	11%	15%	85%
Slightly above average	14%	7,570	2%	2%	9%	13%	87%
Average	34%	18,242	2%	2%	15%	18%	82%
Slightly below average	10%	5,455	2%	1%	20%	23%	77%
Below average	7%	3,694	2%	1%	22%	25%	75%
Far below average	1%	718	1%	0%	18%	19%	81%
Developed	21%	11,174	0%	1%	5%	6%	94%
TOTAL	**100%**	**52,942**	**2%**	**1%**	**13%**	**16%**	**84%**

Resilience & Securement

26% of this habitat scores high for resilience, 16% of the total acreage is secured against conversion, and 3% is protected.

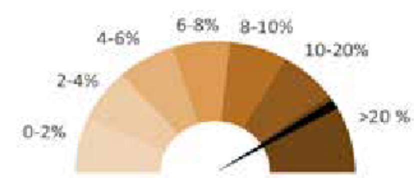
© Ken Lund (Flickr Creative Commons)

Description

Abandoned, marginal, or recovering agricultural land and/or pastures. Ruderal communities may be found interspersed with working farmlands. The vegetation is dominated by a mix of native and non- native grasses and herbs, with shrub cover becoming more extensive the longer the time since abandonment.

Associated Herbs & Shrubs

common milkweed (*Asclepias syriaca*), common strawberry (*Fragaria virginiana*), common grass-leaved-goldenrod (*Euthamia graminifolia*), common evening-primrose (*Oenethera biennis*), Canada goldenrod (*Solidago canadensis*), common wrinkle-leaved goldenrod (*Solidago rugosa*), New England American-aster (*Symphyotrichum novae-angliae*), staghorn sumac (*Rhus hirta*), smooth sumac (*Rhus glabra*), silky dogwood (*Swida amomum*), eastern red cedar (*Juniperus virginiana*)

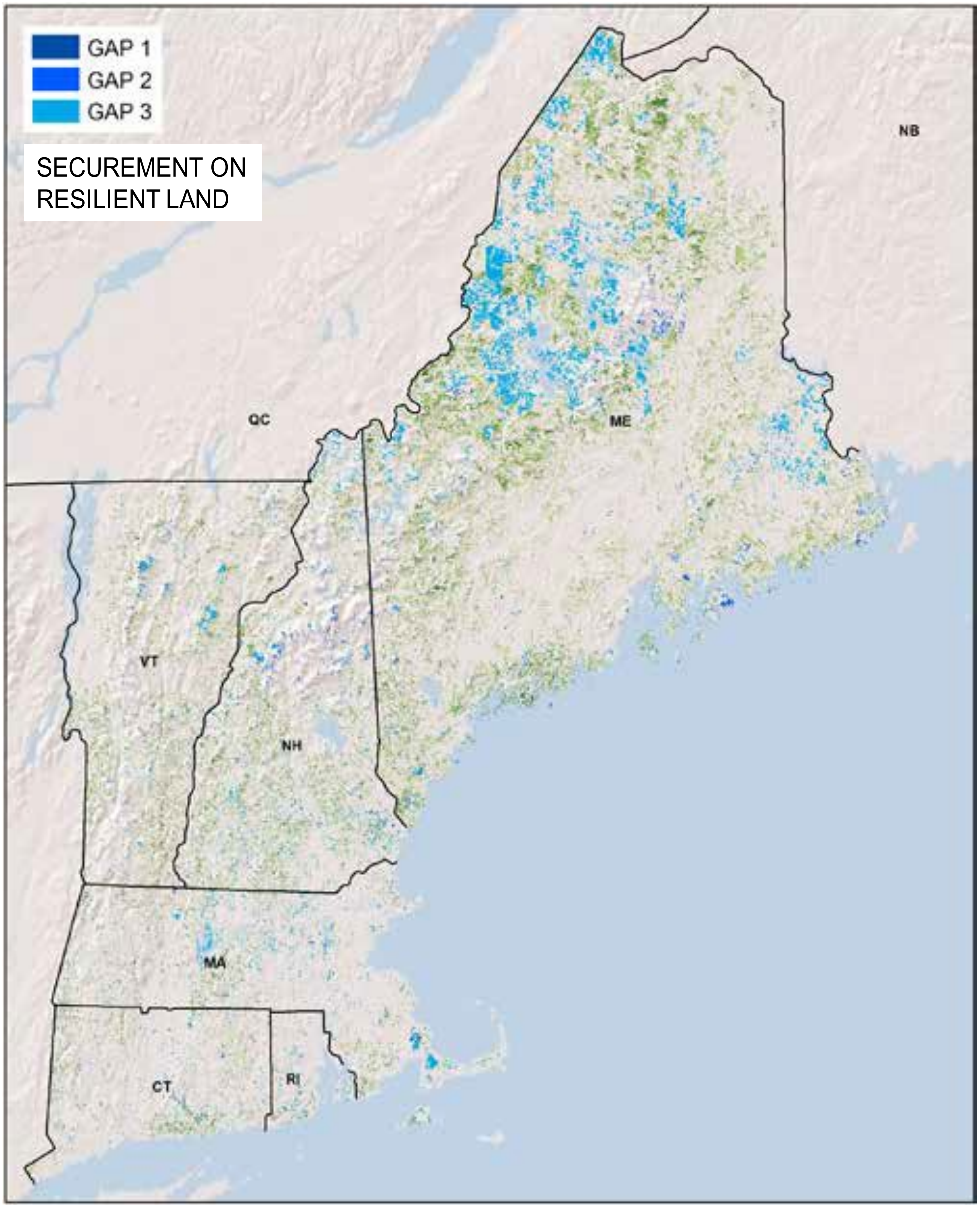


Predicted Loss to Development by 2050

Very high 23%

This community is highly threatened by development, with more than 11,960 acres (23%) likely to be lost over the next 30 years.

Ruderal Grassland & Shrubland



LOCATION	TOTAL ACRES	% SECURED
New England	52,942	16%
CT	5,089	5%
MA	17,992	29%
ME	22,569	8%
NH	4,106	12%
RI	3,185	17%
VT		

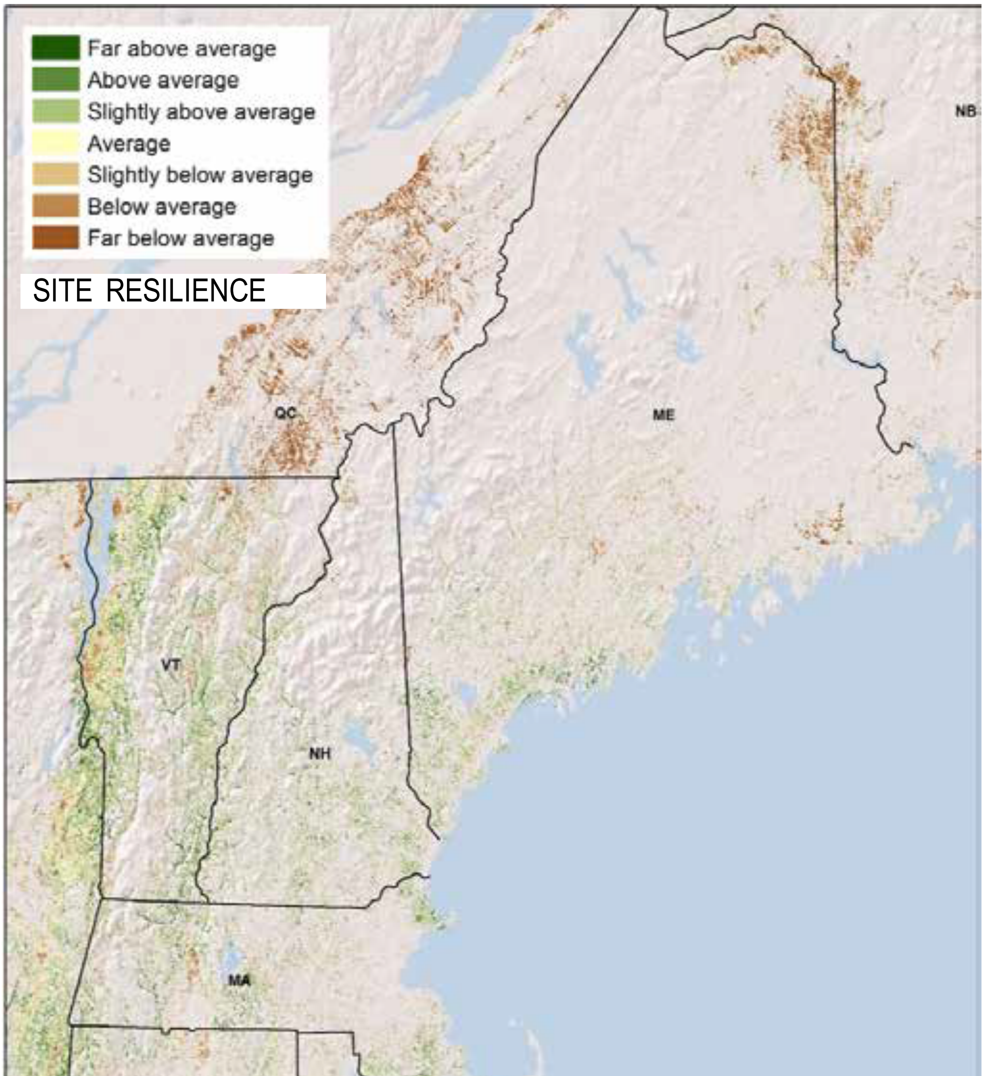
LOCATION	RESILIENT ACRES	% SECURED
New England	13,659	14%
CT	1,246	9%
MA	3,019	25%
ME	8,282	10%
NH	594	25%
RI	518	13%
VT		

Rare or Uncommon Plants Associated with this Habitat

upswept moonwort
(*Botrychium ascendens*)

common moonwort
(*Botrychium lunaria*)

Agricultural Grassland



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	0%	12,809	2%	1%	6%	9%	91%
Above average	4%	104,324	1%	1%	6%	8%	92%
Slightly above average	12%	318,172	0%	1%	5%	6%	94%
Average	30%	766,321	0%	1%	4%	5%	95%
Slightly below average	17%	445,204	0%	0%	3%	3%	97%
Below average	19%	479,378	0%	0%	2%	3%	97%
Far below average	5%	128,286	0%	0%	2%	2%	98%
Developed	13%	322,096	0%	0%	2%	3%	97%
TOTAL	**100%**	**2,576,591**	**0%**	**0%**	**3%**	**4%**	**96%**

Resilience & Securement

16% of this habitat scores high for resilience, but only 4% of the total acreage is securedagainst conversion. The data do not include farmland under conservation easement.

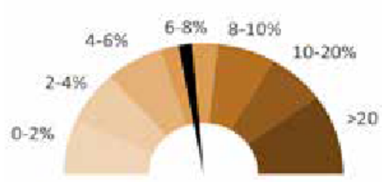
© Barbara Slavin (Flickr Creative Commons)

Description

An agricultural field planted in row crops(corn, potatoes, and soybean), field crops(alfalfa, wheat, timothy, and oat), or hay. This also includes land permanently maintained (or recently abandoned) as a pasture area.

Associated Herbs & Shrubs

common Timothy (*Phleum pratense*), slender meadow-foxtail (*Alopecurus pratensis*), poverty grass (*Danthonia spicata*), little bluestem (*Schizachyrium scoparium*), common wrinkle-leaved goldenrod (*Solidago rugosa*), Canada goldenrod (*Solidago canadensis*), common milkweed (*Asclepias syriaca*), Pennsylvania sedge (*Carex pensylvanica*)



Predicted Loss to Development by 2050

Moderate 7%

About 174,048 acres (7%) are likely to be lost over the next 30 years. Many farms have conservation easements that prevent their conversion; these are not included in the secured lands dataset.

Agricultural Grassland

LOCATION	TOTAL ACRES	% SECURED
New England	2,576,591	4%
CT	273,220	5%
MA	349,751	8%
ME	807,032	1%
NH	257,047	10%
RI	42,435	15%
VT	847,105	2%

LOCATION	RESILIENT ACRES	% SECURED
New England	435,305	6%
CT	35,386	8%
MA	60,482	12%
ME	78,902	4%
NH	62,522	13%
RI	5,340	16%
VT	192,673	3%

Rare or Uncommon Plants Associated with this Habitat

straw sedge
(*Carex foenea*)

creeping juniper
(*Juniperus horizontalis*)

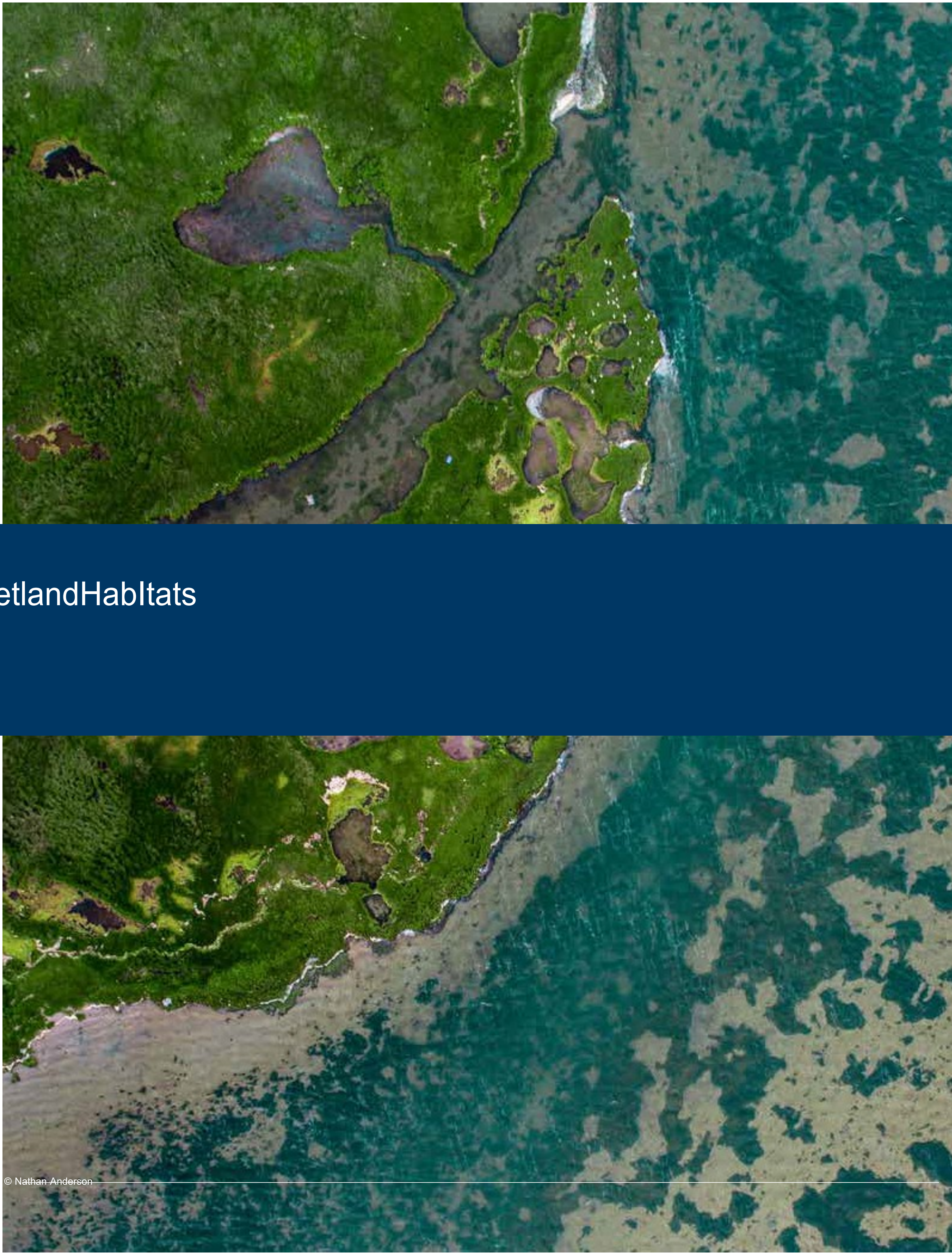
downy arrowwood
(*Viburnum rafinesquianum*)

bristle-leaved sedge
(*Carex eburnea)*

butterfly milkweed
(*Asclepias tuberosa*)

sundial lupine
(*Lupinus perennis*)

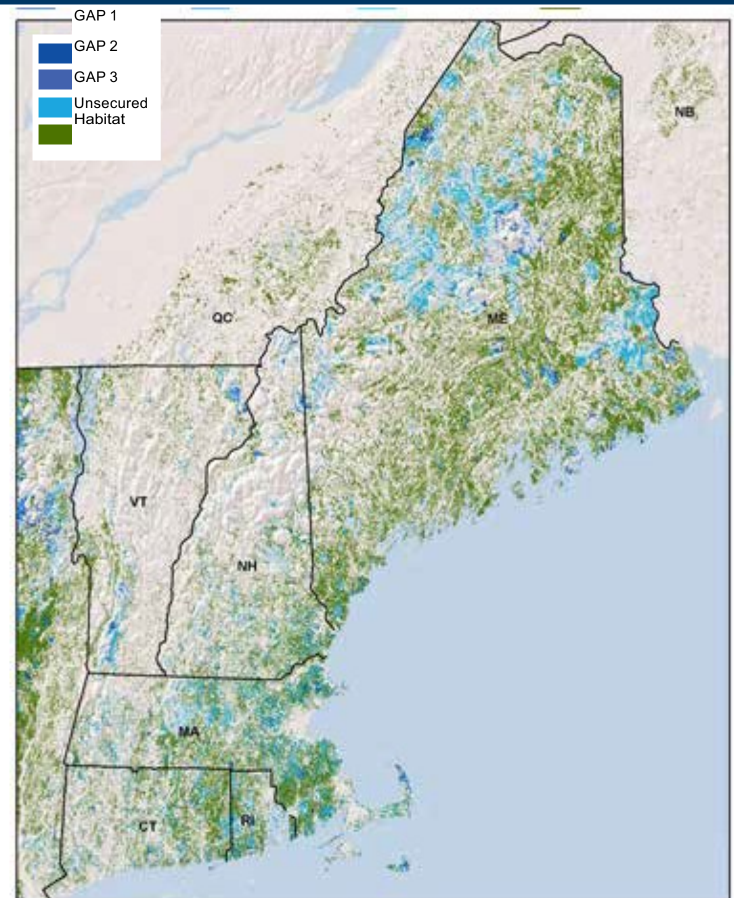
vetlandHabItats



© Nathan Anderson

MACROGROUP

'ORTHERN SWAMP



Northern Swamp
Conifer or mixed forested swamps of permanently saturated basins with seasonal standing water.

Acres in New England
2.2 million

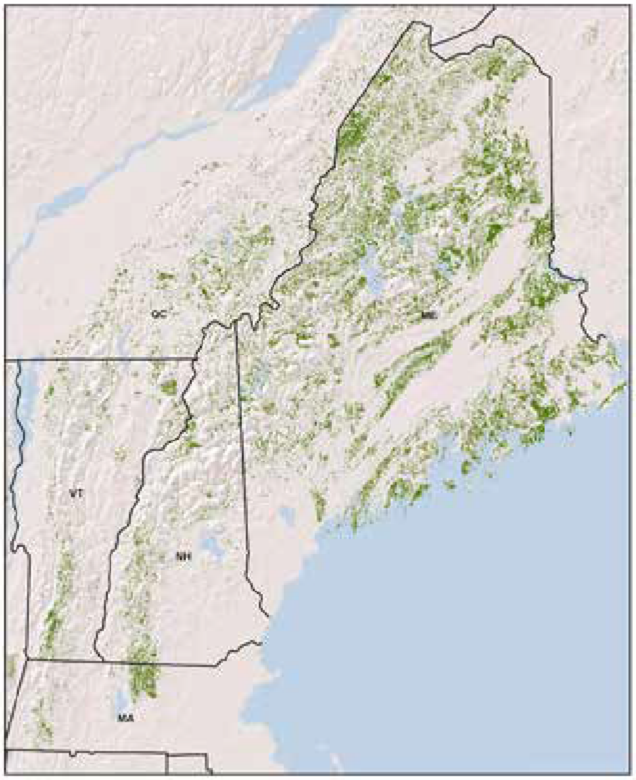
Percent Secured
GAP 1 = 2%
GAP 2 = 3%
GAP 3 = 17%

Predicted Loss to Development by 2050
66,414 acres (3%)

	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS			
						TOTAL	P	S	U
Northern Swamp	**2,195,240**	**2%**	**3%**	**17%**	**77%**	**11**		**2**	**9**
Connecticut	173,279	1%	5%	15%	79%	1			1
Massachusetts	399,178	2%	3%	25%	70%	6		2	4
Maine	1,270,481	2%	2%	15%	81%	1			1
New Hampshire	167,020	3%	4%	19%	74%				
Rhode Island	72,999	3%	7%	20%	71%	3			3
Vermont	112,283	5%	4%	18%	74%				
New England	**2,195,240**	**47,668**	**64,577**	**381,708**	**1,701,287**				

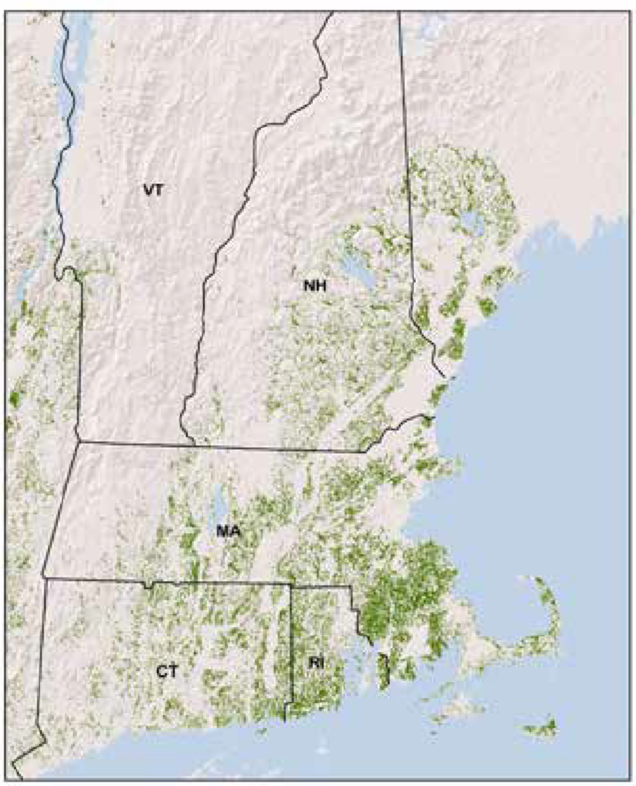
P = Protected S = Secured U = Unsecured

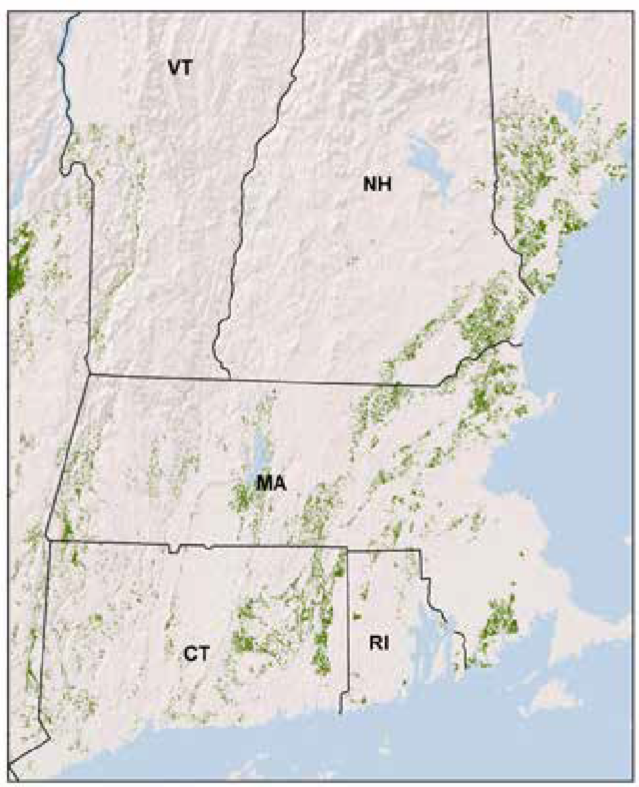
DISTRIBUTION OF HABITATS



NORTHERN | **Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp**

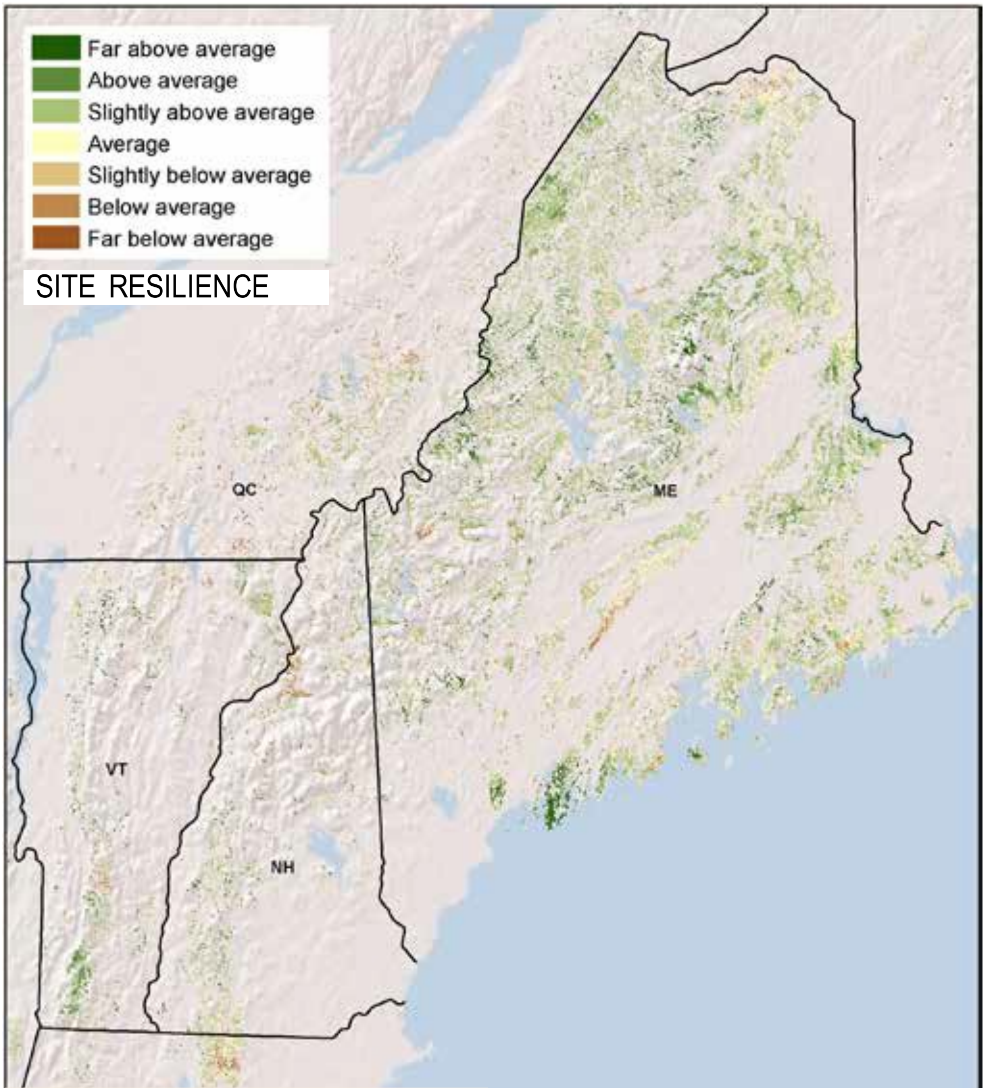
NORTHERN | **Laurentian-Acadian Alkaline Conifer-Hardwood Swamp**





SOUTHERN | **North-Central Interior & Appalachian Rich Swamp**

Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	5,291	13%	5%	16%	33%	67%
Above average	14%	106,926	9%	4%	23%	35%	65%
Slightly above average	54%	409,013	3%	2%	23%	29%	71%
Average	17%	132,211	1%	1%	11%	14%	86%
Slightly below average	7%	55,575	1%	3%	17%	21%	79%
Below average	4%	31,630	1%	4%	13%	18%	82%
Far below average	0%	3,386	1%	1%	8%	11%	89%
Developed	2%	17,480	1%	2%	13%	16%	84%
TOTAL	**100%**	**761,511**	**4%**	**3%**	**20%**	**26%**	**74%**

Resilience & Securement

69% of this habitat scores high for resilience, 26% of the total acreage is secured against conversion, and 7% is protected.

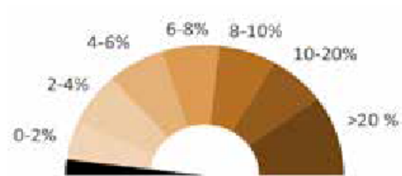
© Maine Natural Areas Program

Description

A conifer or mixed forested swamp of permanently saturated basins with seasonal standing water. Peat soils tend to support black spruce and larch, while mineral soils often include red maple, red spruce and balsam fir.

Associated Herbs & Shrubs

greater water-starwort (*Callitriche heterophylla*), large-leaved avens (*Geum macrophyllum*), northern spicebush (*Lindera benzoin)*, swamp lousewort (*Pedicularis lanceolata*), small-flowered-saxifrage (*Saxifraga pensylvanica*), mosses (*Calliergon obtusifolium, Calliergon richardsonii*)

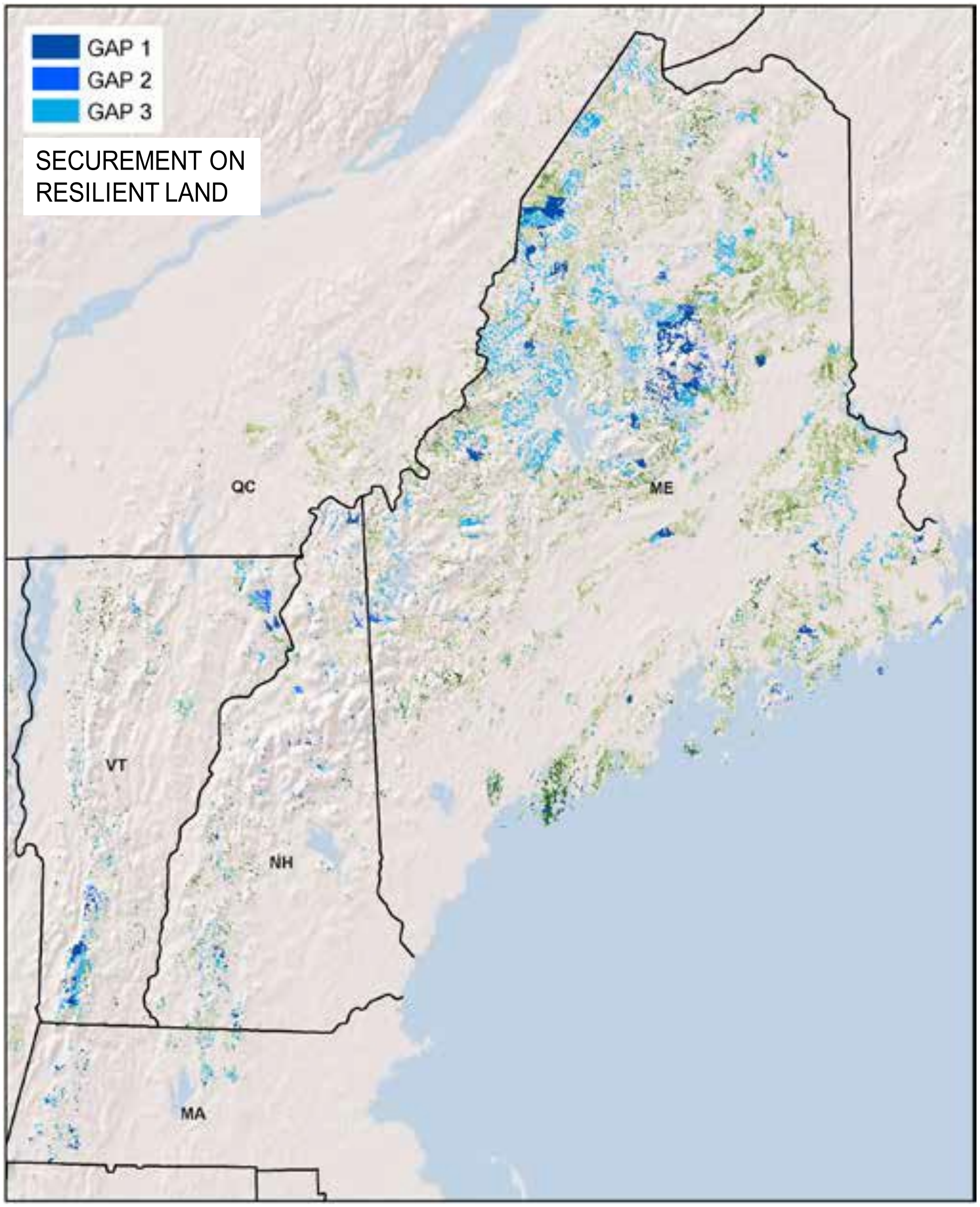


Predicted Loss to Development by 2050

Very low 0%

This community is not threatened by development, with 3,680 acres (0%) likely to be lost over the next 30 years.

Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp



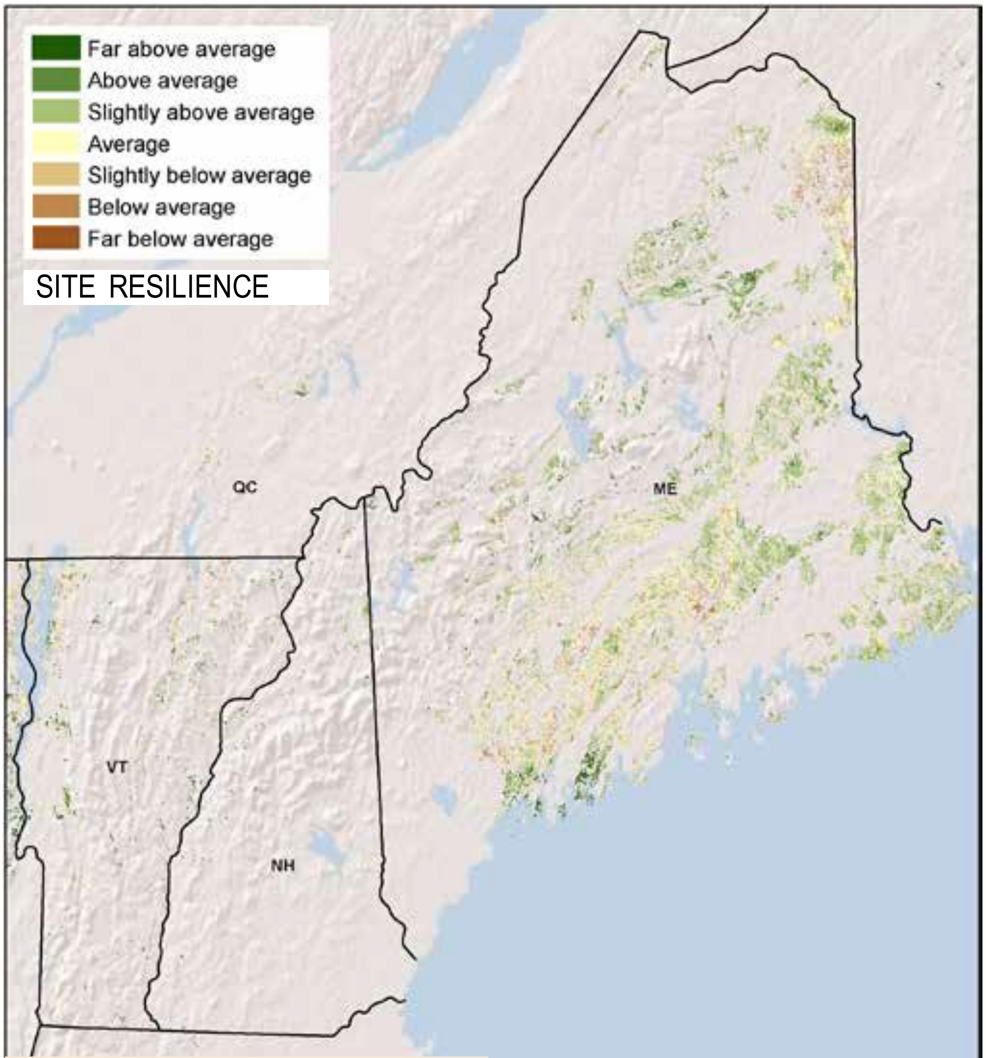
LOCATION	TOTAL ACRES	% SECURED
New England	761,511	26%
CT	218	7%
MA	26,596	44%
ME	639,804	23%
NH	45,741	33%
RI		
VT	49,153	44%

LOCATION	RESILIENT ACRES	% SECURED
New England	521,230	30%
CT	211	7%
MA	9,834	57%
ME	449,498	27%
NH	26,546	40%
RI		
VT	35,141	55%

Rare or Uncommon Plants Associated with this Habitat

slender beadgrass
(*Paspalum setaceum* var. *psammophilum*)

Laurentian-Acadian Alkaline Conifer-Hardwood Swamp




© Elizabeth Thompson (Vermont Land Trust)

Description

A forested swamp of alkaline wetlands associated with limestone or other calcareous substrate. Northern white cedar may dominate the canopy or be mixed with other conifers and hardwoodslike red maple or black ash. Red-osier dogwood is a common shrub.

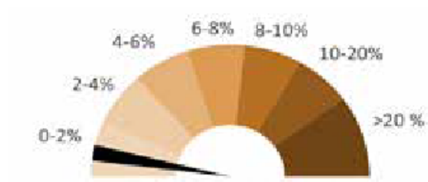
Associated Herbs & Shrubs

bog aster (*Oclemena nemoralis*), fairy-slipper (*Calypso bulbosa*), green adder's-mouth (*Malaxis unifolia*), sage-willow (*Salix candida*), Lapland-crowfoot (*Coptidium lapponicum*), Loesel's wide-lipped orchid (*Liparis loeselii*), pink shinleaf (*Pyrola asarifolia*), swamp thistle (*Cirsium muticum*), Virginia screwstem (*Bartonia virginica*), greater yellow water-crowfoot (*Ranunculus flabellaris*), fen mosses (*Calliergon* spp., *Meesia triquetra*, etc.)

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	0%	2,359	2%	5%	11%	18%	82%
Above average	9%	52,923	2%	4%	16%	21%	79%
Slightly above average	46%	264,129	2%	3%	18%	22%	78%
Average	26%	150,800	1%	2%	7%	10%	90%
Slightly below average	11%	61,218	0%	2%	5%	7%	93%
Below average	5%	27,019	1%	3%	6%	9%	91%
Far below average	0%	1,693	1%	0%	6%	7%	93%
Developed	2%	13,826	0%	2%	7%	9%	91%
TOTAL	**100%**	**573,968**	**1%**	**3%**	**13%**	**17%**	**83%**

Resilience & Securement

45% of this habitat scores high for resilience, 17% of the total acreage is secured against conversion, and 4% is protected.

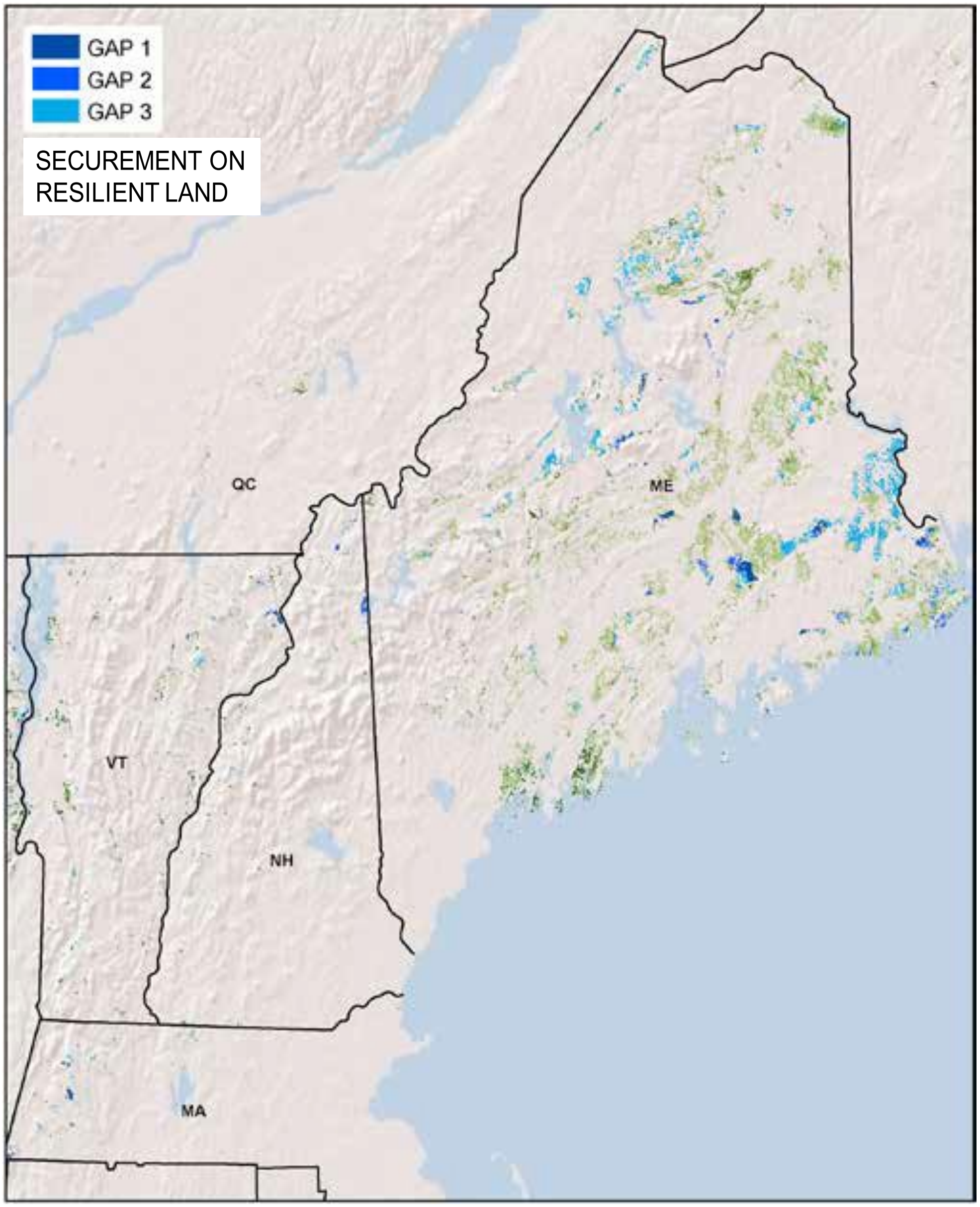


Predicted Loss to Development by 2050

Very low 1%

This community is little threatened by development, with 5,531 acres (1%) likely to be lost over the next 30 years.

Laurentian-Acadian Alkaline Conifer-Hardwood Swamp



LOCATION	TOTAL ACRES	% SECURED
New England	573,968	16%
CT	86	0%
MA	4,253	46%
ME	518,316	16%
NH	7,330	42%
RI		
VT	43,985	14%

LOCATION	RESILIENT ACRES	% SECURED
New England	319,412	22%
CT	36	0%
MA	2,556	52%
ME	295,248	21%
NH	4,781	45%
RI		
VT	16,791	21%

© Charles Ferree (The Nature Conservancy)

Rare or Uncommon Plants Associated with this Habitat

ram's-head lady's-slipper (*Cypripedium arietinum*)

auricled twayblade (*Neottia auriculata*)

bog Jacob's-ladder (*Polemonium vanbruntiae*)

round-leaved orchid (*Amerorchis rotundifolia*)

northern bog sedge (*Carex gynocrates*)

sparse-flowered sedge (*Carex tenuiflora*)

yellow lady's-slipper (*Cypripedium parviflorum* var. *makasin*)

lesser yellow water crowfoot (*Ranunculus gmelinii*)

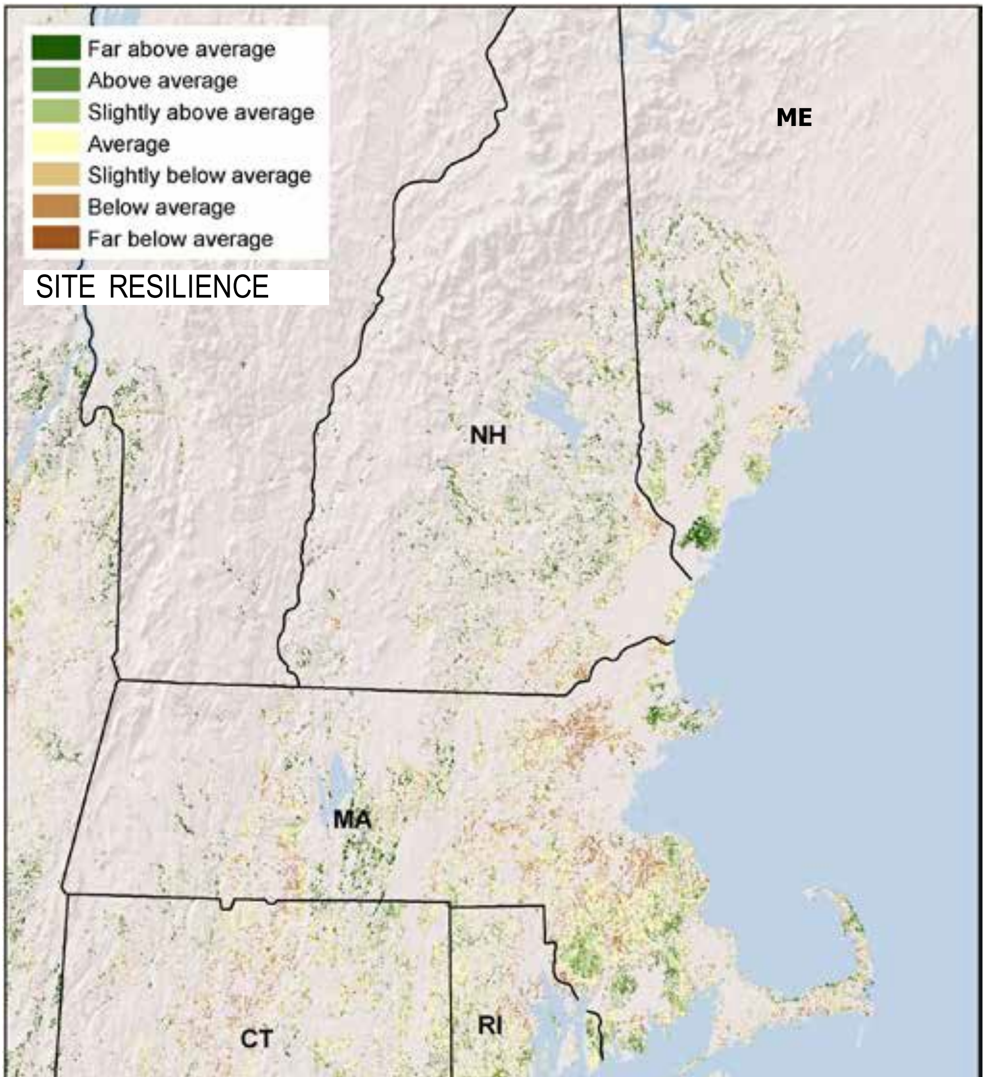
needle beak-sedge (*Rhynchospora capillacea*)

northern spikemoss (*Selaginella selaginoides*)

marsh valerian (*Valeriana uliginosa*)

white adder's-mouth (*Malaxis monophyllos* ssp. *brachypoda*)

North-Central Appalachian Acidic Swamp



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	0%	6,842	2%	5%	32%	39%	61%
Above average	5%	85,295	2%	5%	23%	31%	69%
Slightly above average	11%	148,072	2%	4%	21%	27%	73%
Average	36%	242,192	1%	4%	19%	24%	76%
Slightly below average	16%	48,501	1%	3%	19%	23%	77%
Below average	15%	29,550	1%	1%	19%	21%	79%
Far below average	3%	3,665	0%	1%	14%	15%	85%
Developed	14%	44,112	1%	2%	11%	13%	87%
TOTAL	**100%**	**608,230**	**2%**	**4%**	**20%**	**26%**	**74%**

Resilience & Securement

16% of this habitat scores high for resilience, 26% of the total acreage is secured against conversion, and 6% is protected.

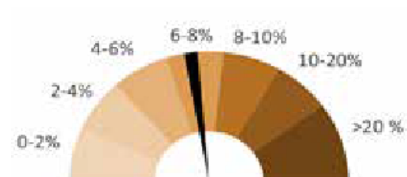
© Shane Gebauer (New York Natural Heritage Program)

Description

A conifer or mixed conifer-hardwood swamp of poorly drained acidic substrates, encompassing a broad range of basin, seepage, and stream-associated wetland communities. Hemlock may be dominant, along with red maple or black gum.

Associated Herbs & Shrubs

bog-rosemary (*Andromeda polifolia* var. *glaucophylla*), boreal bog sedge (*Carex magellanica*), Canada lily (*Lilium canadense*), Labrador-tea (*Ledum groenlandicum*), creeping snowberry (*Gaultheria hispidula*), hairy hedge-nettle (*Stachys pilosa*), hairy-stemmed gooseberry (*Ribes hirtellum*), swamp dock (*Rumex verticillatus*), sweetgale (*Myrica gale*)

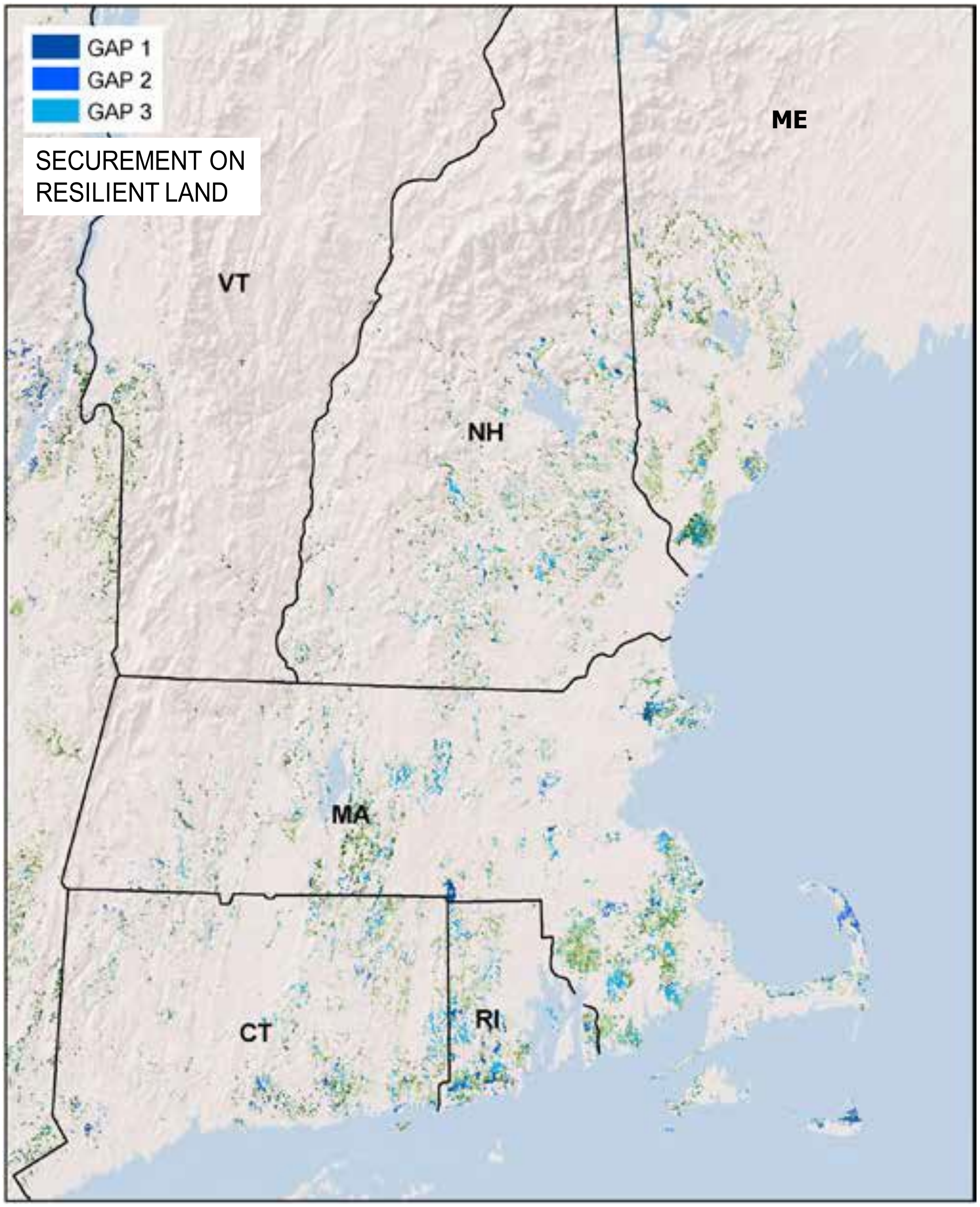


Predicted Loss to Development by 2050

Moderate 7%

This community is somewhat threatened by development, with 43,405 acres (7%) likely to be lost over the next 30 years.

North-Central Appalachian Acidic Swamp



LOCATION	TOTAL ACRES	% SECURED
New England	608,230	25%
CT	111,732	22%
MA	271,609	29%
ME	61,573	13%
NH	85,738	23%
RI	67,364	30%
VT	10,214	7%

LOCATION	RESILIENT ACRES	% SECURED
New England	608,230	25%
CT	111,732	22%
MA	271,609	29%
ME	61,573	13%
NH	85,738	23%
RI	67,364	30%
VT	10,214	7%


© Hal Malde

Rare or Uncommon Plants Associated with this Habitat

southern lady fern
(*Athyrium asplenioides*)

blunt-lobed grapefern
(*Botrychium oneidense*)

Collins' sedge
(*Carex collinsii*)

Mitchell's sedge
(*Carex mitchelliana*)

forked rosette-panicgrass
(*Dichanthelium dichotomum* ssp. *mattamuskeetense*)

sweet-gum
(*Liquidambar styraciflua*)

many-fruited water-primrose
(*Ludwigia polycarpa*)

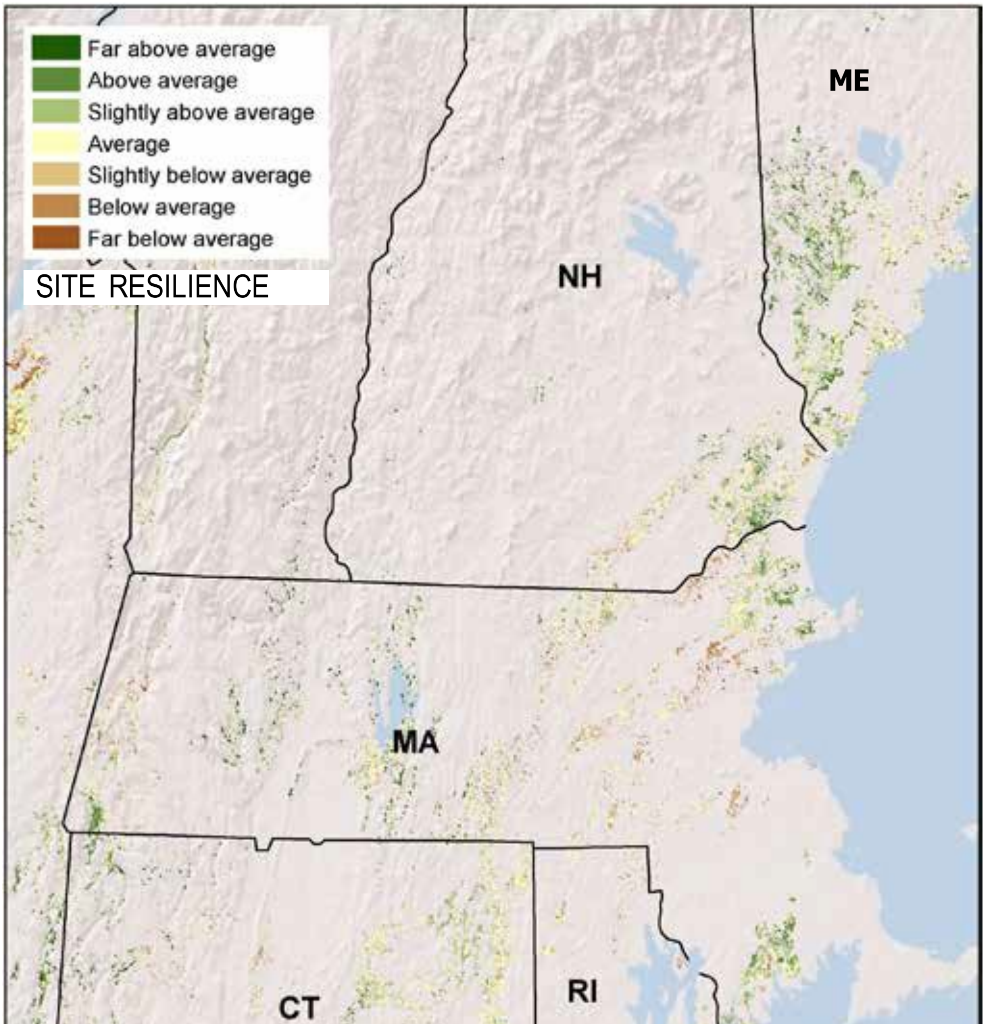
stalked water-horehound
(*Lycopus rubellus*)

sweet-bay
(*Magnolia virginiana* ssp. *virginiana*)

orange fringed bod-orchid
(*Platanthera ciliaris*)

water-plantain crowfoot
(*Ranunculus ambigens*)

North-Central Interior & Appalachian Rich Swamp



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	3,705	5%	4%	23%	32%	68%
Above average	17%	42,458	4%	3%	17%	24%	76%
Slightly above average	25%	64,044	2%	3%	17%	23%	77%
Average	39%	98,535	1%	3%	15%	19%	81%
Slightly below average	6%	16,054	1%	4%	16%	20%	80%
Below average	4%	9,153	1%	3%	15%	18%	82%
Far below average	0%	1,231	0%	1%	9%	10%	90%
Developed	7%	16,351	1%	2%	8%	10%	90%
TOTAL	**100%**	**251,531**	**2%**	**3%**	**16%**	**21%**	**79%**

Resilience & Securement

43% of this habitat scores high for resilience, 21% of the total acreage is secured against conversion, and 5% is protected.

© Elizabeth Thompson (Vermont Land Trust)

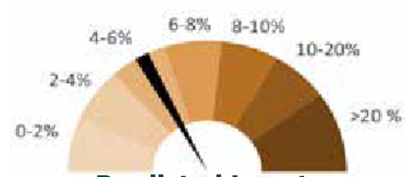
Description

A hardwood or mixed swamp of alkaline wetlands associated with limestone or other calcareous substrate. Red maple and black ash are generally dominant, and conifers may include larch. A diverse ground cover is made up of herbs indicative of nutrient-rich conditions, ferns, and bryophytes characteristic

offens.

Associated Herbs & Shrubs

bunchberry (*Chamaepericlymenum canadense*), four-flowered yellow-loosestrife (*Lysimachia quadriflora*), naked bishop's-cap (*Mitella nuda*), water avens (*Geum rivale*), rough-leaved goldenrod (*Solidago patula*), showy lady's-slipper (*Cypripedium reginae*), yellow-green sedge (*Carex flava*)

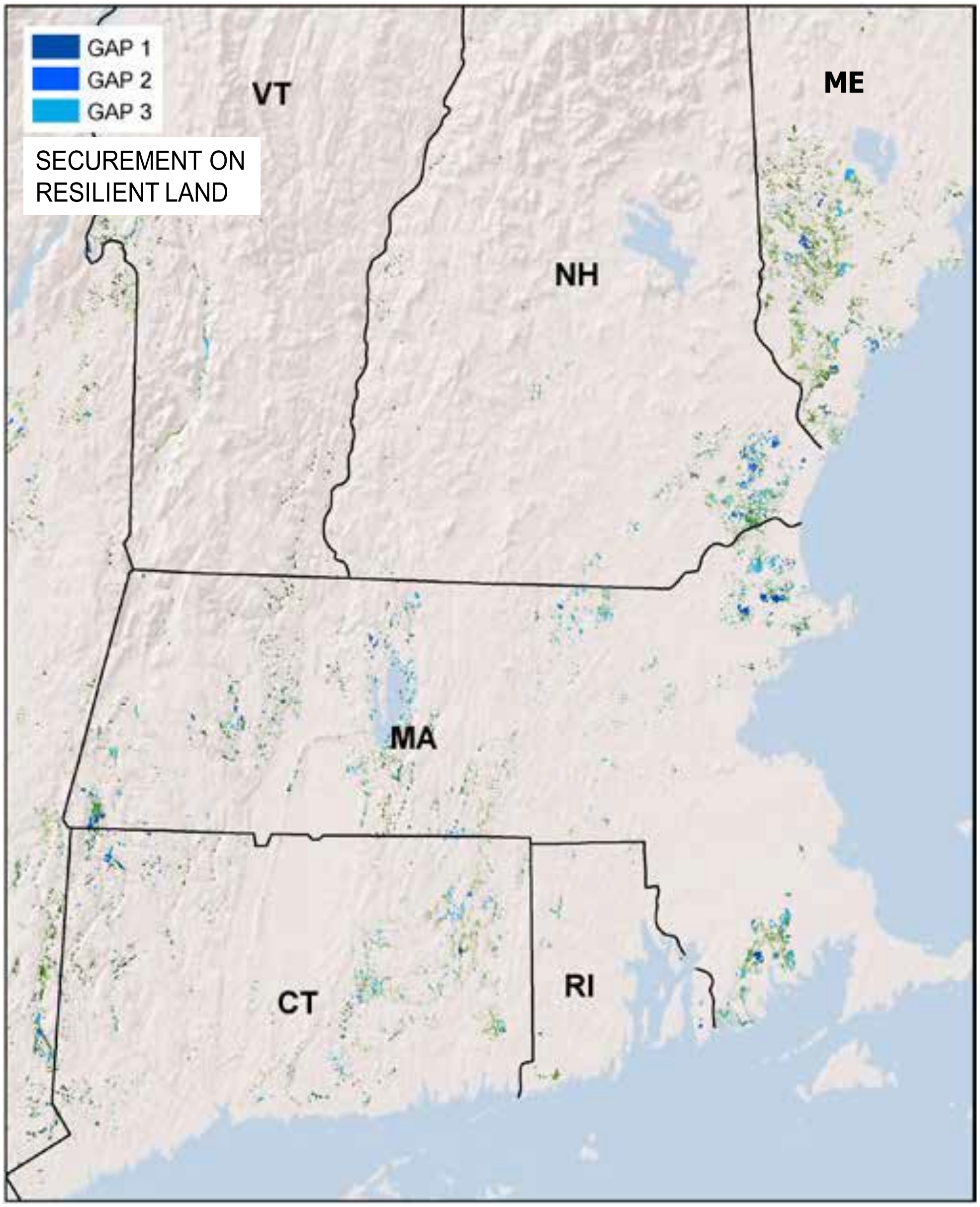


Predicted Loss to Development by 2050

Moderately low 5%

This community is somewhat threatened by development, with 13,798 acres (5%) likely to be lost over the next 30 years.

North-Central Interior & Appalachian Rich Swamp



LOCATION	TOTAL ACRES	% SECURED
New England	251,531	20%
CT	61,244	19%
MA	96,720	27%
ME	50,788	11%
NH	28,212	24%
RI	5,635	18%
VT	8,932	9%

LOCATION	RESILIENT ACRES	% SECURED
New England	110,206	23%
CT	23,010	23%
MA	37,937	33%
ME	30,976	12%
NH	12,219	29%
RI	1,665	16%
VT	4,400	14%

Rare or Uncommon Plants Associated with this Habitat

white cuckoo bitter-cress
(*Cardamine dentata*)

pink bitter-cress
(*Cardamine douglassii*)

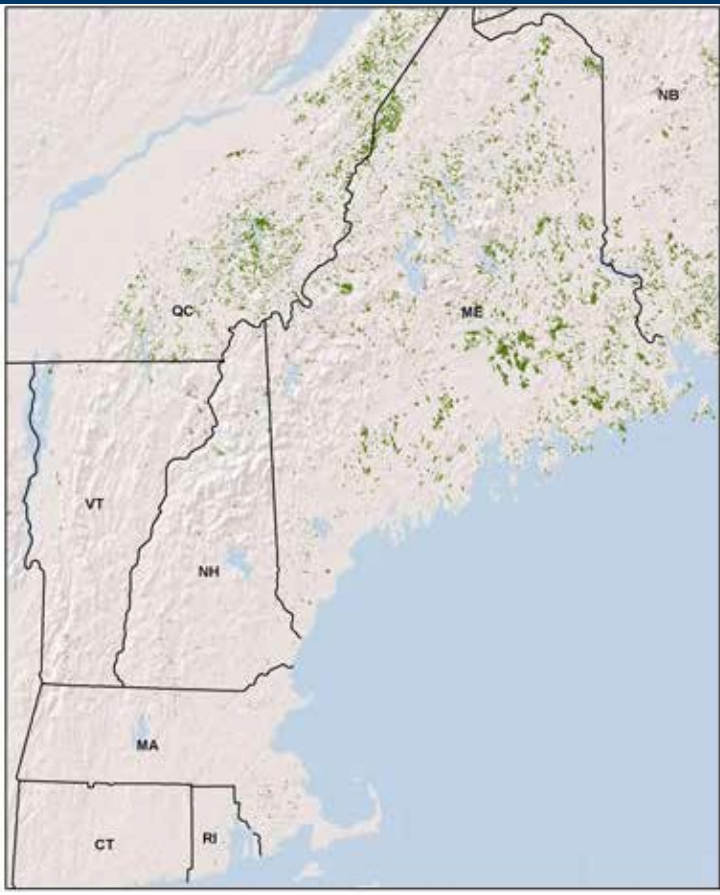
Crawe's sedge
(*Carex crawei*)

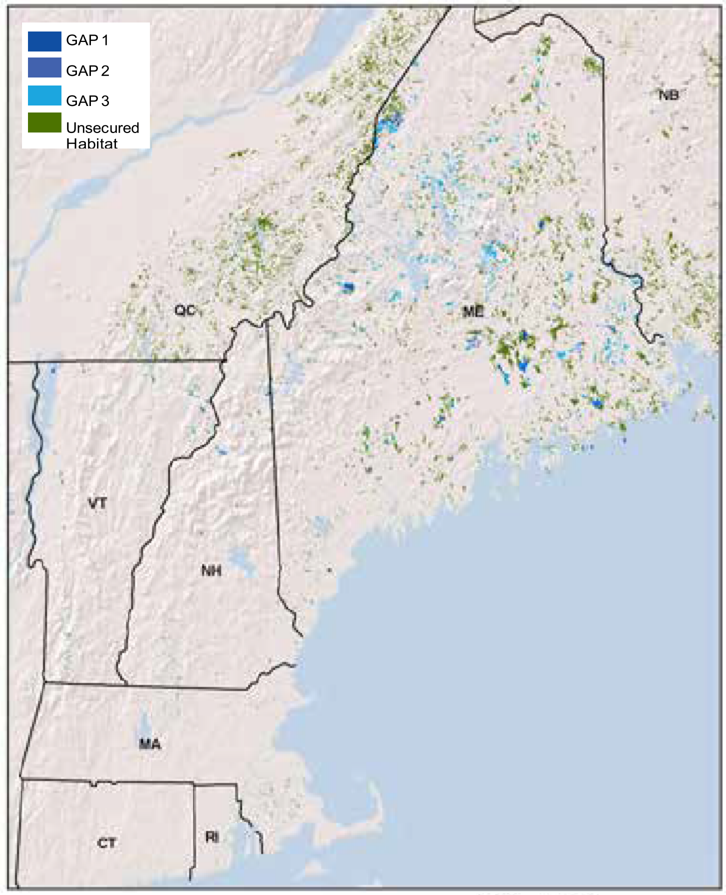
needle beak-sedge
(*Rhynchospora capillacea*)

water speedwell
(*Veronica catenata*)

© Elizabeth Thompson (Vermont Land Trust)

MACROGROUP
NORTHERN PEATLAND

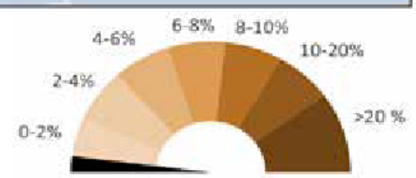




Northern Peatland
Sedge, grass, dwarf-shrub, or tree-dominated peatlands, mostly in northern New England.

Acres in New England
386,247

Percent Secured
GAP 1 = 5%
GAP 2 = 6%
GAP 3 = 19%

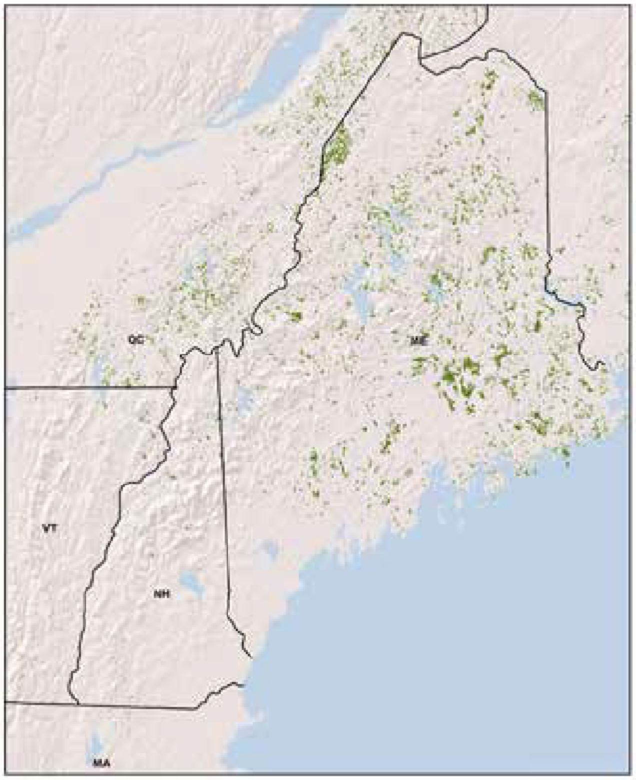


Predicted Loss to Development by 2050
1,965 acres (<1%)

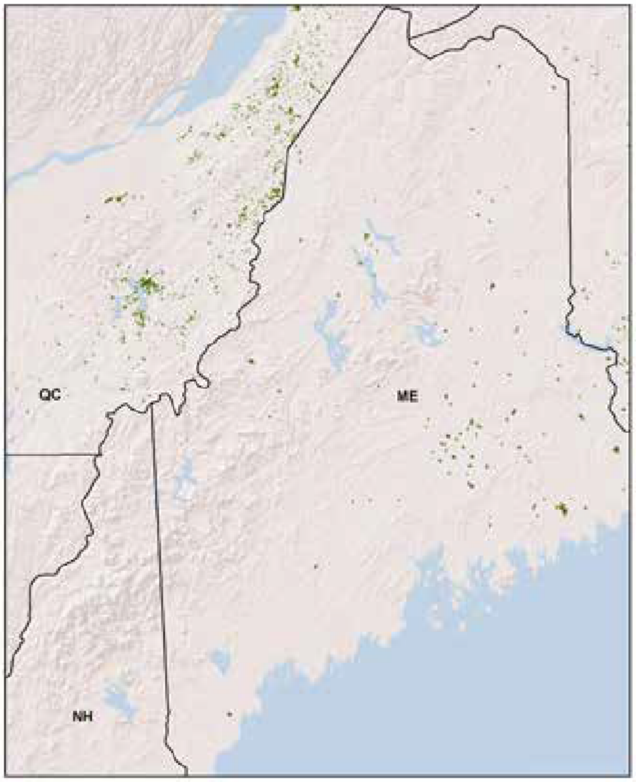
	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS			
						TOTAL	P	S	U
Northern Peatland	**381,257**	**5%**	**6%**	**19%**	**69%**	**1**			**1**
Connecticut	558	8%	7%	18%	67%				
Massachusetts	4,539	3%	4%	33%	61%				
Maine	357,092	5%	6%	18%	71%	1			1
New Hampshire	9,657	15%	9%	22%	53%				
Rhode Island	333	0%	11%	62%	27%				
Vermont	9,078	13%	27%	24%	35%				
New England	**381,257**	**20,627**	**24,162**	**71,515**	**264,952**				

P = Protected S = Secured U = Unsecured

DISTRIBUTION OF HABITATS

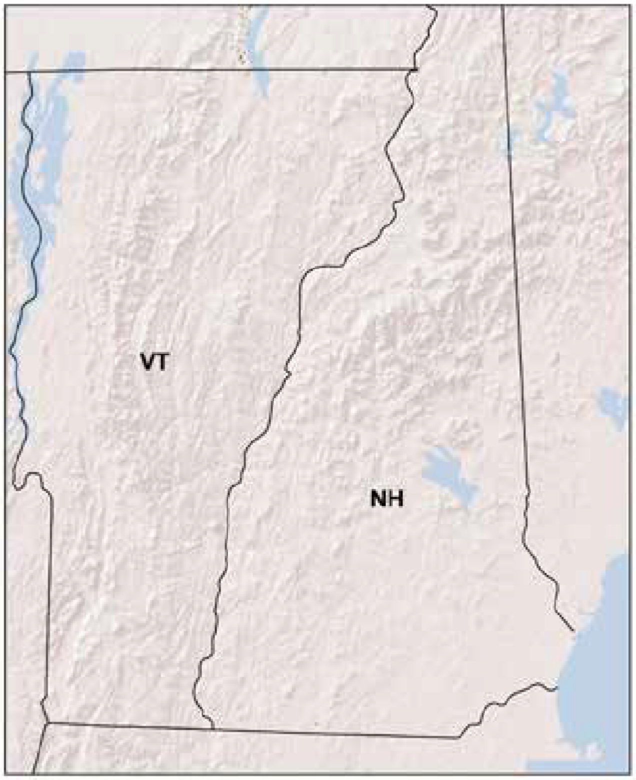


Boreal-Laurentian-Acadian Acidic Basin Fen



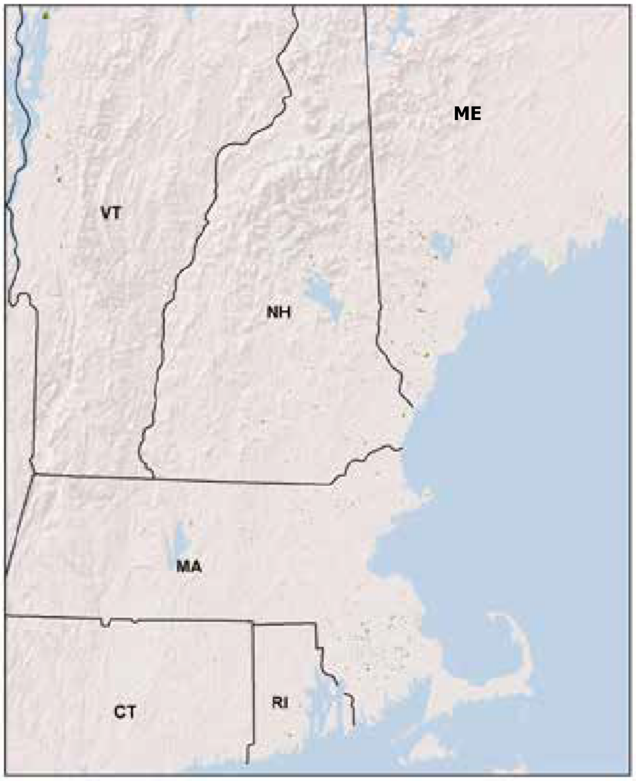
Boreal-Laurentian Bog

Acadian Maritime Bog



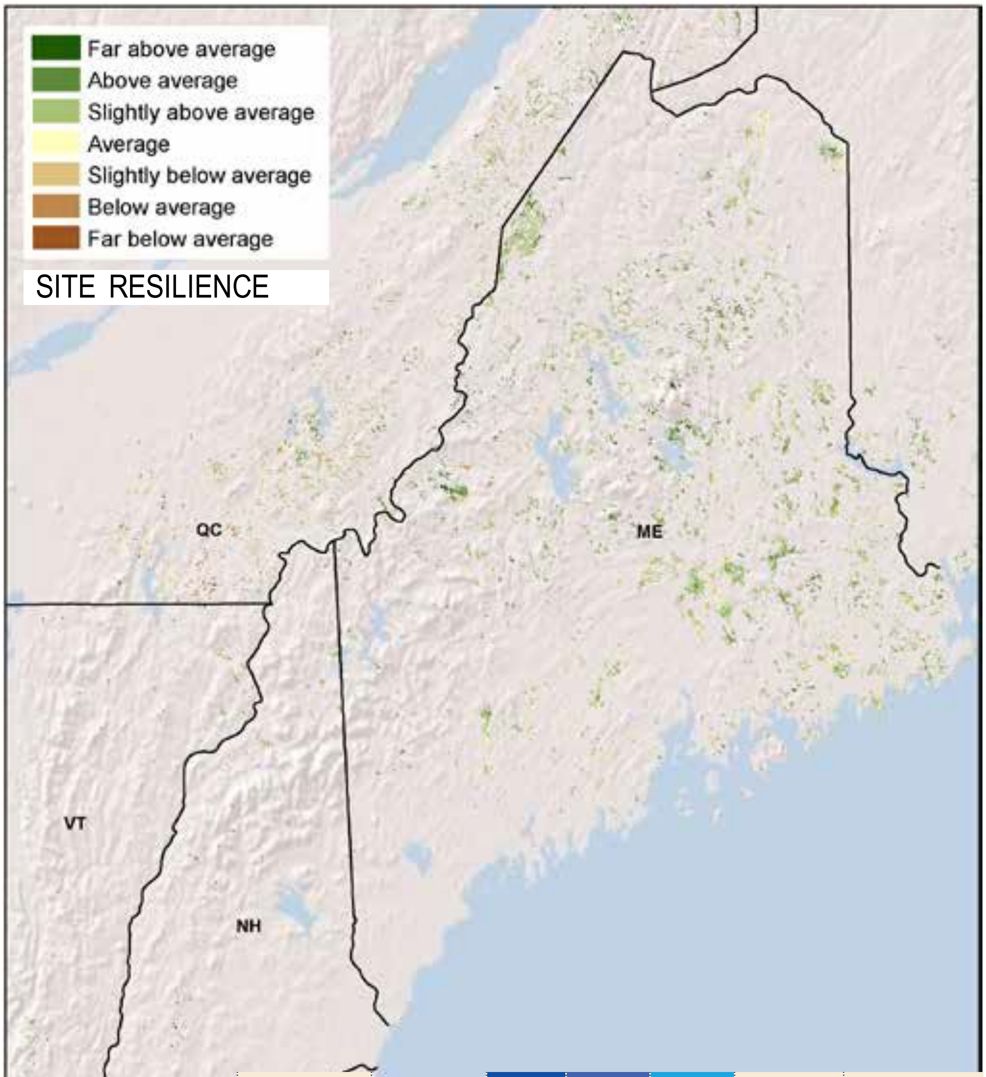
Laurentian-Acadian Alkaline Fen

DISTRIBUTION OF HABITATS



North-Central Interior & Appalachian Acidic Peatland

Boreal-Laurentian-Acadian Acidic Basin Fen



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	0%	1,435	17%	3%	33%	53%	47%
Above average	20%	63,531	8%	4%	22%	34%	66%
Slightly above average	59%	190,194	5%	5%	21%	31%	69%
Average	14%	46,890	2%	6%	9%	17%	83%
Slightly below average	4%	13,987	3%	8%	19%	30%	70%
Below average	1%	4,108	12%	10%	21%	43%	57%
Far below average	0%	159	16%	5%	11%	32%	68%
Developed	1%	3,570	3%	3%	12%	18%	82%
TOTAL	**100%**	**323,874**	**5%**	**5%**	**19%**	**29%**	**71%**

Resilience & Securement

79% of this habitat scores high for resilience, 29% of the total acreage is secured against conversion, and 10% is protected.

© Eric Sorenson (Vermont Fish & Wildlife)

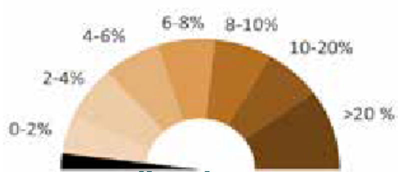
Description

A sedge, grass, and dwarf-shrub dominated peatland of the north. Intermediate between a marsh and a bog, these fens develop in relatively shallow basins with nutrient-poor and acidic conditions and may form a floating

peat-based mat over water. Sparse trees.

Associated Herbs & Shrubs

aster (*Oclemena nemoralis*), northern bog bedstraw (*Galium labradoricum*), boreal bog sedge (*Carex magellanica*), bog willow (*Salix pedicellaris*), dwarf water-lily (*Nymphaea leibergii*), mud sedge (*Carex limosa*), prickly bog sedge (*Carex atlantica*), swamp birch (*Betula pumila*), inkberry (*Ilex glabra*)

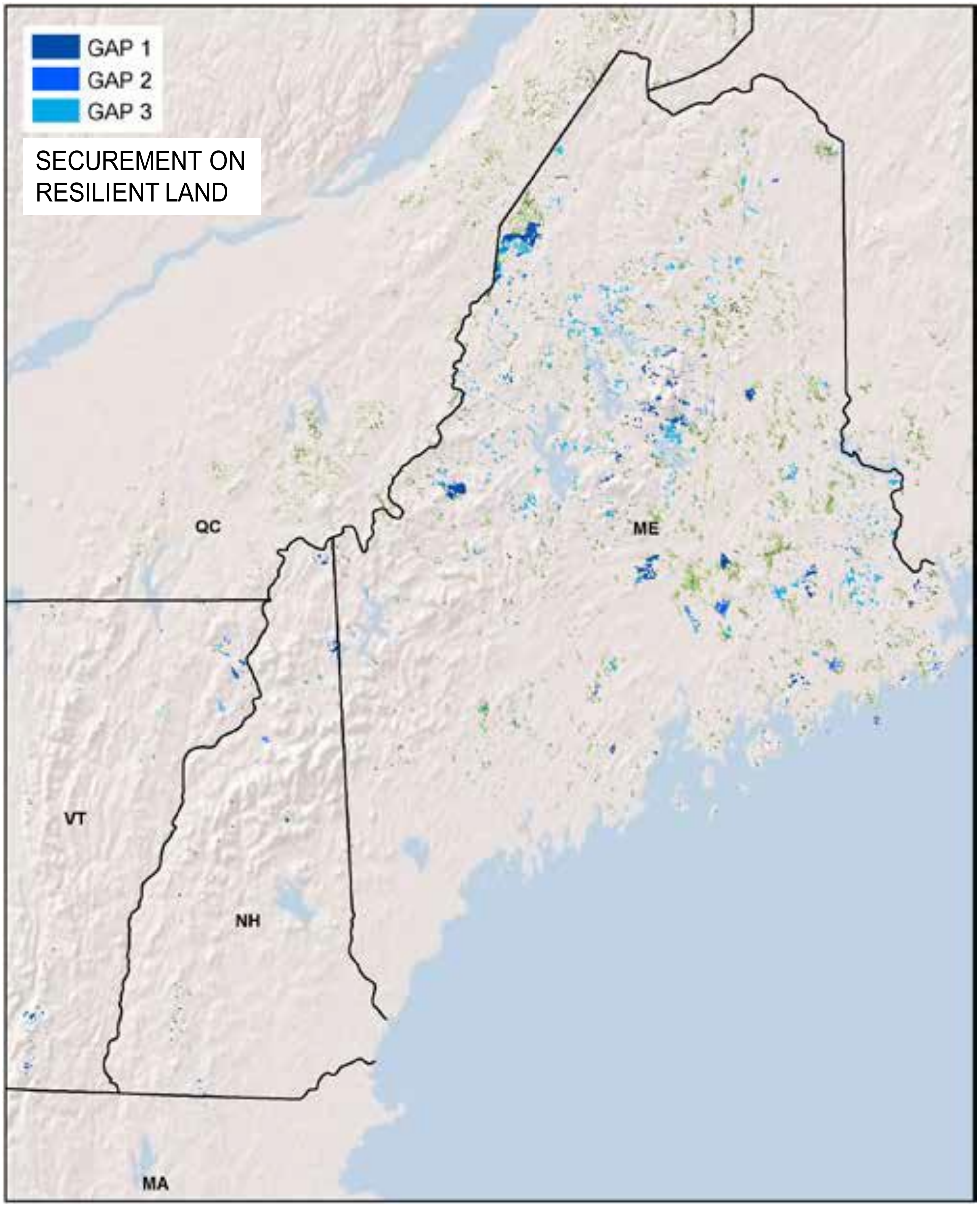


Predicted Loss to Development by 2050

Very low 0%

This community isnot threatened by development.

Boreal-Laurentian-Acadian Acidic Basin Fen



LOCATION	TOTAL ACRES	% SECURED
New England	323,874	29%
CT		
MA	684	38%
ME	309,849	28%
NH	6,950	50%
RI		
VT	6,391	65%

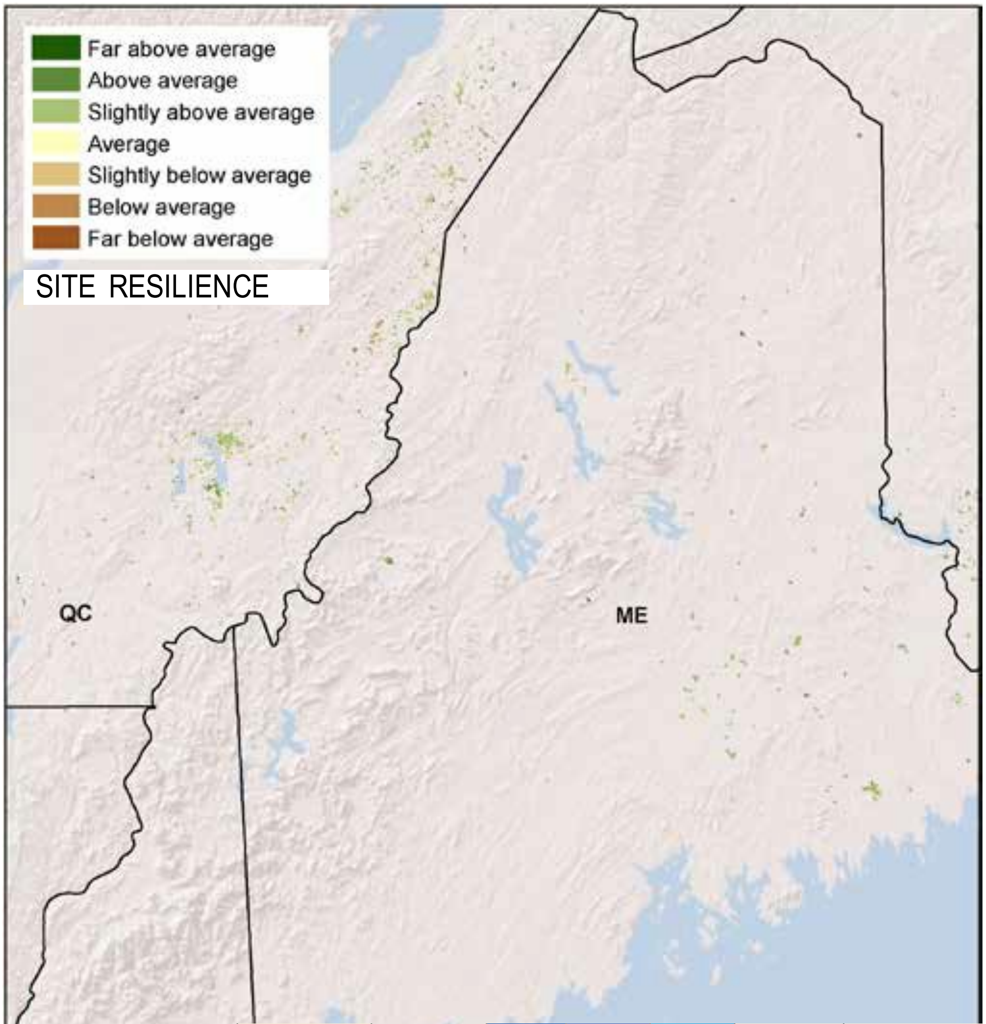
LOCATION	RESILIENT ACRES	% SECURED
New England	255,161	32%
CT		
MA	309	53%
ME	245,653	31%
NH	4,792	50%
RI		
VT	4,407	69%

Rare or Uncommon Plants Associated with this Habitat

Long's woolsedge
(*Scirpus longii*)

© Elizabeth Thompson (Vermont Land Trust)

Boreal-Laurentian Bog



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	0%	73	15%	13%	28%	56%	44%
Above average	15%	5,553	6%	20%	13%	39%	61%
Slightly above average	57%	21,393	7%	14%	16%	37%	63%
Average	21%	7,930	17%	12%	7%	36%	64%
Slightly below average	6%	2,266	0%	7%	26%	32%	68%
Below average	1%	257	0%	0%	10%	10%	90%
Far below average	0%						
Developed	0%	65	0%	2%	4%	6%	94%
TOTAL	**100%**	**37,537**	**9%**	**14%**	**14%**	**37%**	**63%**

Resilience & Securement

72% of this habitat scores high for resilience, 37% of the total acreage is secured against conversion, and 23% is protected.

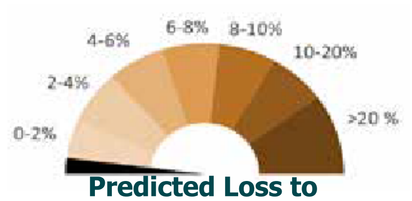
© Maine Natural Areas Program

Description

A raised peatland of near-boreal latitudes dominated by low heath shrubs (sheep laurel, bog laurel, Labrador tea, leatherleaf) and patches of sedge and bryophyte lawns. Sparse black spruce and larch are characteristic. Typical forbs include sundews, pitcher plants, and several orchids.

Associated Herbs & Shrubs

bog aster (*Oclemena nemoralis*), boreal bog sedge (*Carex magellanica*), inkberry (*Ilex glabra*), green alder (*Alnus viridis* ssp. *crispa*), mountain cranberry (*Vaccinium vitis-idaea*), twining bartonia (*Bartonia paniculata*), swamp birch (*Betula pumila*)

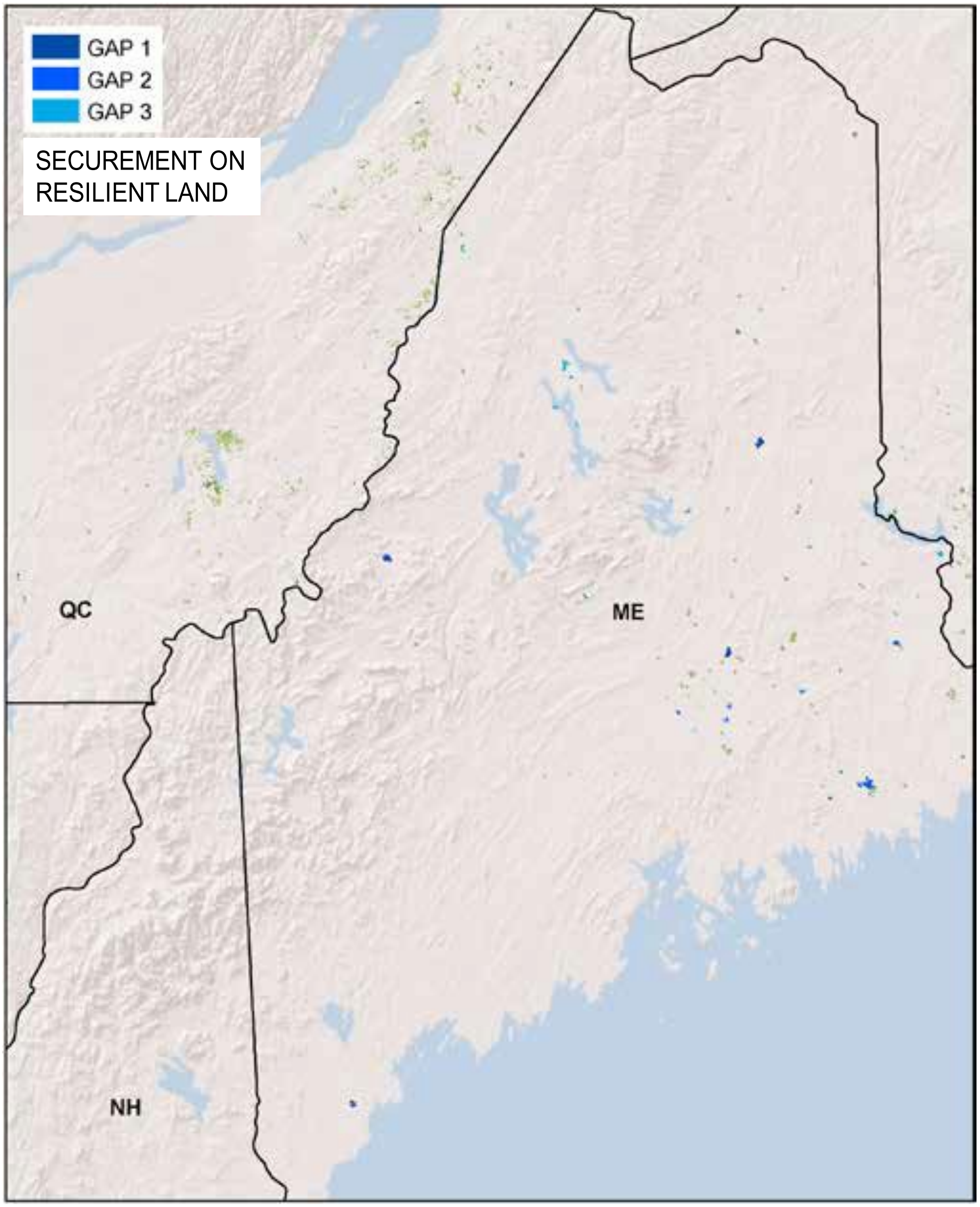


Predicted Loss to Development by 2050

Very low 0%

This community is not threatened by development.

Boreal-Laurentian Bog



LOCATION	TOTAL ACRES	% SECURED
New England	37,537	37%
CT		
MA		
ME	37,381	36%
NH	2	57%
RI		
VT	154	100%

LOCATION	RESILIENT ACRES	% SECURED
New England	27,019	38%
CT		
MA		
ME	26,865	37%
NH	0	
RI		
VT	154	100%

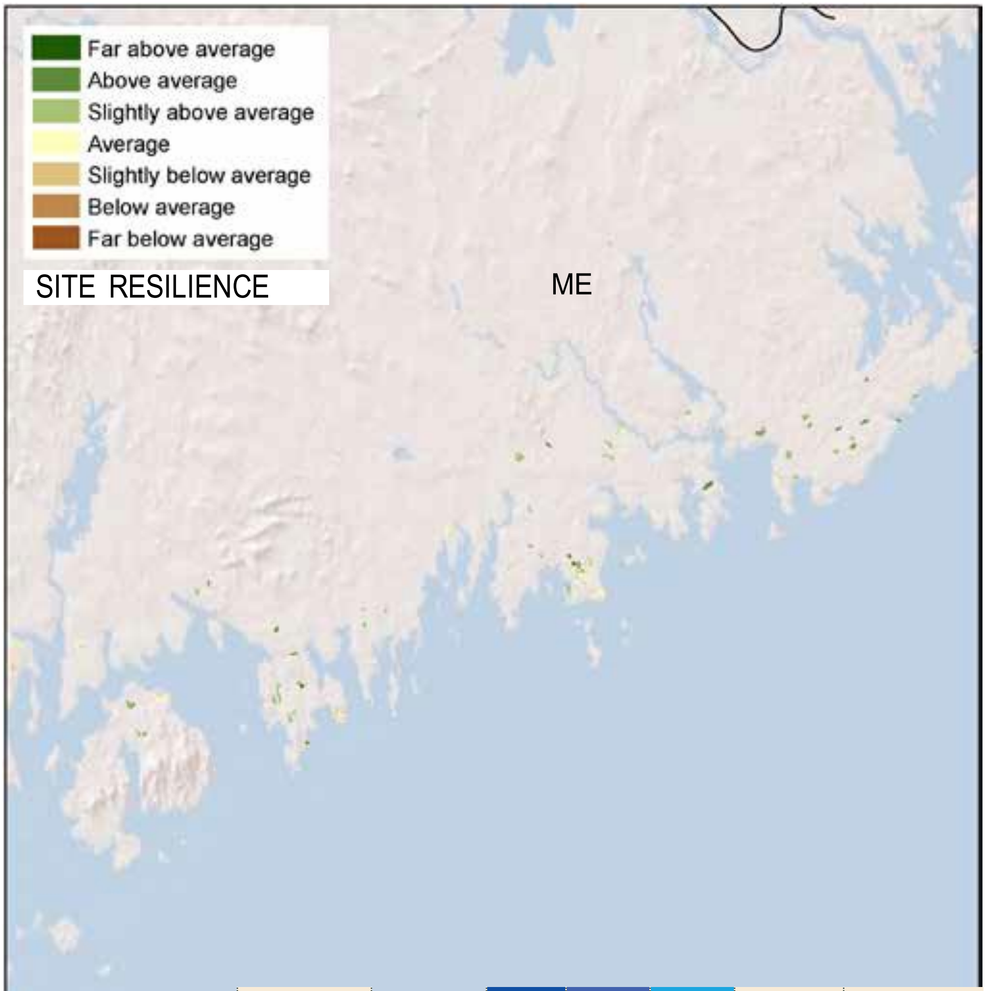
Rare or Uncommon Plants Associated with this Habitat

livid sedge
(*Carex livida*)

southern twayblade
(*Neottia bifolia*)

© Andy Cutco (Maine Natural Areas Program)

Acadian Maritime Bog



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	38	18%	22%	0%	40%	60%
Above average	15%	773	12%	29%	4%	45%	55%
Slightly above average	43%	2,252	2%	18%	4%	24%	76%
Average	34%	1,757	3%	19%	1%	22%	78%
Slightly below average	6%	310	3%	30%	0%	32%	68%
Below average	1%	54	0%	21%	0%	22%	78%
Far below average	0%	1	0%	100%	0%	100%	0%
Developed	1%	38	0%	53%	6%	59%	41%
TOTAL	**100%**	**5,223**	**4%**	**21%**	**3%**	**27%**	**73%**

Resilience & Securement

59% of this habitat scores high for resilience, 28% of the total acreage is secured against conversion, and 25% is protected.

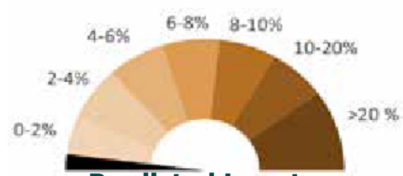
© Maine Natural Areas Program

Description

An acidic peatland dominated by dwarfshrubs, sedges, and peat-mosses and occurring along the northern Atlantic Coast. When these form in basins, they develop raised plateaus with undulating sedge and dwarf-shrub vegetation. They also occur as "blanket bogs" over a sloping rocky substrate in extreme maritime settings.

Associated Herbs & Shrubs

swamp birch (*Betula pumila*), sheep-laurel (*Kalmia angustifolia*), bog laurel (*Kalmia polifolia*), black huckleberry (*Gaylussacia baccata*), Labrador-tea (*Rhododendron groenlandicum*), black crowberry (*Empetrum nigrum*)

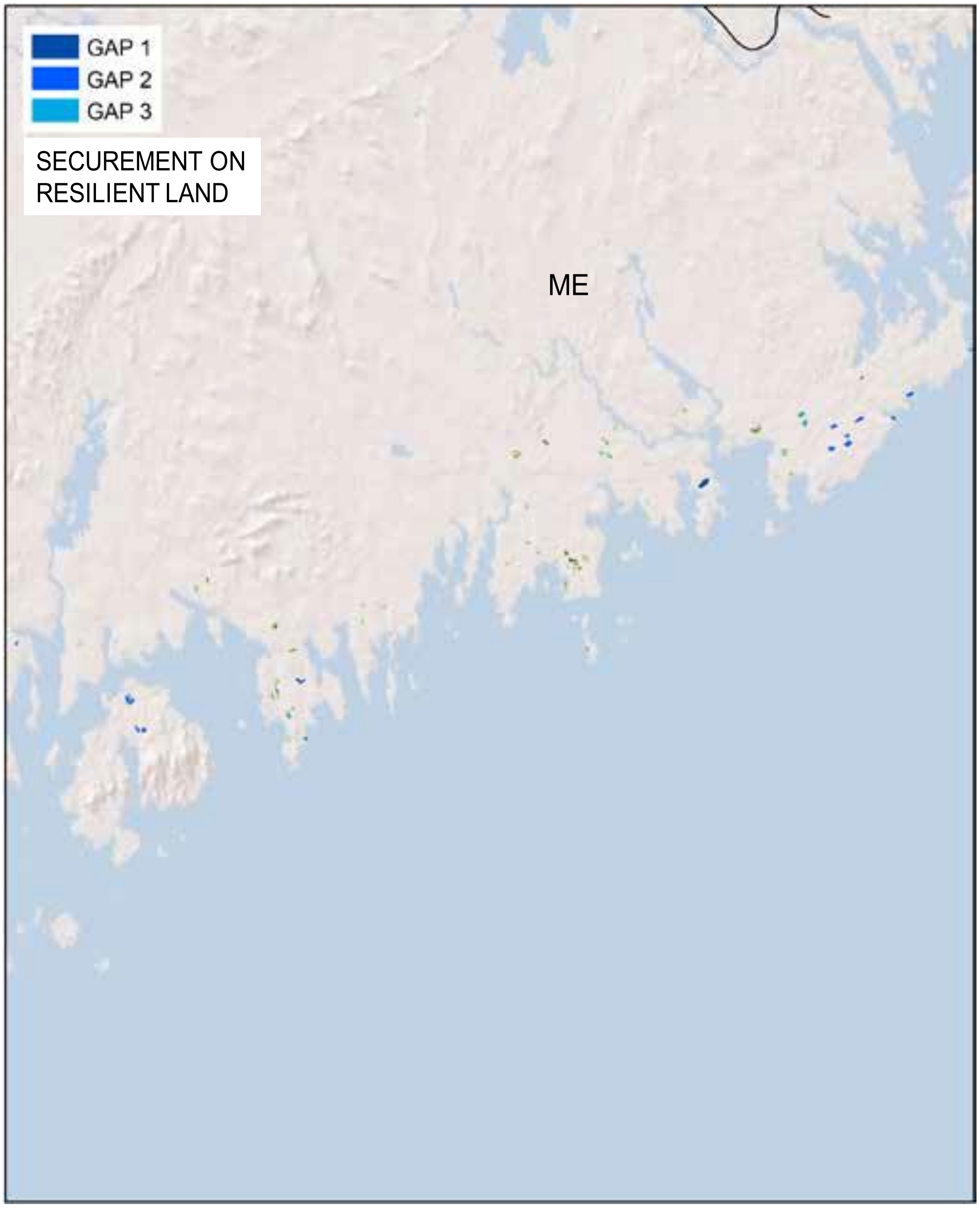


Predicted Loss to Development by 2050

Very low 0%

This community isnot threatened by development.

Acadian Maritime Bog



LOCATION	TOTAL ACRES	% SECURED
New England	5,223	27%
CT		
MA		
ME	5,223	27%
NH		
RI		
VT		

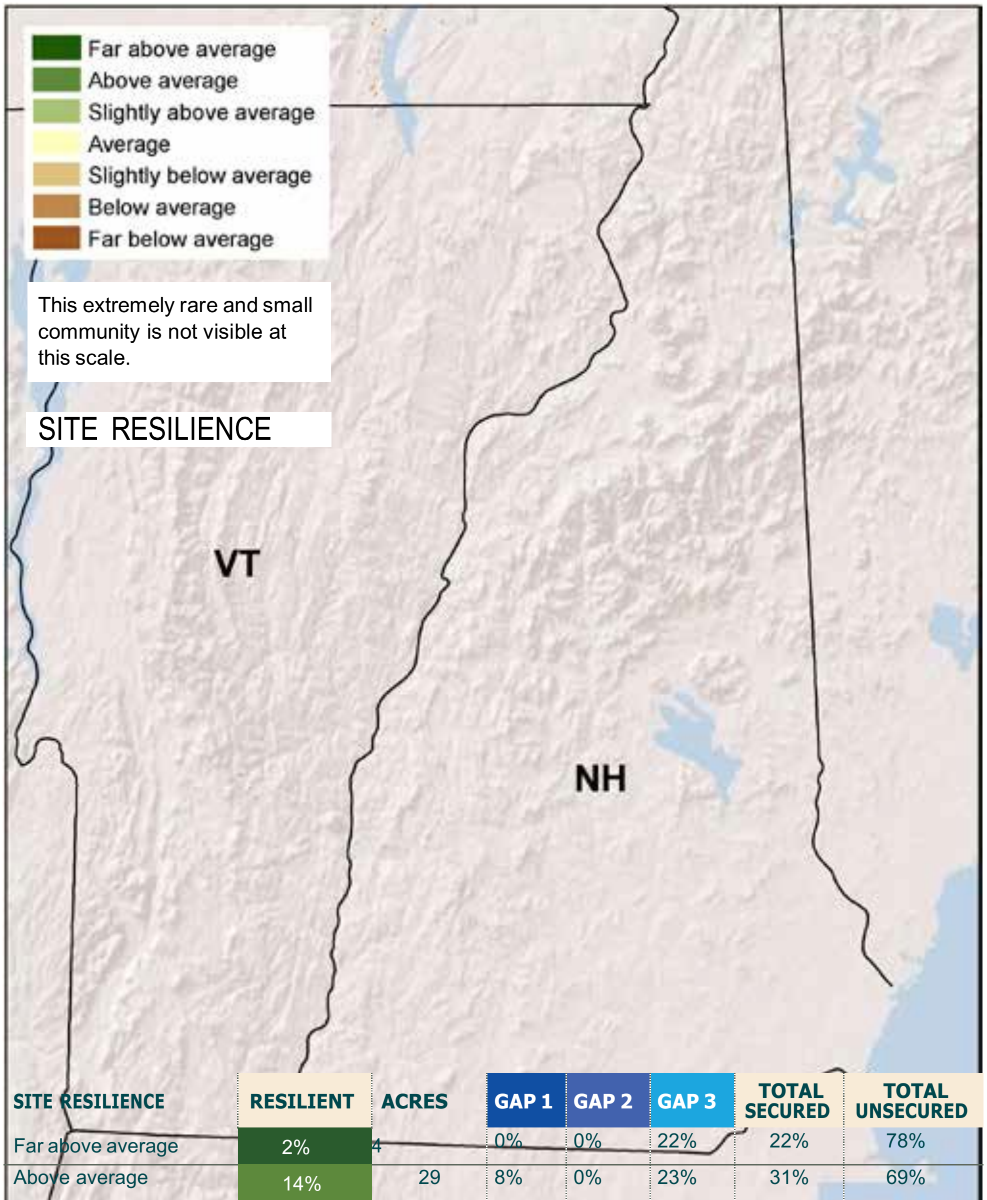
LOCATION	RESILIENT ACRES	% SECURED
New England	3,063	29%
CT		
MA		
ME	3,063	29%
NH		
RI		
VT		

Rare or Uncommon Plants Associated with this Habitat

baked-apple-berry
(*Rubus chamaemorus*)

northern comandra
(*Geocaulon lividum*)

Laurentian-Acadian Alkaline Fen



SITE RESILIENCE	RESILIENT	ACRES	GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	2%	4	0%	0%	22%	22%	78%
Above average	14%	29	8%	0%	23%	31%	69%
Slightly above average	30%	65	2%	0%	60%	62%	38%
Average	21%	46	0%	0%	29%	29%	71%
Slightly below average	27%	58	0%	0%	3%	3%	97%
Below average	6%	14	6%	0%	6%	13%	87%
Far below average	0%						
Developed	1%	1	0%	0%	40%	40%	60%
TOTAL	**100%**	**217**	**2%**		**29%**	**31%**	**69%**

Resilience & Securement

46% of this rare habitat scores high for resilience, 31% of the total acreage is securedagainst conversion, and 2% is protected.

© Maine Natural Areas Program

Description

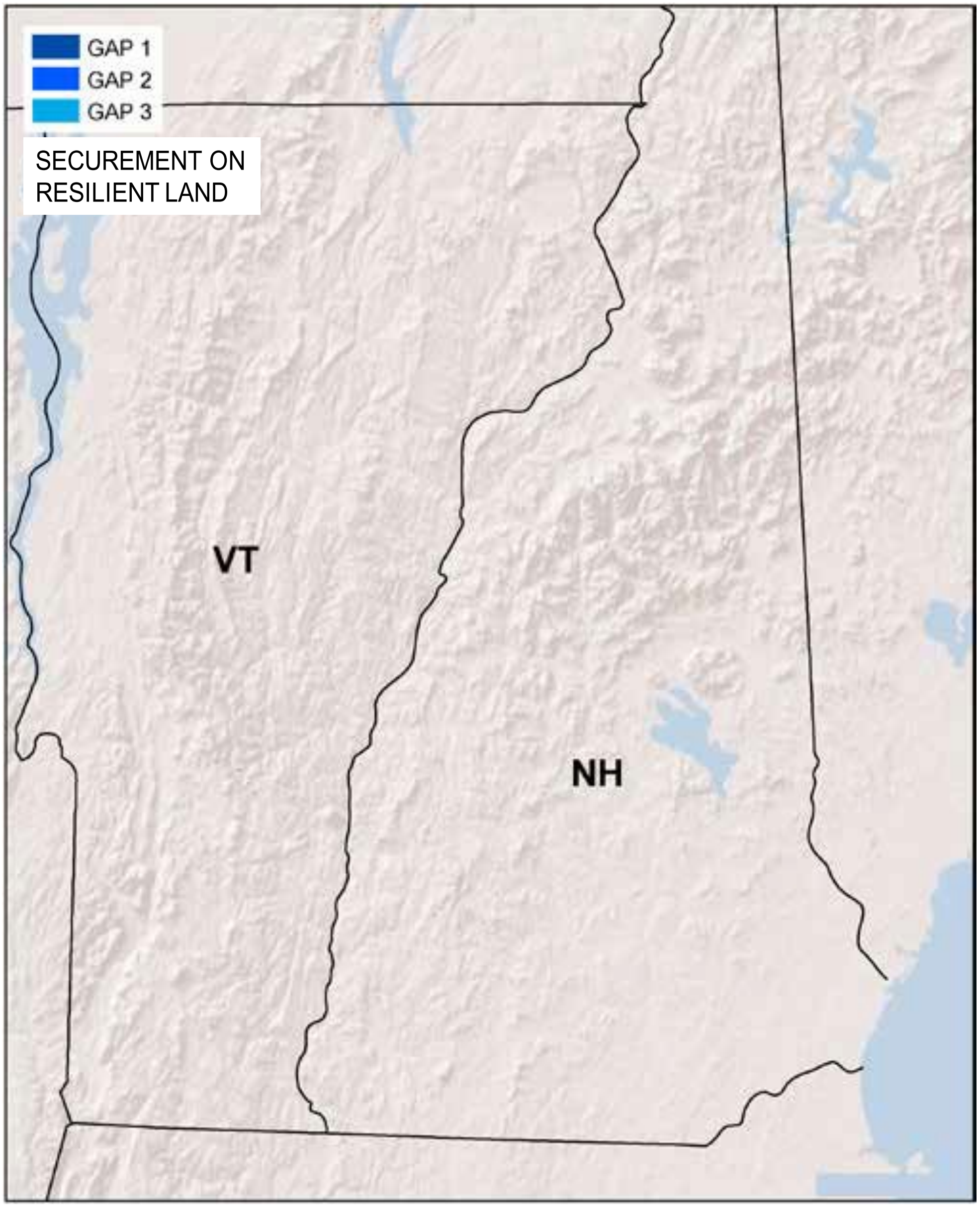
A sedge-shrub wetland associated withcalcareous groundwater or seepage. Dominated by sedges such as yellow-green sedge, wooly-fruited sedge, andherbs such as fen grass-of-Parnassus, buck-bean, and shrubby-cinquefoil.

Associated Herbs & Shrubs

boreal bedstraw (*Galium kamtchaticum*), bog willow (*Salix pedicellaris*), seaside arrow-grass (*Triglochin maritima*), rope-root sedge (*Carex chordohrizza*), dragon's-mouth (*Arethusa bulbosa*), rigid sedge (*Carex tetanica*), few-flowered spikesedge (*Eleocharis quinqueflora*), flat-leaved bladderwort (*Utricularia intermedia*), hard-stemmed club-bulrush (*Schoenoplectus acutus*), many-headed sedge (*Carex synchocephala*), prairie sedge (*Carex prairea*), slender cottongrass (*Eriophorum gracile*), bog birch (*Betula pumila*), swamp thistle (*Cirsium muticum*), northern sweet-coltsfoot (*Petasites frigidus* var. *palmatus*), water sedge (*Carex aquatilis*)

This rare habitat is not well mapped, and the numbers on these pages should be considered very approximate.

Laurentian-Acadian Alkaline Fen



LOCATION	TOTAL ACRES	% SECURED
New England	217	31%
CT		
MA	23	38%
ME	20	76%
NH	80	53%
RI		
VT	95	1%

LOCATION	RESILIENT ACRES	% SECURED
New England	98	51%
CT		
MA	17	43%
ME	20	76%
NH	35	75%
RI		
VT	26	5%

Rare or Uncommon Plants Associated with this Habitat

livid sedge
(*Carex livida*)

English sundew
(*Drosera anglica*)

slender-leaved sundew
(*Drosera linearis*)

moor rush
(*Juncus stygius* ssp. *americanus*)

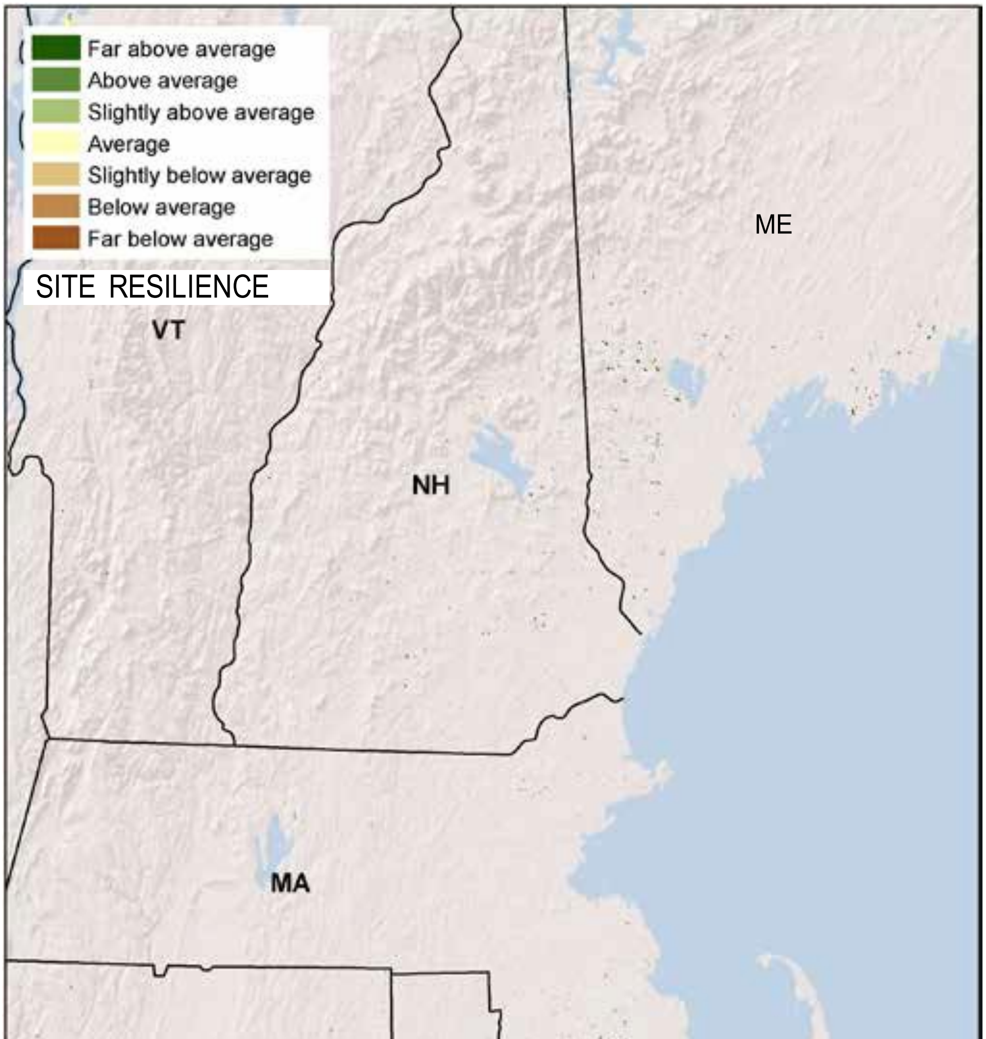
northern spikemoss
(*Selaginella selaginoides*)

hair-like sedge
(*Carex capillaris* ssp. *capillaris*)

needle beaksedge
(*Rhynchospora capillacea*)

sparse-flowered sedge
(*Carex tenuiflora*)

North-Central Interior & Appalachian Acidic Peatland



© Maine Natural Areas Program

Description

A dwarf-shrub peatland of small basinsnear the glacial boundary, where stagnated ice left coarse deposits and glacial depressions. Dominatedby heath shrubs and dwarf-shrubs (e.g.,leatherleaf), with patches of sedges and forbs, and sparse trees (black spruce, larch, pitch pine).

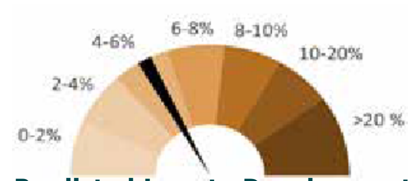
Associated Herbs & Shrubs

bog goldenrod (*Solidago uliginosa*), bog-rosemary (*Andromeda polifolia*), boreal bog sedge (*Carex magellanica*), northern comandra (*Geocaulon lividum*), north wind bog-orchid (*Platanthera aquilonis*), sword-like bog-mat (*Wolffiella gladiata*), smooth saw-edge (*Cladium mariscoides*) pod-grass (*Scheuchzeria palustris*), flat-leaved bladderwort (*Utricularia intermedia*)

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	3%	362	5%	3%	28%	37%	63%
Above average	31%	4,437	3%	4%	25%	32%	68%
Slightly above average	25%	3,624	2%	8%	28%	38%	62%
Average	32%	4,663	2%	25%	21%	48%	52%
Slightly below average	4%	595	0%	33%	23%	55%	45%
Below average	2%	234	0%	0%	33%	34%	66%
Far below average	0%	10	0%	0%	0%	0%	100%
Developed	3%	481	2%	5%	13%	20%	80%
TOTAL	**100%**	**14,406**	**2%**	**13%**	**24%**	**39%**	**61%**

Resilience & Securement

59% of this rare habitat scores high for resilience, 39% of the total acreage is securedagainst conversion, and 15% is protected, mostly in areas with average resilience.

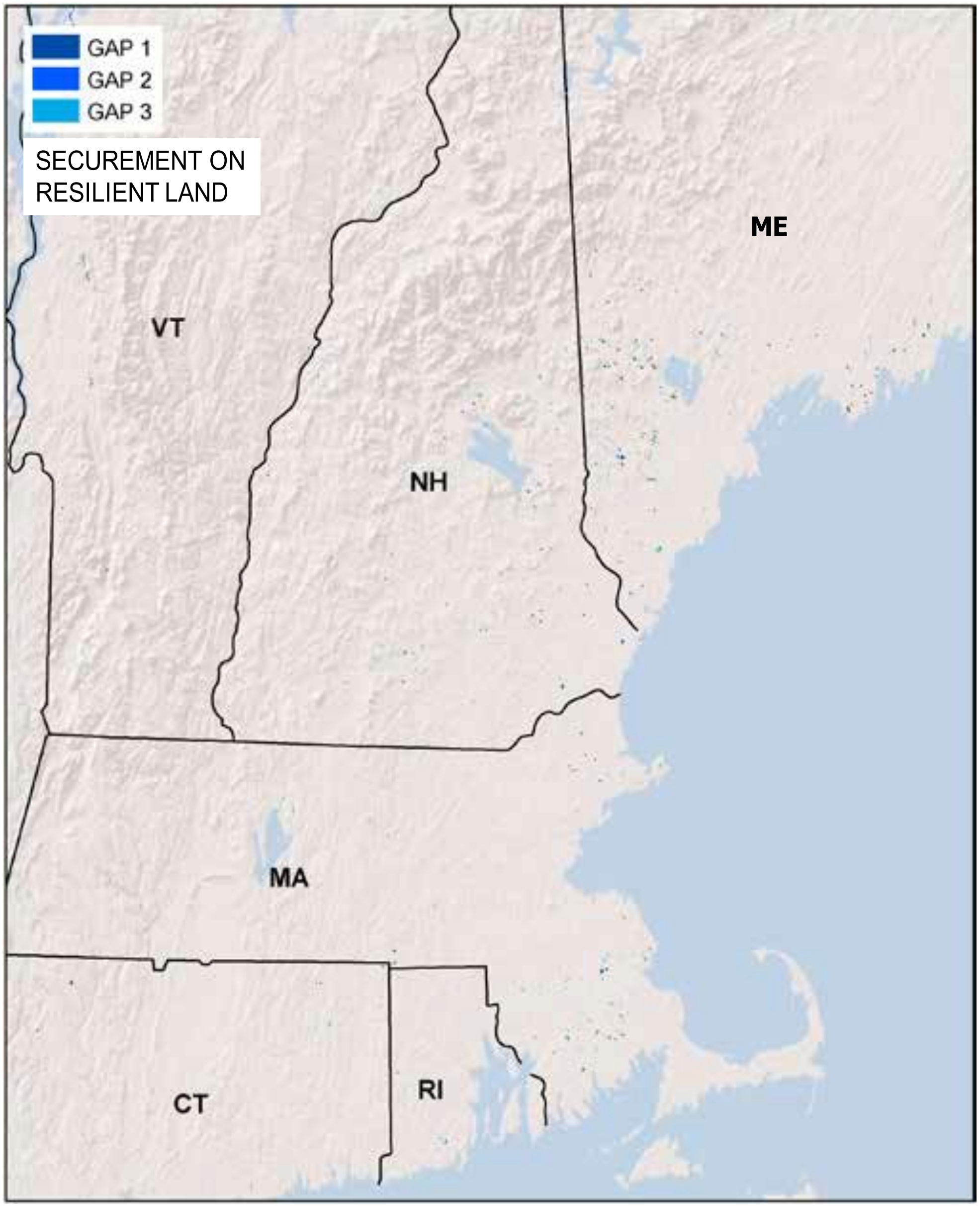


Predicted Loss to Development by 2050

Moderately low 5%

This community is mildly threatenedby development, with 738 acres (5%) likely to be lost over the next 30 years.

North-Central Interior & Appalachian Acidic Peatland



LOCATION	TOTAL ACRES	% SECURED
New England	14,406	40%
CT	558	33%
MA	3,833	39%
ME	4,619	25%
NH	2,626	39%
RI	333	73%
VT	2,437	65%

LOCATION	RESILIENT ACRES	% SECURED
New England	8,423	35%
CT	293	52%
MA	1,694	42%
ME	3,720	27%
NH	1,728	39%
RI	103	83%
VT	885	37%

Rare or Uncommon Plants Associated with this Habitat

dragon's mouth
(*Arethusa bulbosa*)

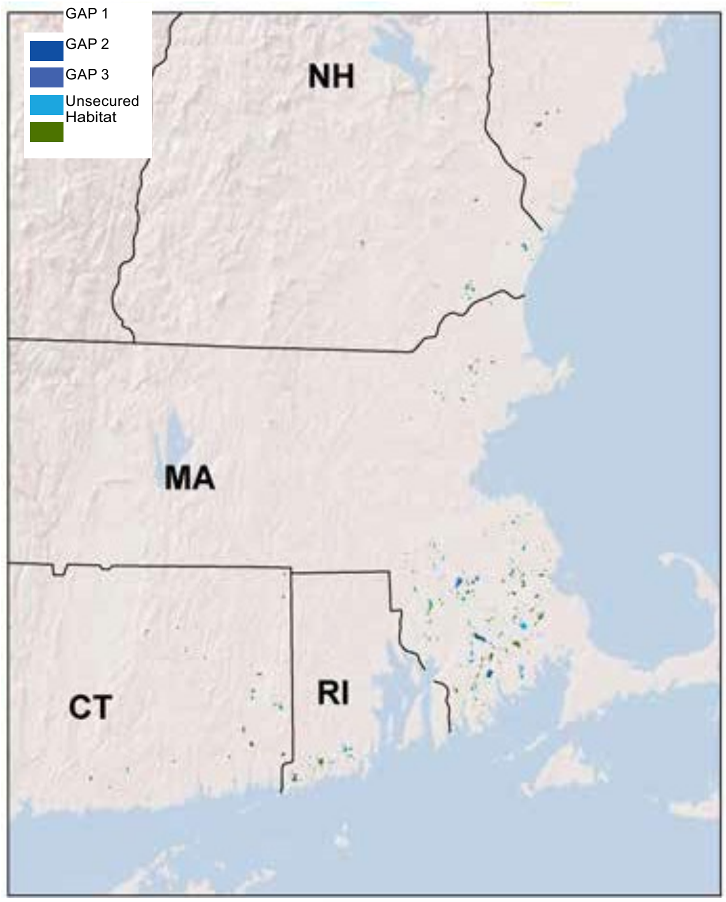
Long's woolsedge
(*Scirpus longii*)

mud sedge
(*Carex limosa*)

bog birch
(*Betula pumila*)

MACROGROUP

OASTAL PLAIN SWAMP & PEATLAND



Coastal Plain Swamp & Peatland

Sedge, grass, dwarf-shrub, or tree-dominated peatlands in southern New England.

Acres in New England

18,628

Percent Secured

GAP 1 = 10%

GAP 2 = 7%

GAP 3 = 26%

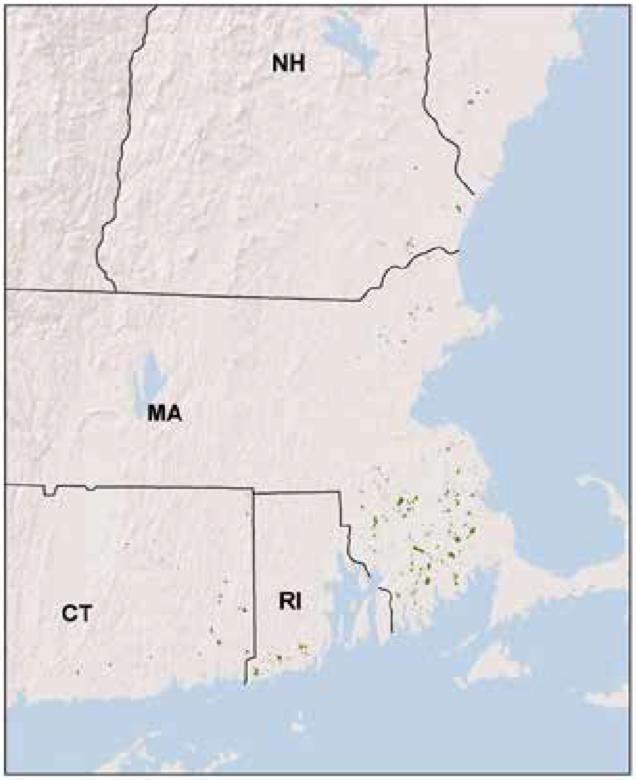
Predicted Loss to Development by 2050

571 acres (3%)

	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS TOTAL	P	S	U
Coastal Plain Swamp & Peatland	**18,628**	**10%**	**7%**	**26%**	**56%**				
Connecticut	2,474	1%	8%	24%	67%				
Massachusetts	12,619	12%	8%	27%	53%				
Maine	637	0%	4%	17%	79%				
New Hampshire	1,154	18%	4%	38%	40%				
Rhode Island	1,744	6%	3%	25%	66%				
New England	**18,628**	**1,911**	**1,313**	**4,924**	**10,480**				

P = Protected S = Secured U = Unsecured

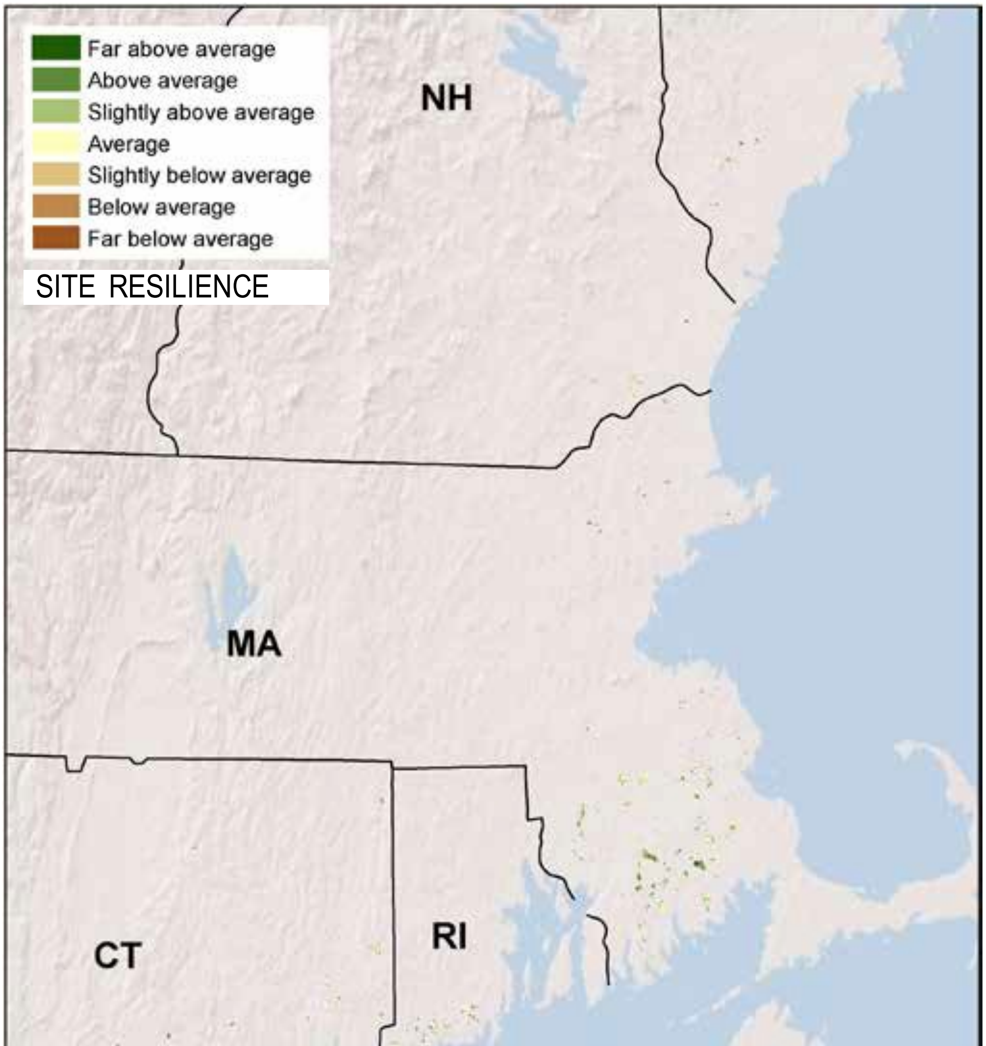
DISTRIBUTION OF HABITATS



North Atlantic Coastal Plain Basin Peat Swamp

Atlantic Coastal Plain Northern Bog

North Atlantic Coastal Plain Basin Peat Swamp



© Robert Coxe (Delaware Species Conservation & Research Program)

Description

A forested swamp of peat-accumulating basins in the coastal plain. Atlantic white cedar is characteristic; red maple and/or black spruce may be present. Understory plants include alder, great laurel, high-bushblueberry, winterberry, swamp azalea, and sphagnum moss.

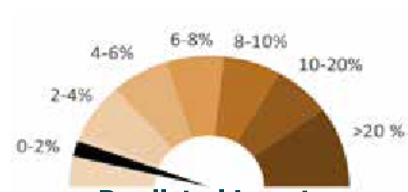
Associated Herbs & Shrubs

bayonet rush (*Juncus militaris*), bushy bluestem (*Andropogon glomeratus*), coastal sedge (*Carex exilis*), woolly-fruited sedge (*Carex lasiocarpa*), tussock sedge (*Carex stricta*), Billings' sedge (*Carex billingsii*), tawny cottonsedge (*Eriophorum virginicum*), leatherleaf (*Chamaedaphne calyculata*), bayonet rush (*Juncus militaris*), bushy bluestem (*Andropogon glomeratus*), coastal sedge (*Carex exilis*)

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	137	0%	5%	9%	15%	85%
Above average	21%	3,743	15%	5%	24%	44%	56%
Slightly above average	28%	4,945	11%	4%	28%	43%	57%
Average	42%	7,522	10%	10%	27%	47%	53%
Slightly below average	4%	757	2%	4%	35%	41%	59%
Below average	2%	359	0%	0%	22%	22%	78%
Far below average	0%	10	0%	0%	11%	11%	89%
Developed	2%	310	7%	3%	18%	28%	72%
TOTAL	**100%**	**17,783**	**11%**	**7%**	**27%**	**45%**	**55%**

Resilience & Securement

50% of this rare habitat scores high for resilience, 45% of the total acreage is securedagainst conversion, and 18% is protected.

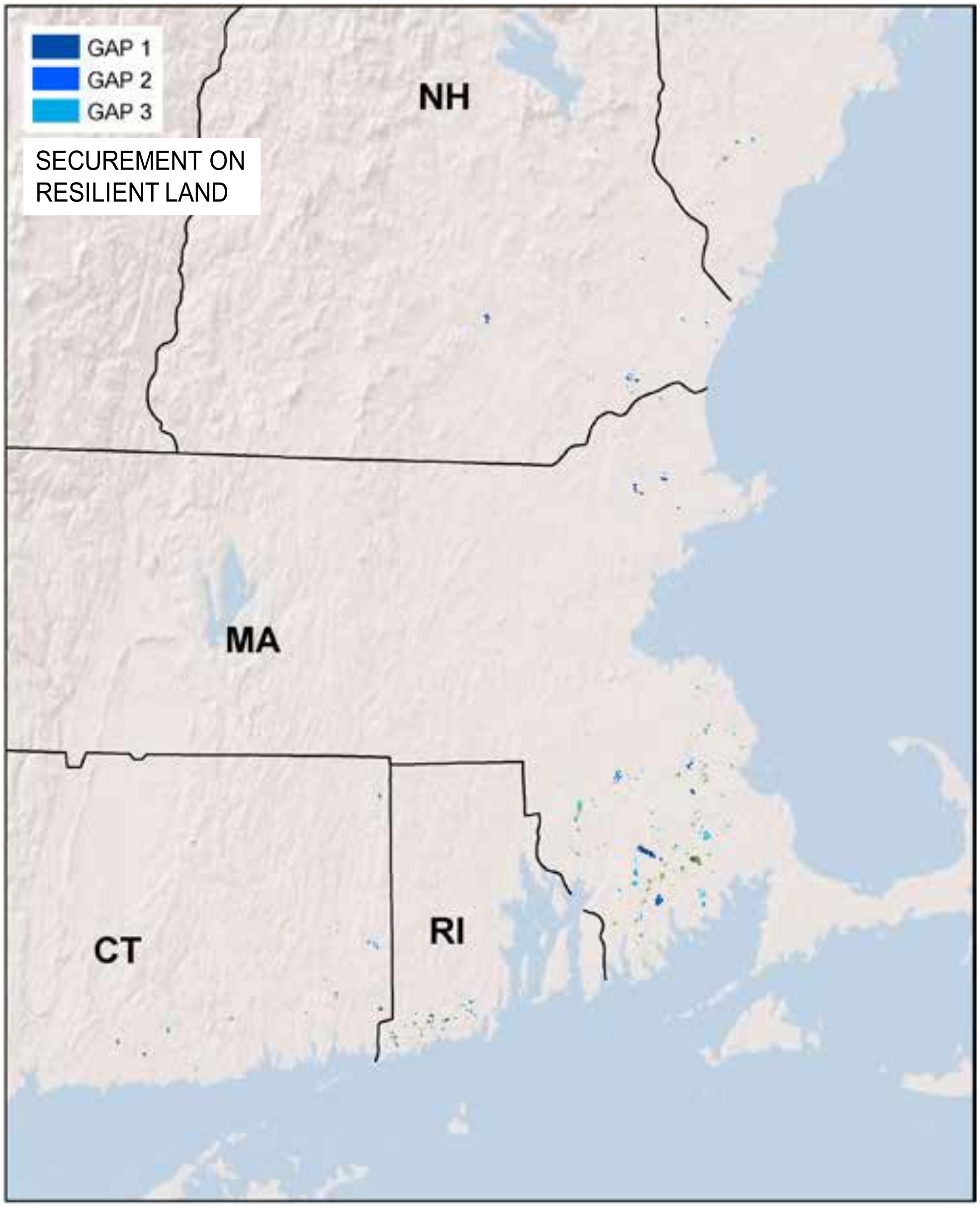


Predicted Loss to Development by 2050

Low 2%

This community has a low development threat, with 444 acres (2%) likely to be lost over the next 30 years.

North Atlantic Coastal Plain Basin Peat Swamp



LOCATION	TOTAL ACRES	% SECURED
New England	17,783	44%
CT	2,475	33%
MA	11,774	47%
ME	637	21%
NH	1,154	60%
RI	1,744	34%
VT		

LOCATION	RESILIENT ACRES	% SECURED
New England	8,826	43%
CT	1,234	36%
MA	5,950	45%
ME	443	25%
NH	389	54%
RI	810	43%
VT		

Rare or Uncommon Plants Associated with this Habitat

Collins' sedge (*Carex collinsii*)

swamp wedgescale (*Sphenopholis pensylvanica*)

Atlantic Coastal Plain Northern Bog

© Kathleen Strakosch Walz
(New Jersey Natural Heritage Program)

Description

Dwarf-shrub and sphagnum bogs occurring in isolated glacial kettleholes. The system is characterized by acidic, tannic water supporting a floating or grounded sphagnum mat over which leatherleaf and dwarf huckleberry

are rooted.

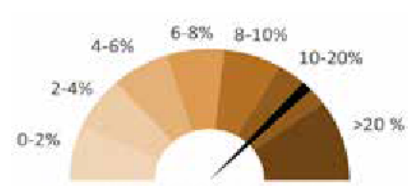
Associated Herbs & Shrubs

highbush blueberry (*Vaccinium corymbosum*) swamp-loosestrife (*Decodon verticillatus*), pitch pine (*Pinus rigida*), Atlantic white cedar (*Chamaecyparis thyoides*), black spruce (*Picea mariana*), white water-lily (*Nymphaea odorata*)

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	7	0%	0%	0%	0%	100%
Above average	21%	181	0%	49%	21%	70%	30%
Slightly above average	16%	135	1%	7%	38%	46%	54%
Average	38%	322	4%	0%	24%	28%	72%
Slightly below average	7%	60	15%	0%	21%	35%	65%
Below average	2%	20	0%	0%	13%	13%	88%
Far below average	0%	0					
Developed	14%	121	0%	8%	20%	29%	71%
TOTAL	**100%**	**845**	**3%**	**13%**	**24%**	**40%**	**60%**

Resilience & Securement

38% of this rare habitat scores high for resilience, 40% of the total acreage is secured against conversion, and 16% is protected.



Predicted Loss to Development by 2050

High 15%

This community is threatened by development, with 127 acres (15%) likely to be lost over the next 30 years.

Atlantic Coastal Plain Northern Bog

LOCATION	TOTAL ACRES	% SECURED
New England	845	40%
CT		
MA	845	40%
ME		
NH		
RI		
VT		

LOCATION	RESILIENT ACRES	% SECURED
New England	323	58%
CT		
MA	323	58%
ME		
NH		
RI		
VT		

Rare or Uncommon Plants Associated with this Habitat

dwarf mistletoe
(*Arceuthobium pusillum*)

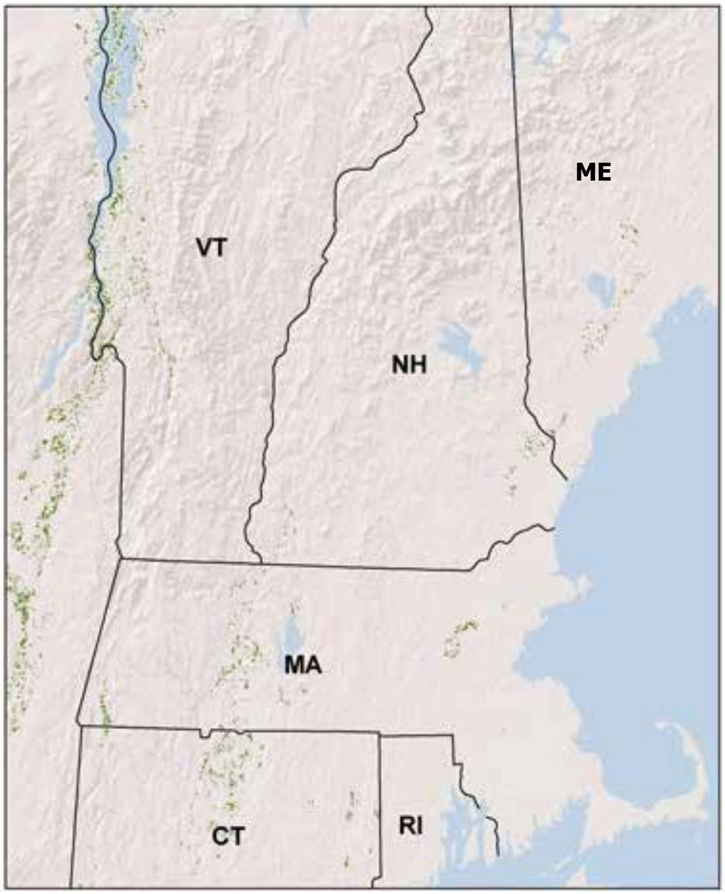
mud sedge
(*Carex limosa*)

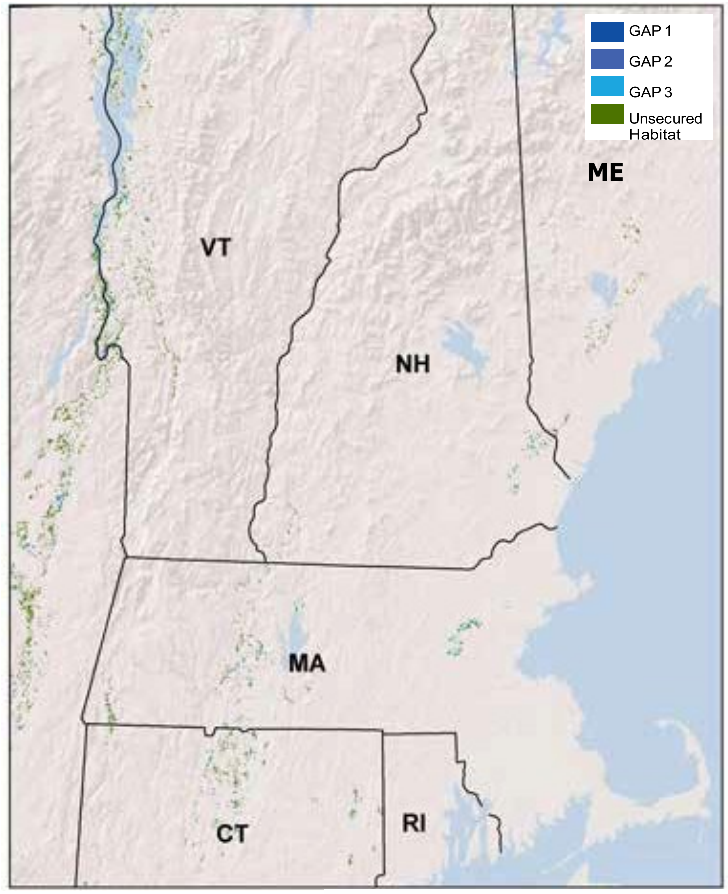
pod-grass
(*Scheuchzeria palustris*)

Long's woolsedge
(Scirpus longii)

MACROGROUP

CENTRAL HARDWOOD SWAMP





Central Hardwood Swamp

Broadleaved or mixed forested swamps in central New England.

Acres in New England

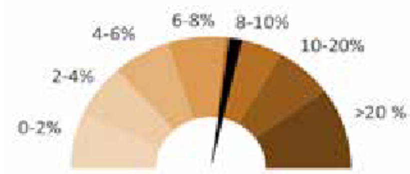
39,338

Percent Secured

GAP 1 = 1%

GAP 2 = 2%

GAP 3 = 11%



Predicted Loss to Development by 2050

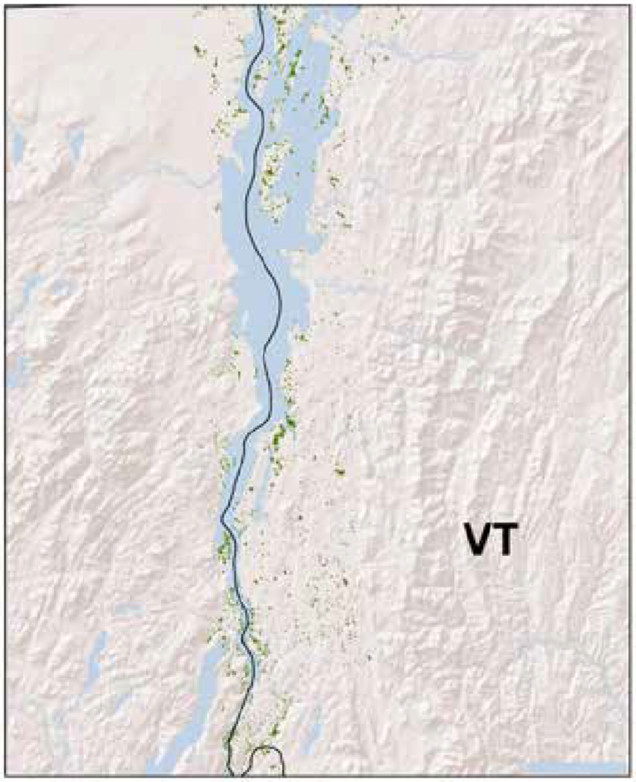
3,120 acres (8%)

	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS			
						TOTAL	P	S	U
Central Hardwood Swamp	**39,338**	**1%**	**2%**	**11%**	**85%**	**1**			**1**
Connecticut	9,249	0%	3%	13%	84%				
Massachusetts	9,553	0%	3%	17%	80%	1			1
Maine	2,783	0%	2%	1%	97%				
New Hampshire	1,955	1%	3%	20%	76%				
Rhode Island	0	0%	0%	0%	100%				
Vermont	15,798	3%	0%	8%	88%				
New England	**39,338**	**499**	**787**	**4,501**	**33,550**				

P = Protected S = Secured U = Unsecured

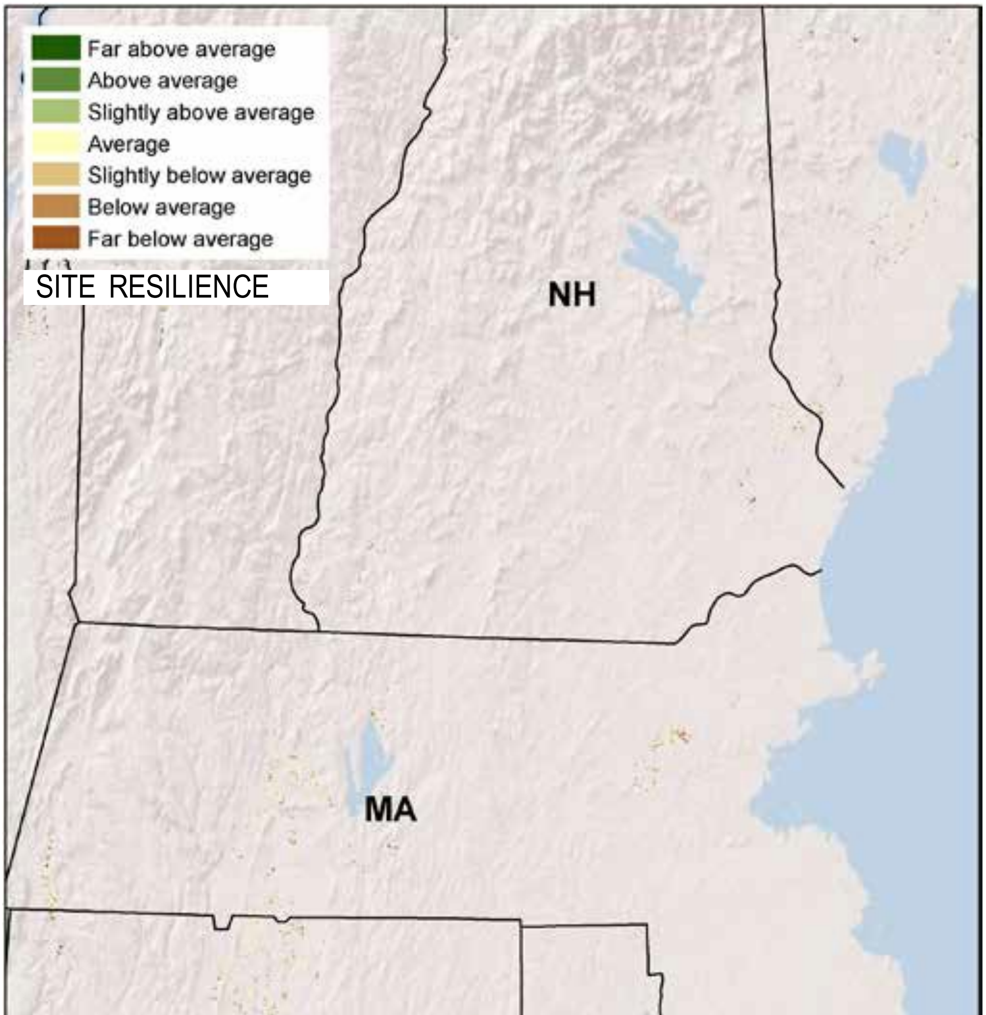
DISTRIBUTION OF HABITATS

North-Central Interior Wet Flatwoods



Glacial Marine & Lake Wet Clayplain Forest

North Central Interior Wet Flatwoods



SITE RESILIENCE	RESILIENT	ACRES	GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	0%	88	6%	[illegible]	6%	12%	88%
Above average	8%	1,901	2%	2%	14%	17%	83%
Slightly above average	17%	4,308	0%	5%	12%	17%	83%
Average	44%	11,016	0%	3%	13%	16%	84%
Slightly below average	13%	3,405	0%	1%	13%	15%	85%
Below average	11%	2,725	0%	2%	17%	19%	81%
Far below average	1%	296	1%	4%	11%	16%	84%
Developed	6%	1,565	0%	2%	10%	12%	88%
TOTAL	**100%**	**25,306**	**0%**	**3%**	**13%**	**16%**	**84%**

Resilience & Securement

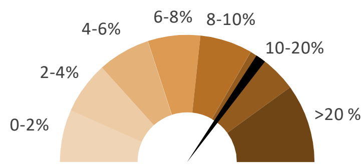
25% of this rare habitat scores high for resilience, 16% of the total acreage is secured against conversion, and 3% is protected.

Description

A hardwood forest of upland and wetland species occurring in depressions or poorly drained lowlands. Pin oak dominates in many areas; other common trees include swamp white oak, bur oak, black gum, sweet gum, and red maple. Buttonbush, winterberry, alder, various sedges, and cinnamon fern are typical.

Associated Herbs & Shrubs

Canada moonseed (*Menispermum canadense*), American climbing fern (*Lygodium palmatum*), common hackberry (*Celtis occidentalis*), fall sneezeweed (*Helenium autumnale*), fox-tail sedge (*Carex alopecoidea*), Virginia spring-beauty (*Claytonia virginica*), pink bitter-cress (*Cardamine douglassii*)

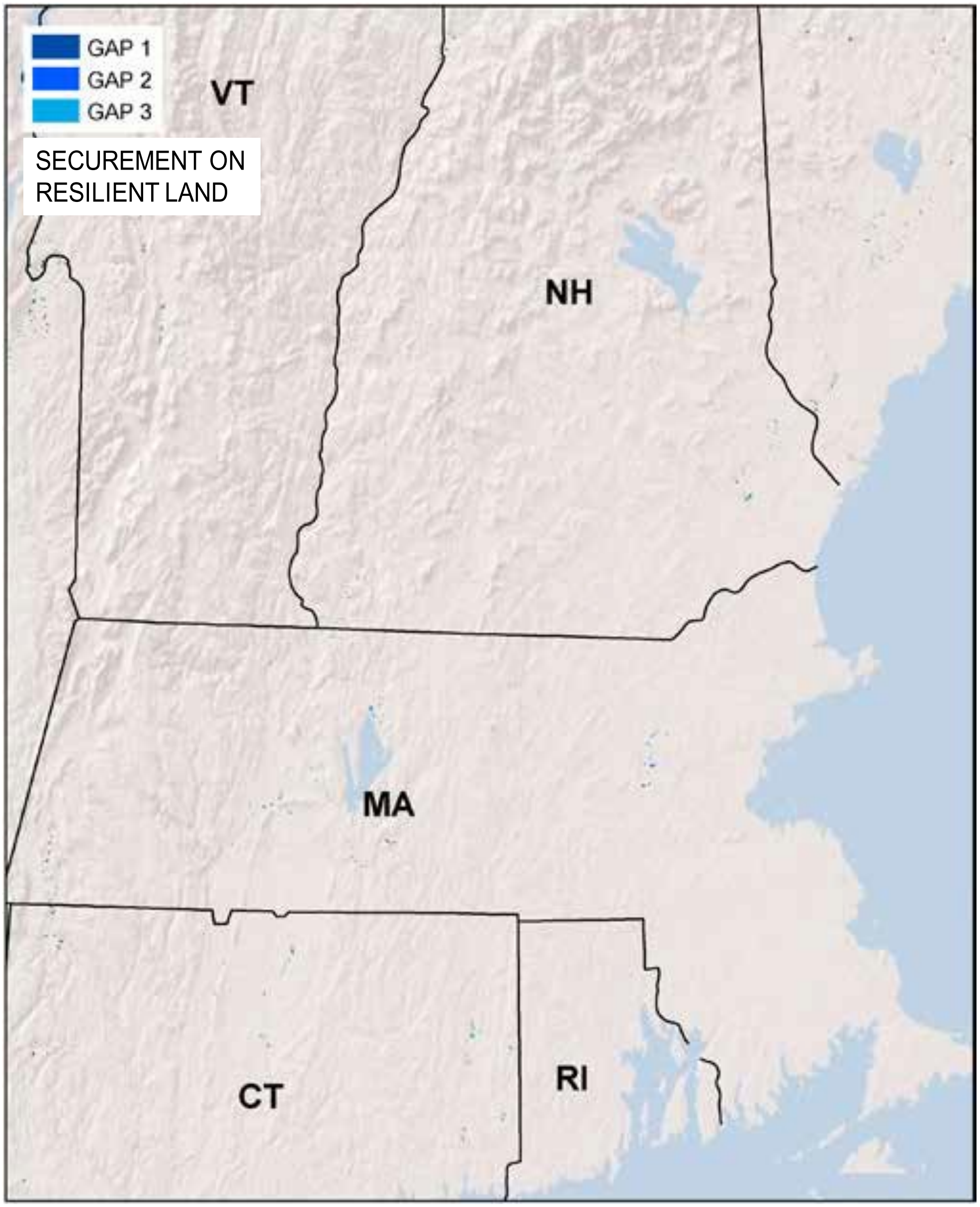


Predicted Loss to Development by 2050

High 11%

This community is threatened by development, with 2,743 acres (11%) likely to be lost over the next 30 years.

North Central Interior Wet Flatwoods



LOCATION	TOTAL ACRES	% SECURED
New England	25,306	16%
CT	9,249	16%
MA	9,553	20%
ME	2,783	3%
NH	1,955	24%
RI		
VT	1,765	6%

LOCATION	RESILIENT ACRES	% SECURED
New England	6,297	17%
CT	1,551	21%
MA	1,829	26%
ME	1,548	3%
NH	613	23%
RI		
VT	757	9%

Rare or Uncommon Plants Associated with this Habitat

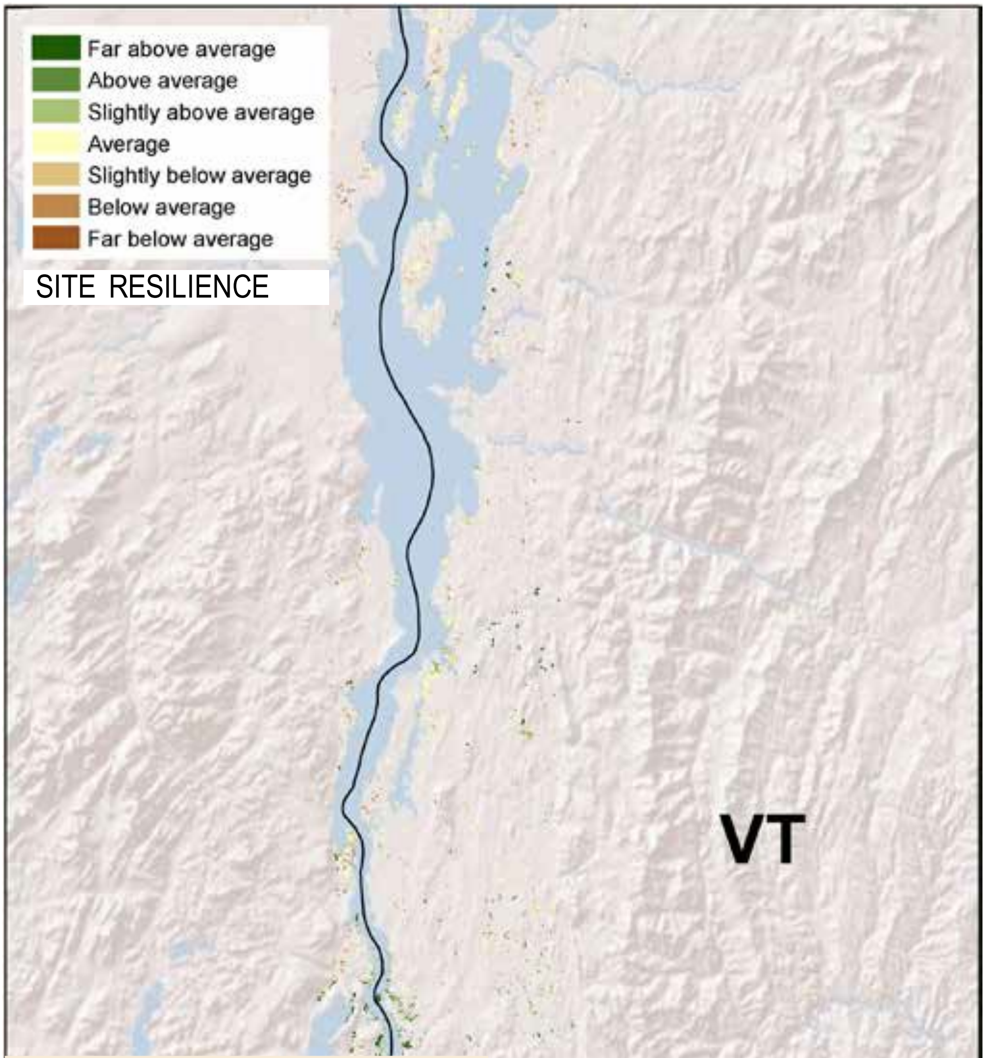
southern agrimony (*Agrimonia parviflora*)

fox-tail sedge (*Carex alopecoidea*)

Virginia spring-beauty (*Claytonia virginica*)

sweet-gum (*Liquidambar styraciflua*)

Glacial Marine & Lake Wet Clayplain Forest




© Eric Sorenson (Vermont Fish & Wildlife)

Description

A wetland variant of the mesic clayplain forest. The two types occur in a tight mosaic on the landscape. Swamp white oak, green ash, red maple, black ash, andmusclewood are common along with moisture-loving sedges and herbs such as sensitive fern and water hemlock.

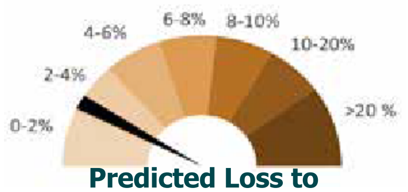
Associated Herbs & Shrubs

American hazelnut (*Corylus americana*) broad beech fern (*Phegopteris hexagonoptera*), buxbaum's sedge (*Carex buxbaumii*), folliculate sedge (*Carex folliculate*), fragrant sumac (*Rhus aromatic*), rough avens (*Geum laciniatum*), spicebush (*Lindera benzoin*), leafy bulrush (*Scirpus polyphyllus*), white ash (*Fraxinus americana*), green ash (*Fraxinus pennsylvanica*), black ash (*Fraxinus nigra*), eastern hemlock (*Tsuga canadensis*), northern red oak (*Quercus rubra*)

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	2%	301	13%	0%	6%	19%	81%
Above average	10%	1,396	8%	1%	5%	14%	86%
Slightly above average	19%	2,642	6%	1%	7%	14%	86%
Average	52%	7,332	2%	0%	10%	12%	88%
Slightly below average	11%	1,513	0%	0%	9%	9%	91%
Below average	3%	449	0%	0%	3%	3%	97%
Far below average	0%	18	0%	0%	0%	0%	100%
Developed	3%	381	1%	1%	15%	17%	83%
TOTAL	**100%**	**14,032**	**3%**	**0%**	**9%**	**12%**	**88%**

Resilience & Securement

31% of this rare habitat scores high for resilience, 12% of the total acreage is securedagainst conversion, and 3% is protected.

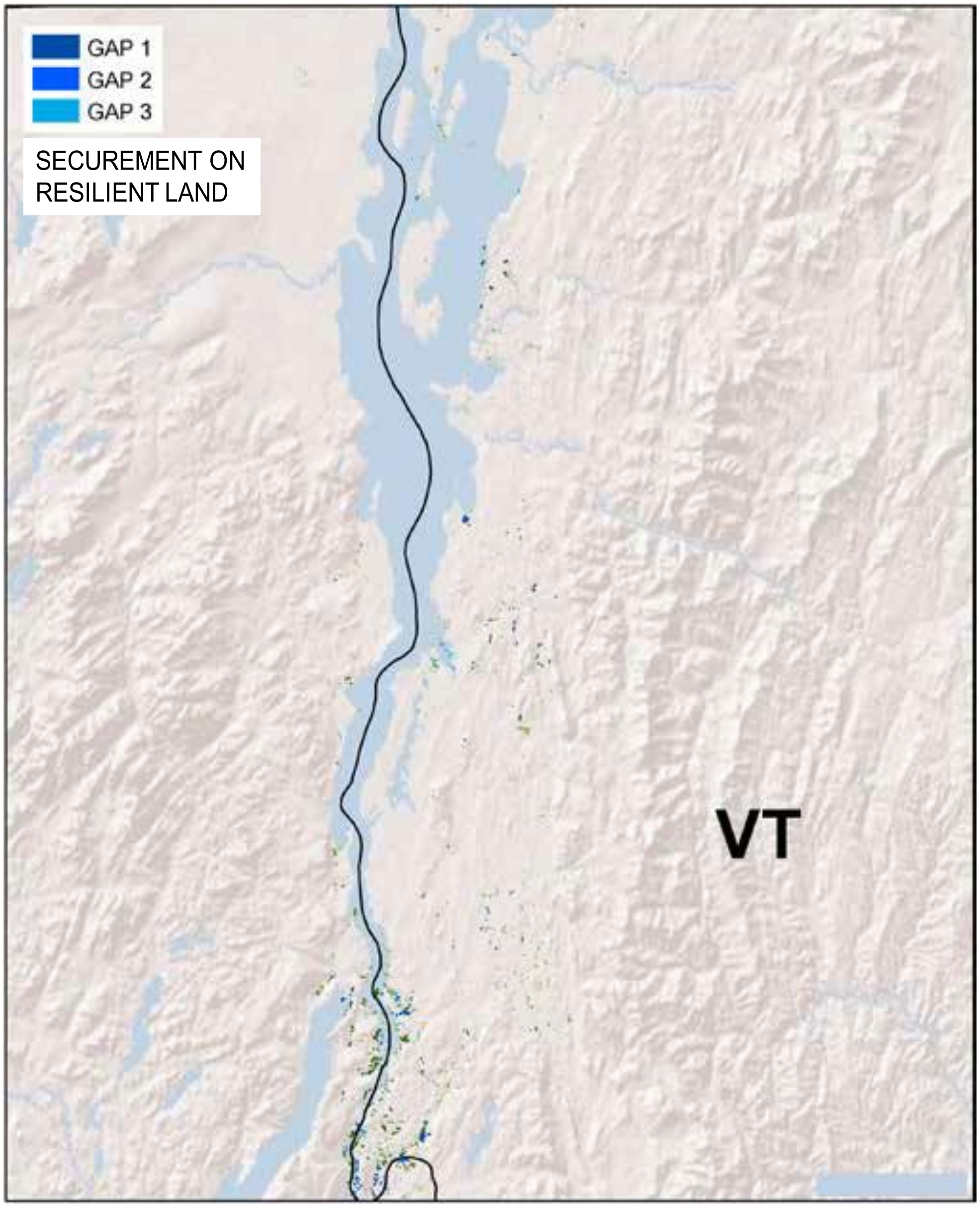


Predicted Loss to Development by 2050

Low 3%

This community is not threatenedby development, with 377 acres (3%) likely to be lost over the next30 years.

Glacial Marine & Lake Wet Clayplain Forest



LOCATION	TOTAL ACRES	% SECURED
New England	14,032	12%
CT		
MA		
ME		
NH		
RI		
VT	14,032	12%

LOCATION	RESILIENT ACRES	% SECURED
New England	4,340	14%
CT		
MA		
ME		
NH		
RI		
VT	4,340	14%

Rare or Uncommon Plants Associated with this Habitat

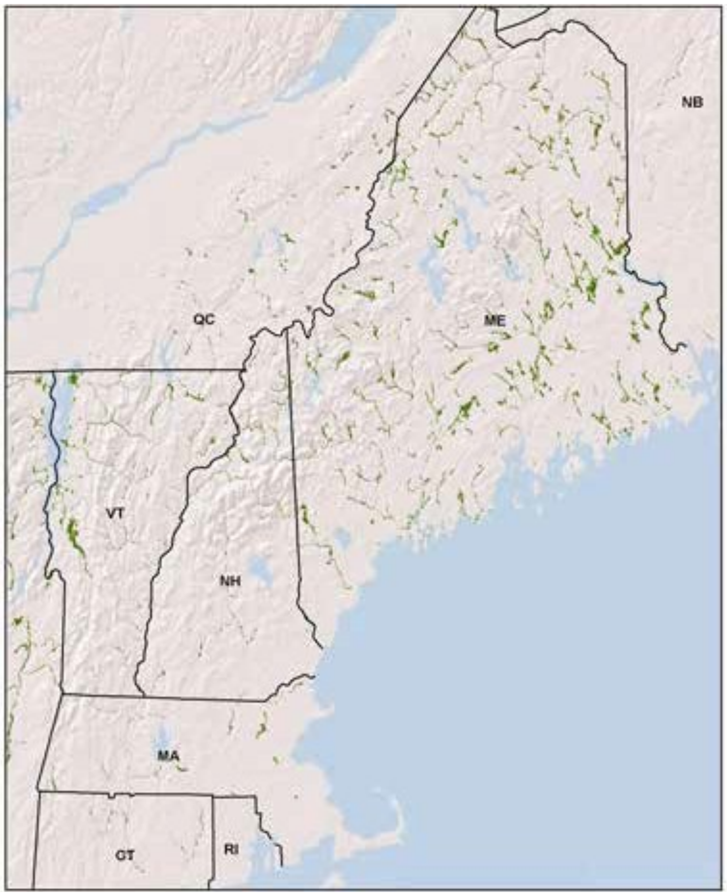
handsome sedge
(*Carex formosa*)

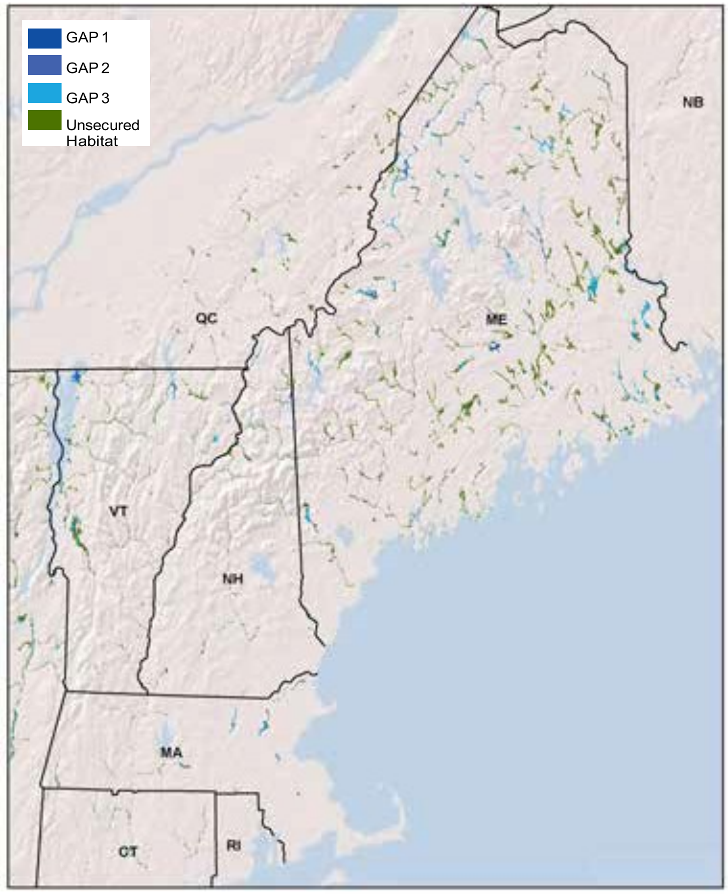
American ginseng
(*Panax quinquefolius*)

pine-drops
(*Pterospora andromedea*)

© Elizabeth Thompson (Vermont Land Trust)

MACROGROUP
LARGE RIVER FLOODPLAIN



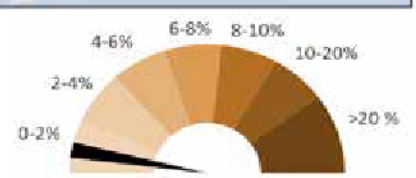


Large River Floodplain

A complex of wetland and upland vegetation on floodplains of medium to large rivers in New England.

Acres in New England

340,644



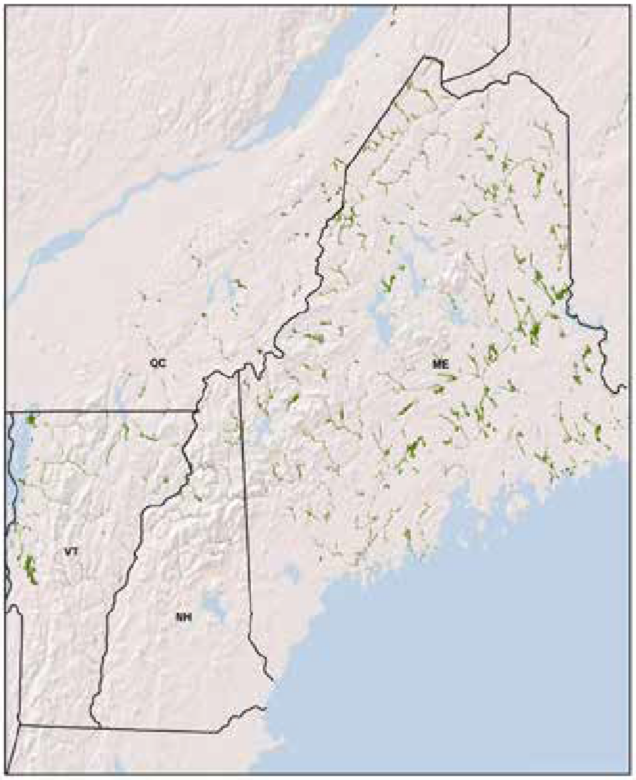
Predicted Loss to Development by 2050

3,846 acres (1%)

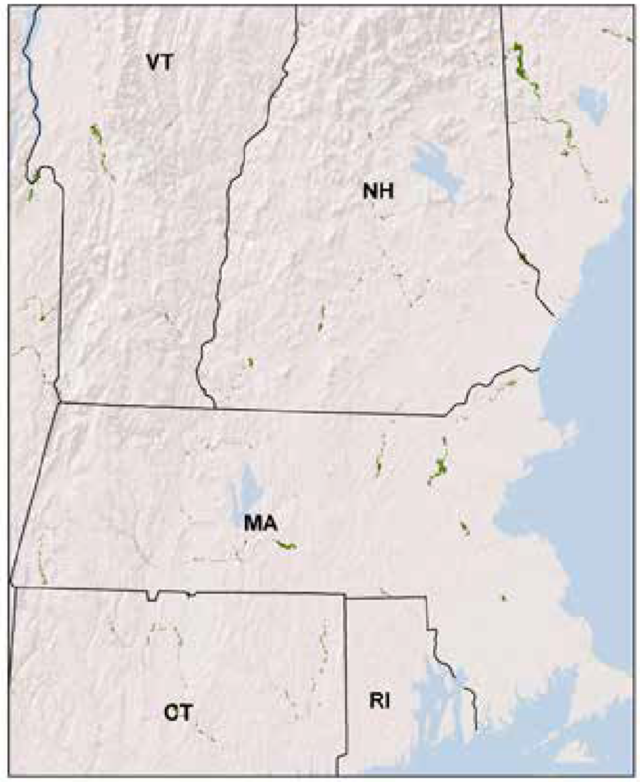
	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS TOTAL	P	S	U
Large River Floodplain	**340,644**	**3%**	**5%**	**17%**	**75%**	**3**			**3**
Connecticut	3,814	0%	6%	25%	68%				
Massachusetts	9,684	0%	17%	24%	59%	3		1	2
Maine	259,721	3%	3%	18%	76%				
New Hampshire	16,413	3%	5%	12%	80%				
Rhode Island	19	0%	0%	12%	88%				
Vermont	50,993	2%	9%	14%	74%				
New England	**340,644**	**9,409**	**16,055**	**59,440**	**255,741**				

P = Protected S = Secured
U = Unsecured

DISTRIBUTION OF HABITATS

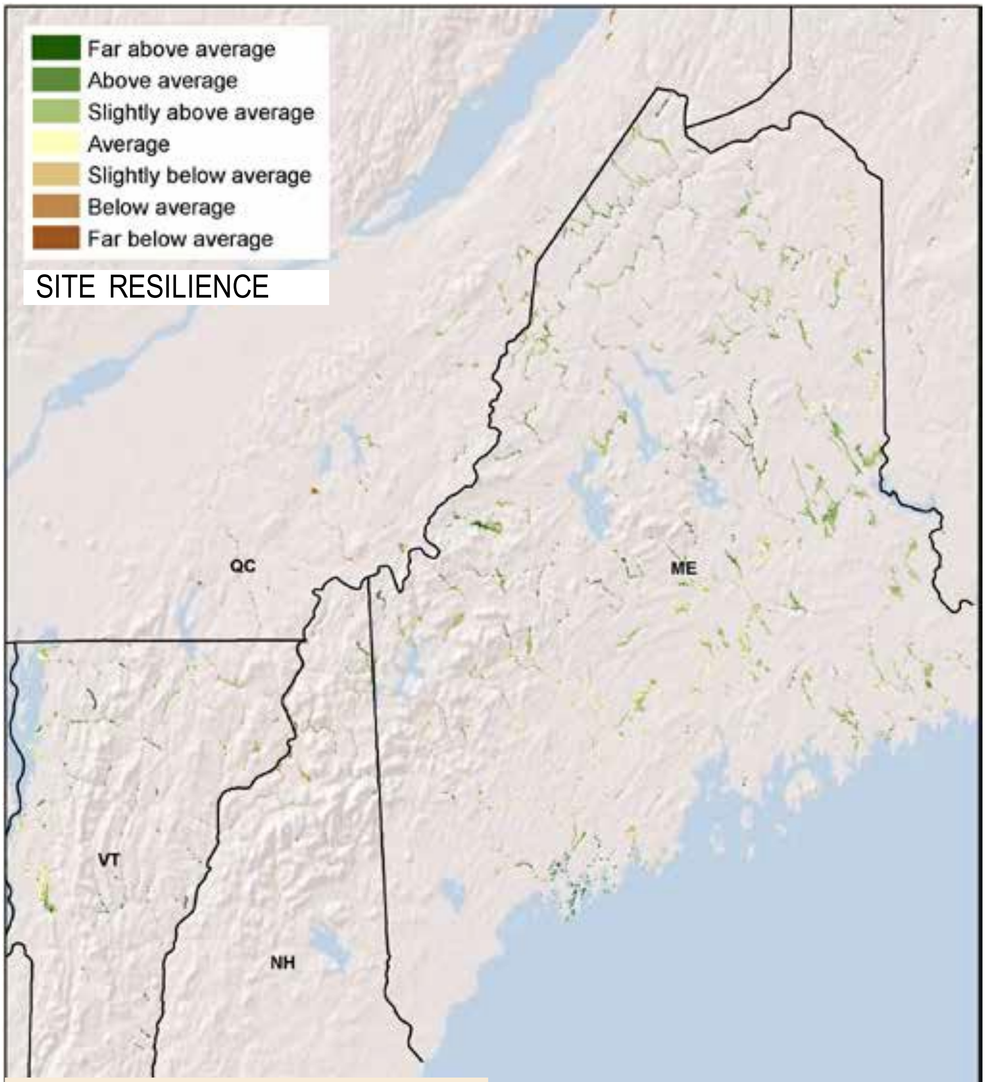


Laurentian-Acadian Large River Floodplain



North-Central Appalachian Large River Floodplain

Laurentian-Acadian Large River Floodplain



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	2,828	4%	5%	20%	29%	71%
Above average	18%	56,876	5%	6%	21%	32%	68%
Slightly above average	49%	152,433	3%	4%	21%	27%	73%
Average	20%	62,774	2%	6%	9%	16%	84%
Slightly below average	5%	16,559	2%	2%	6%	10%	90%
Below average	3%	8,681	0%	4%	6%	11%	89%
Far below average	0%	913	0%	0%	6%	6%	94%
Developed	3%	7,992	1%	3%	11%	15%	85%
TOTAL	**100%**	**309,055**	**3%**	**5%**	**17%**	**25%**	**75%**

Resilience & Securement

68% of this habitat scores high for resilience, and 25% of the total acreage is secured against conversion, with the resilient areas having the highest proportion of securement.

© Elizabeth Thompson (Vermont Land Trust)

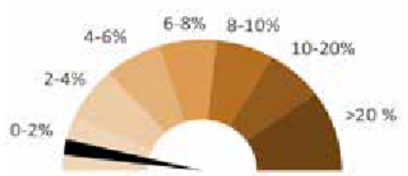
Description

A complex of wetland and upland vegetation on floodplains of medium to large northern rivers. Vegetation includes silver maple forests as well as shrub wetlands. Green ash, American elm, red maple, and musclewood are typical.

Spring ephemeral herbs are abundant.

Associated Herbs & Shrubs

eastern bottle-brush grass (*Elymus hystrix*), green-dragon (*Arisaema dracontium*), lance-leaved figwort (*Scrophularia lanceolata*), cut-leaved windflower (*Anemone multifida*), winged loosestrife (*Lythrum alatum*), false water-pepper smartweed (*Polygonum hydropiperoides*), purple virgin's-bower (*Clematis occidentalis*), Virginia water-horehound (*Lycopus virginicus*), greater yellow water crowfoot (*Ranunculus flabellaris*)

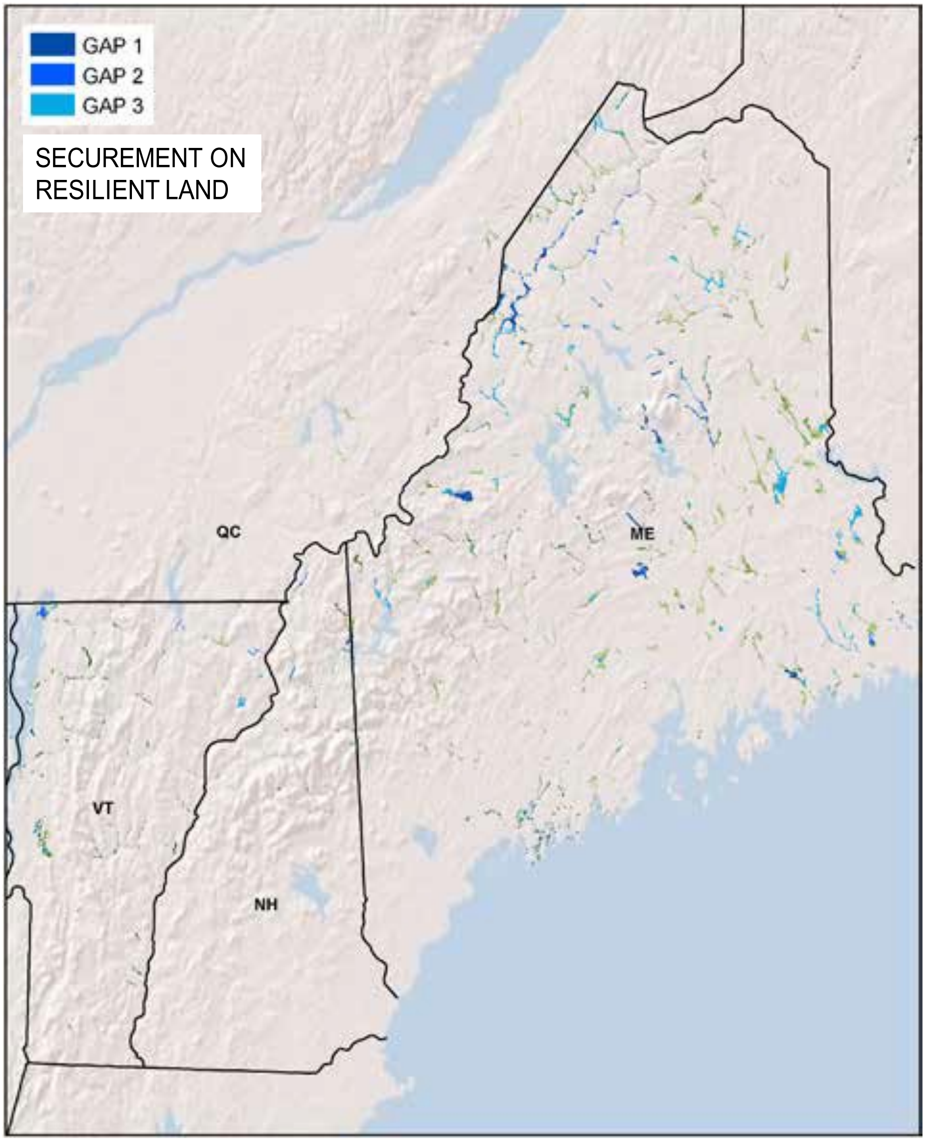


Predicted Loss to Development by 2050

Very low <1%

This community is not threatened by development, with 2,405 acres (<1%) likely to be lost over the next 30 years.

Laurentian-Acadian Large River Floodplain



LOCATION	TOTAL ACRES	% SECURED
New England	309,055	24%
CT		
MA		
ME	249,426	24%
NH	12,010	20%
RI		
VT	47,620	26%

LOCATION	RESILIENT ACRES	% SECURED
New England	212,136	29%
CT		
MA		
ME	186,857	29%
NH	5,373	27%
RI		
VT	19,906	27%

Rare or Uncommon Plants Associated with this Habitat

Eaton's beggar-ticks (*Bidens eatonii*)

Long's bitter-cress (*Cardamine longii*)

tidal spikesedge (*Eleocharis aestuum*)

Provancher's Philadelphia fleabane (*Erigeron philadelphicus* var. *provancheri*)

parker's pipewort (*Eriocaulon parkeri*)

Robinson's hawkweed (*Hieracium robinsonii*)

auricled twayblade (*Neottia auriculata*)

Furbish's lousewort (*Pedicularis furbishiae*)

Anticosti American-aster (*Symphyotrichum anticostense*)

Gaspe serviceberry (*Amelanchier gaspensis*)

scabrous black sedge (*Carex atratiformis*)

Crawe's sedge (*Carex crawei*)

beaked sedge (*Carex rostrata*)

early wild-rye (*Elymus macgregorii*)

hyssop-leaved fleabane (*Erigeron hyssopifolius*)

musky monkey-flower (*Erythranthe [Mimulus] moschata*)

northern dwarf-gentian (*Gentianella amarella* ssp. *acuta*)

greater creeping rush (*Juncus subtilis*)

Vasey's rush (*Juncus vaseyi*)

field oxytrope (*Oxytropis campestris* var. *johannensis*)

bayberry willow (*Salix myricoides*)

northern wild senna (*Senna hebecarpa*)

rough dropseed (*Sporobolus compositus* var. *drummondii*)

eastern tansy (*Tanacetum bipinnatum* ssp. *huronense*)

veiny-leavedmeadow-rue (*Thalictrum venulosum* var. *confine*)

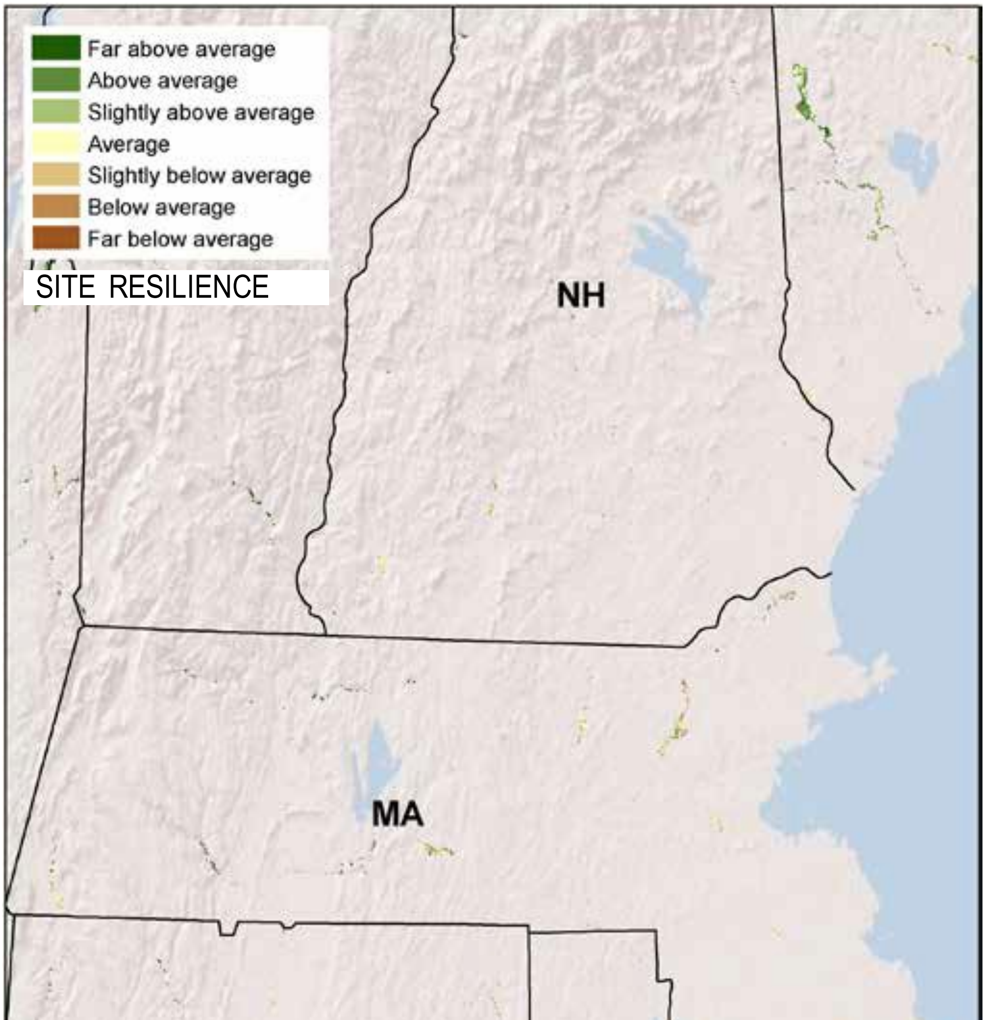
water speedwell (*Veronica catenata*)

Clinton's bulrush (*Trichophorum clintonii*)

New England violet (*Viola novae-angliae*)

elk sedge (*Carex garberi*)

North-Central Appalachian Large River Floodplain



© Bruce A. Sorrie (Massachusetts Division of Fisheries & Wildlife/ Natural Heritage & Endangered Species Program)

Description

A complex of wetland and upland vegetation on floodplains of medium to large rivers. The vegetation includes floodplain forests of silver maple, sycamore, box elder, and cottonwood,as well as herbaceous sloughs, shrub wetlands, ice scours, and riverside prairies.

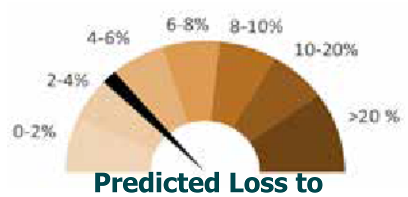
Associated Herbs & Shrubs

green-dragon (*Arisaema dracontium*), Canada moonseed (*Menispermum canadense*), smooth beggar-ticks (*Bidens laevis*)

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	4%	1,183	9%	5%	21%	36%	64%
Above average	24%	7,575	5%	3%	28%	37%	63%
Slightly above average	22%	7,081	1%	4%	26%	31%	69%
Average	34%	10,655	0%	9%	18%	28%	72%
Slightly below average	7%	2,064	1%	14%	18%	33%	67%
Below average	3%	993	2%	10%	14%	25%	75%
Far below average	0%	60	0%	0%	6%	6%	94%
Developed	6%	1,979	1%	5%	12%	18%	82%
TOTAL	**100%**	**31,590**	**2%**	**6%**	**22%**	**30%**	**70%**

Resilience & Securement

50% of this habitat scores high for resilience, 30% of the total acreage is secured against conversion, and 8% is protected.

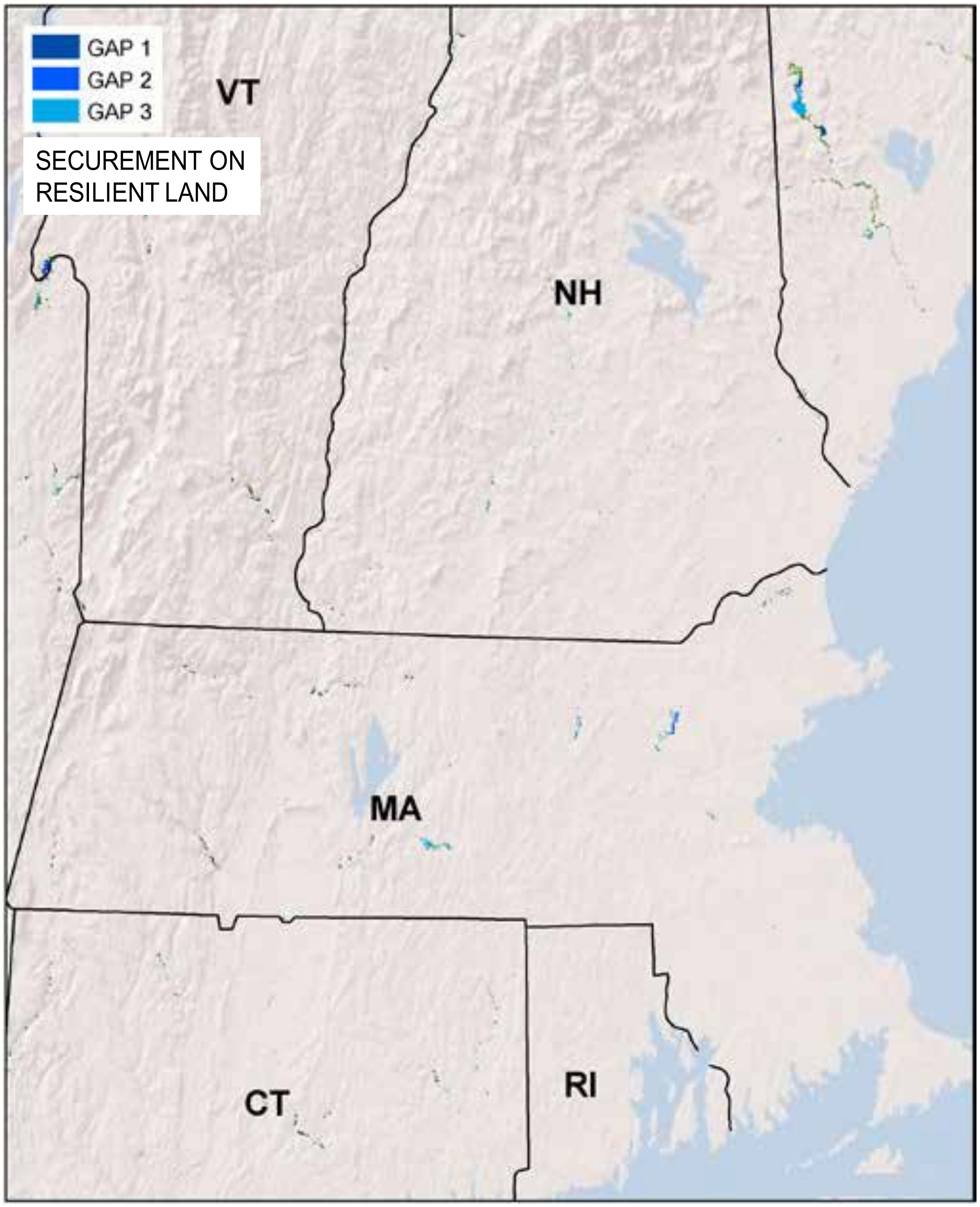


Predicted Loss to Development by 2050

Moderately low 4%

This community is moderately threatened by development, with 1,441 acres (4%) likely to be lost over the next 30 years.

North-Central Appalachian Large River Floodplain



LOCATION	TOTAL ACRES	% SECURED
New England	31,590	30%
CT	3,814	32%
MA	9,684	41%
ME	10,296	30%
NH	4,403	20%
RI	19	12%
VT	3,374	15%

LOCATION	RESILIENT ACRES	% SECURED
New England	15,839	34%
CT	1,277	32%
MA	3,173	40%
ME	7,770	37%
NH	1,345	29%
RI	1	0%
VT	2,274	18%

© Michael Batcher

Rare or Uncommon Plants Associated with this Habitat

Provancher's Philadelphia fleabane
(*Erigeron philadelphicus* var. *provancheri*)

Robinson's hawkweed
(*Hieracium robinsonii*)

early wild-rye
(*Elymus macgregorii*)

musky monkey-flower
(*Erythranthe [Mimulus] moschata*)

northern wild senna
(*Senna hebecarpa*)

hairy hedge-nettle
(*Stachys pilosa* var. *arenicola*)

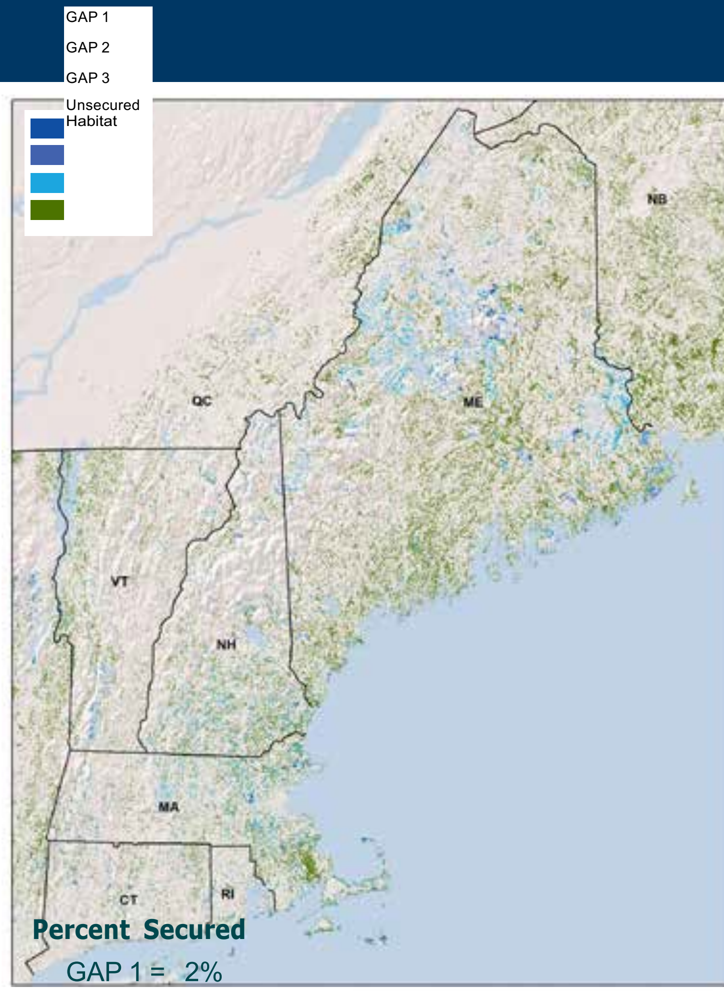
crooked-stemmed American-aster
(*Symphyotrichum prenanthoides*)

MACROGROUP

FRESHWATER MARSH & SHRUB SWAMP

Freshwater Marsh & Shrub Swamp

Acres in New England
860,248



Percent Secured

GAP 1 = 2%

GAP 2 = 4%

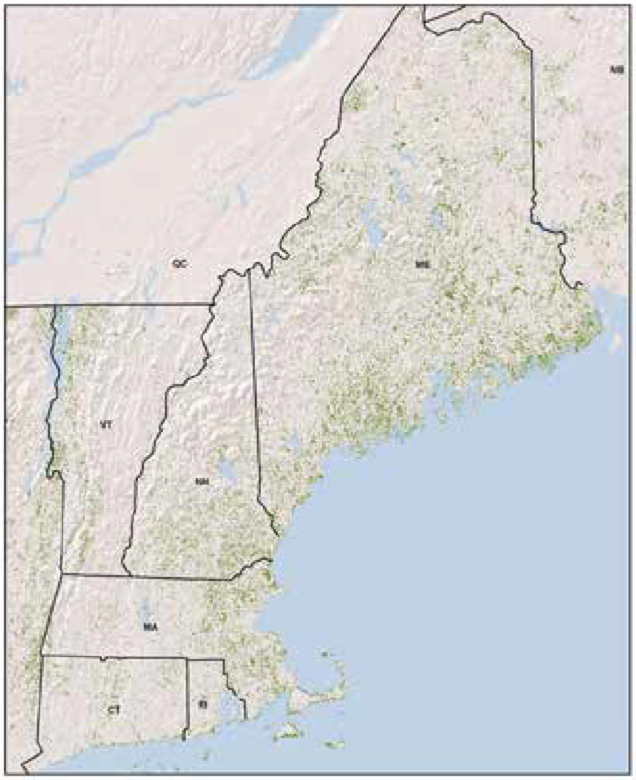
GAP 3 = 16%

Freshwater marshes, meadows, and shrub swamps dominated by herbaceous or shrubby vegetation without trees.

	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	IMPORTANT PLANT AREAS TOTAL	P	S	U
Freshwater Marsh & Shrub Swamp	**860,248**	**2%**	**4%**	**16%**	**77%**	**8**		**1**	**7**
Connecticut	37,445	1%	7%	16%	76%	2			2
Massachusetts	125,850	2%	5%	25%	69%	5		1	4
Maine	503,015	2%	4%	14%	80%	1			1
New Hampshire	104,684	2%	4%	22%	72%				
Rhode Island	9,349	2%	7%	24%	66%				
Vermont	79,905	0	0	0	1%				
New England	**860,248**	**19,621**	**33,048**	**141,563**	**666,016**				

P = Protected S = Secured
U = Unsecured

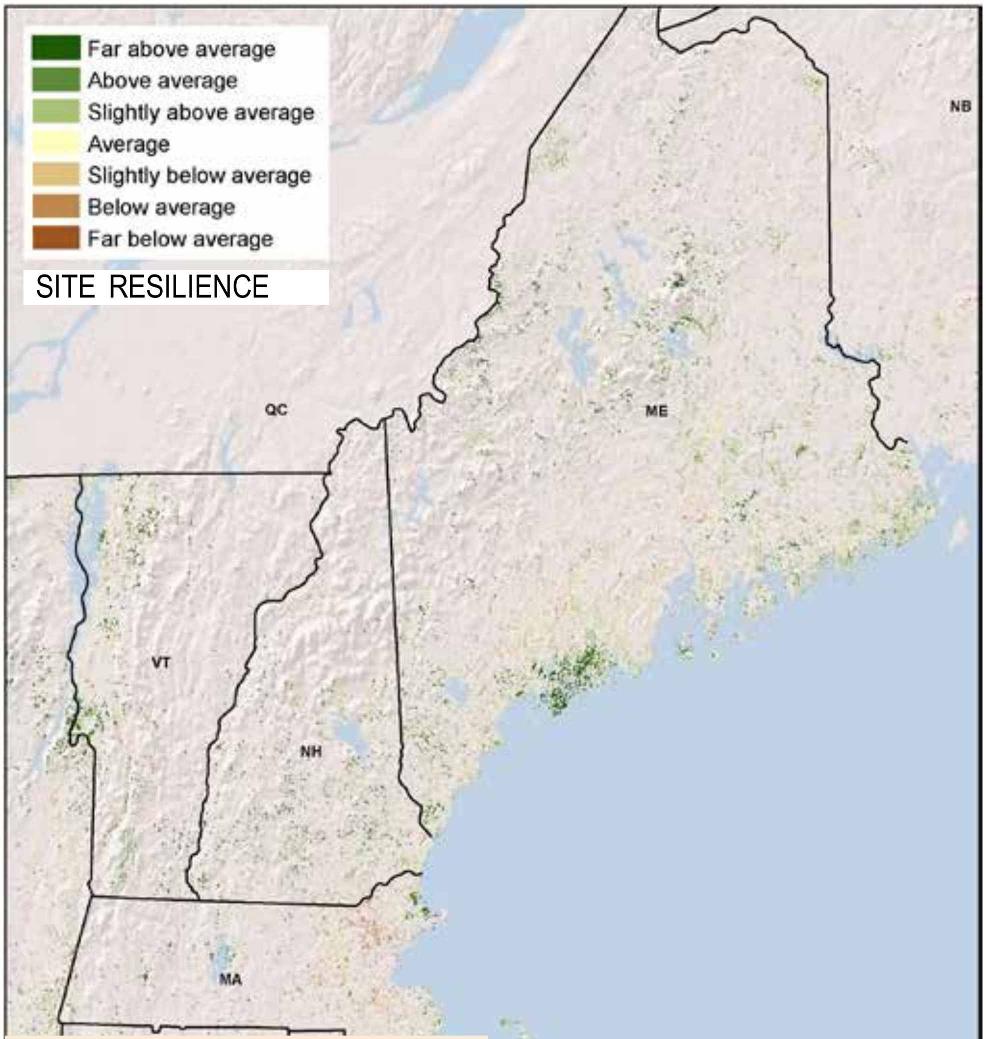
DISTRIBUTION OF HABITATS



Laurentian-Acadian Freshwater Marsh

Laurentian-Acadian Wet Meadow-Shrub Swamp

Laurentian-Acadian Freshwater Marsh



			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	2%	6,717	7%	7%	18%	32%	68%
Above average	18%	67,429	7%	6%	20%	33%	67%
Slightly above average	39%	141,544	2%	4%	18%	24%	76%
Average	25%	92,775	1%	4%	13%	18%	82%
Slightly below average	7%	23,899	1%	4%	13%	18%	82%
Below average	3%	12,784	1%	4%	12%	17%	83%
Far below average	1%	2,019	1%	2%	11%	13%	87%
Developed	6%	20,339	1%	2%	9%	12%	88%
TOTAL	**100%**	**367,506**	**3%**	**4%**	**16%**	**23%**	**77%**

Resilience & Securement

59% of this habitat scores high for resilience, and 23% of the total acreage is secured against conversion, with the resilient areas having the highest proportion of securement.

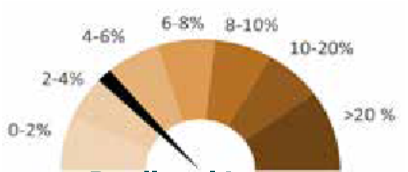
© Maine Natural Areas Program

Description

An emergent or submergent freshwatermarsh dominated by herbaceous vegetation and associated with basins, streamways, and seepage slopes.
Typical plants include cattails, marsh fern,touch-me-not, pondweeds, water lilies, pickerelweed, and tall rushes that die back in winter.

Associated Herbs & Shrubs

autumn water-starwort (*Callitriche hermaphroditica*), hard-stemmed club-bulrush (*Schoenoplectus acutus*), marsh-felwort (*Lomatogonium rotatum*), hairy hedge-nettle (*Stachys pilosa*), whorled marsh-pennywort (*Hydrocotyle verticillata*)

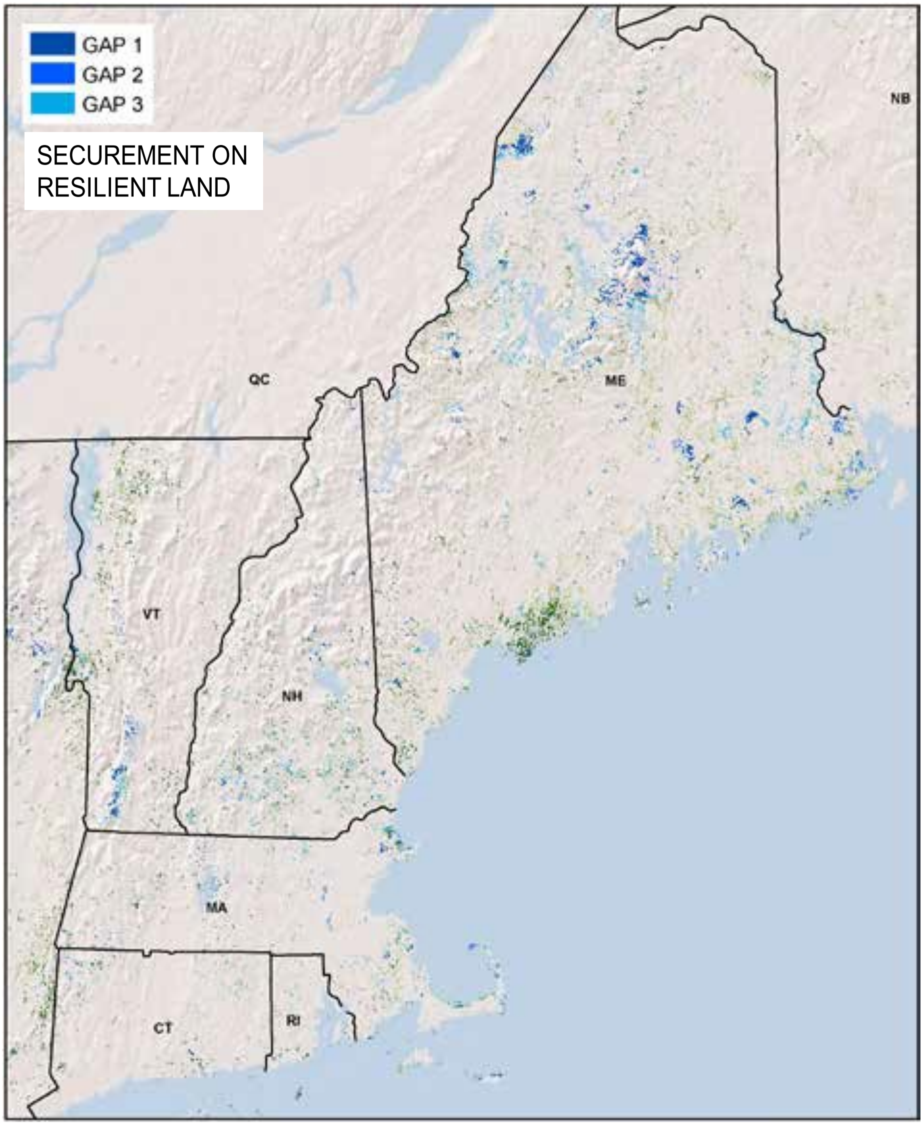


Predicted Loss to Development by 2050

Moderately low 4%

This community is somewhat threatened by development, with 14,428 acres (4%) likely to be lost over the next 30 years.

Laurentian-Acadian Freshwater Marsh



LOCATION	TOTAL ACRES	% SECURED
New England	367,506	23%
CT	14,698	27%
MA	50,638	32%
ME	213,591	20%
NH	46,252	28%
RI	4,321	30%
VT	38,007	20%

LOCATION	RESILIENT ACRES	% SECURED
New England	215,690	27%
CT	5,917	35%
MA	15,450	40%
ME	144,533	24%
NH	27,559	32%
RI	1,468	44%
VT	20,763	29%

Rare or Uncommon Plants Associated with this Habitat

New England thoroughwort (*Eupatorium novae-angliae*)

Plymouth rose-gentian (*Sabatia kennedyana*)

quill-leaved arrowhead (*Sagittaria teres*)

northeastern bulrush (*Scirpus ancistrochaetus*)

southern agrimony (*Agrimonia parviflora*)

wheat sedge (*Carex atherodes*)

Emory's sedge (*Carex emoryi*)

Mitchell's sedge (*Carex mitchelliana*)

Walter's sedge (*Carex striata*)

collared dodder (*Cuscuta indecora* var. *indecora*)

American waterwort (*Elatine americana*)

horsetail spikesedge (*Eleocharis equisetoides*)

square-stemmed spikesedge (*Eleocharis quadrangulata*)

dwarf burhead (*Helanthium tenellum*)

large grass-leaved rush (*Juncus biflorus*)

many-fruited water-primrose (*Ludwigia polycarpa*)

round-pod water-primrose (*Ludwigia sphaerocarpa*)

foxtail bog-clubmoss

(*Lycopodiella alopecuroides*)

cut-leaved water-milfoil (*Myriophyllum pinnatum*)

golden-club (*Orontium aquaticum*)

Puritan smartweed (*Persicaria puritanorum*)

crested orangebog-orchid (*Platanthera cristata*)

Maryland meadow-beauty (*Rhexia mariana* var. *mariana*)

narrow-fruited beaksedge (*Rhynchospora inundata*)

short-beaked beaksedge (*Rhynchospora nitens*)

toothcup (*Rotala ramosior*)

slender rose-gentian (*Sabatia campanulata*)

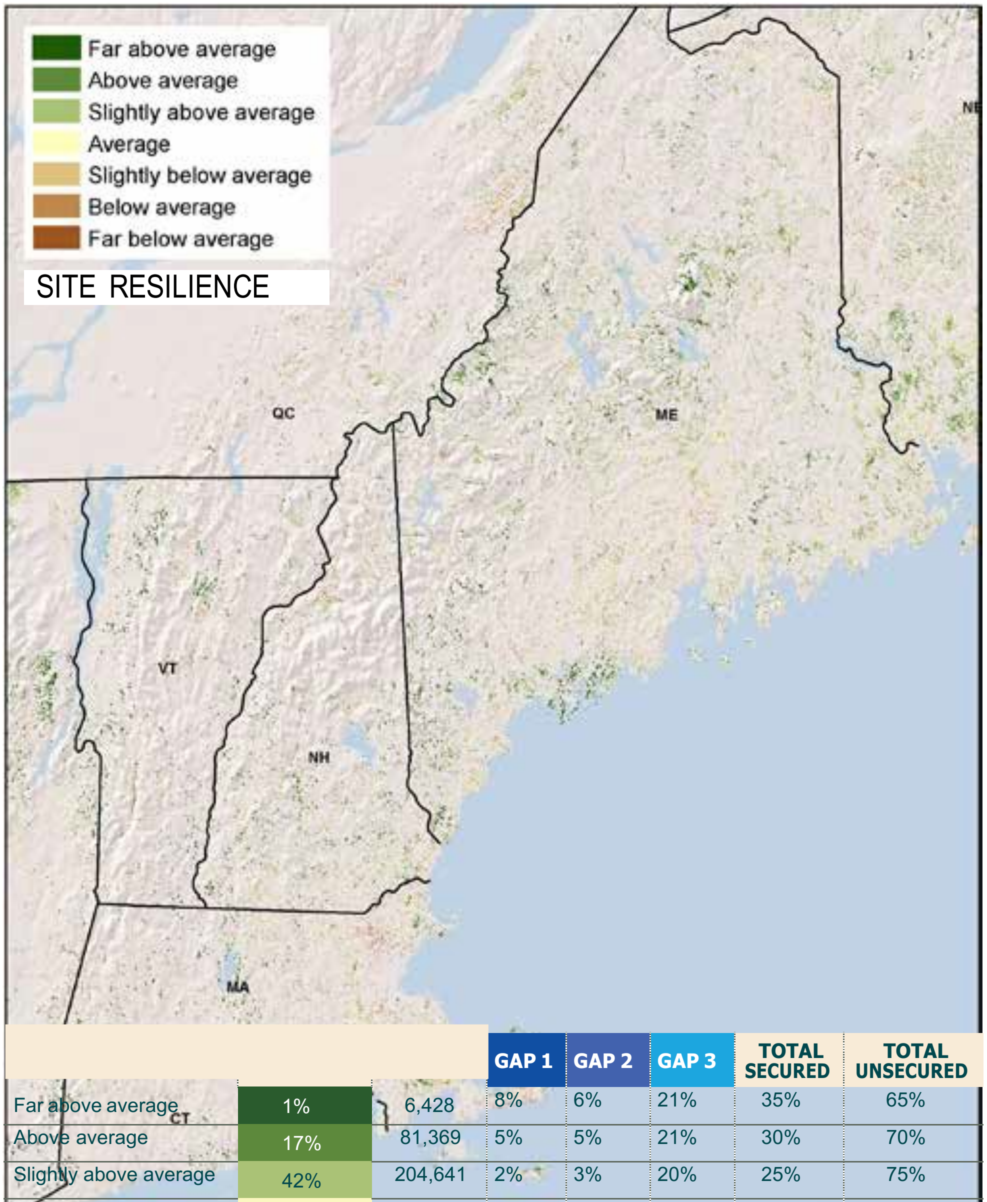
lizard's-tail (*Saururus cernuus*)

whip nutsedge (*Scleria triglomerata*)

sclerolepis (*Sclerolepis uniflora*)

swamp wedgescale (*Sphenopholis pensylvanica*)

Laurentian-Acadian Wet Meadow-Shrub Swamp



© Maine Natural Areas Program

Description

A shrub-dominated swamp or wet meadow on mineral soils. Examples occur in association with waterbodies and can be small and solitary or part of a larger wetland. Typical species include willow, red-osier dogwood, alder, buttonbush, meadowsweet, bluejoint grass, tall sedges, and rushes.

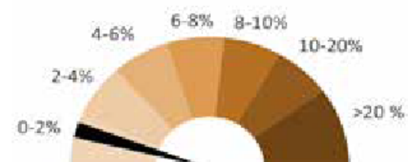
Associated Herbs & Shrubs

northern adder's-tongue fern (*Ophioglossum pusillum*), auricled twayblade (*Neottia auriculata*), marsh bellflower (*Campanula aparinoides*), swamp birch (*Betula pumila*), swamp lousewort (*Pedicularis lanceolata*)

			GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	1%	6,428	8%	6%	21%	35%	65%
Above average	17%	81,369	5%	5%	21%	30%	70%
Slightly above average	42%	204,641	2%	3%	20%	25%	75%
Average	25%	121,444	1%	3%	13%	16%	84%
Slightly below average	7%	33,117	1%	3%	13%	17%	83%
Below average	4%	18,811	1%	3%	12%	16%	84%
Far below average	0%	2,349	2%	2%	8%	12%	88%
Developed	5%	24,582	1%	3%	9%	12%	88%
TOTAL	**100%**	**492,741**	**2%**	**3%**	**17%**	**22%**	**78%**

Resilience & Securement

61% of this habitat scores high for resilience, 22% of the total acreage is secured against conversion, and 5% is protected.

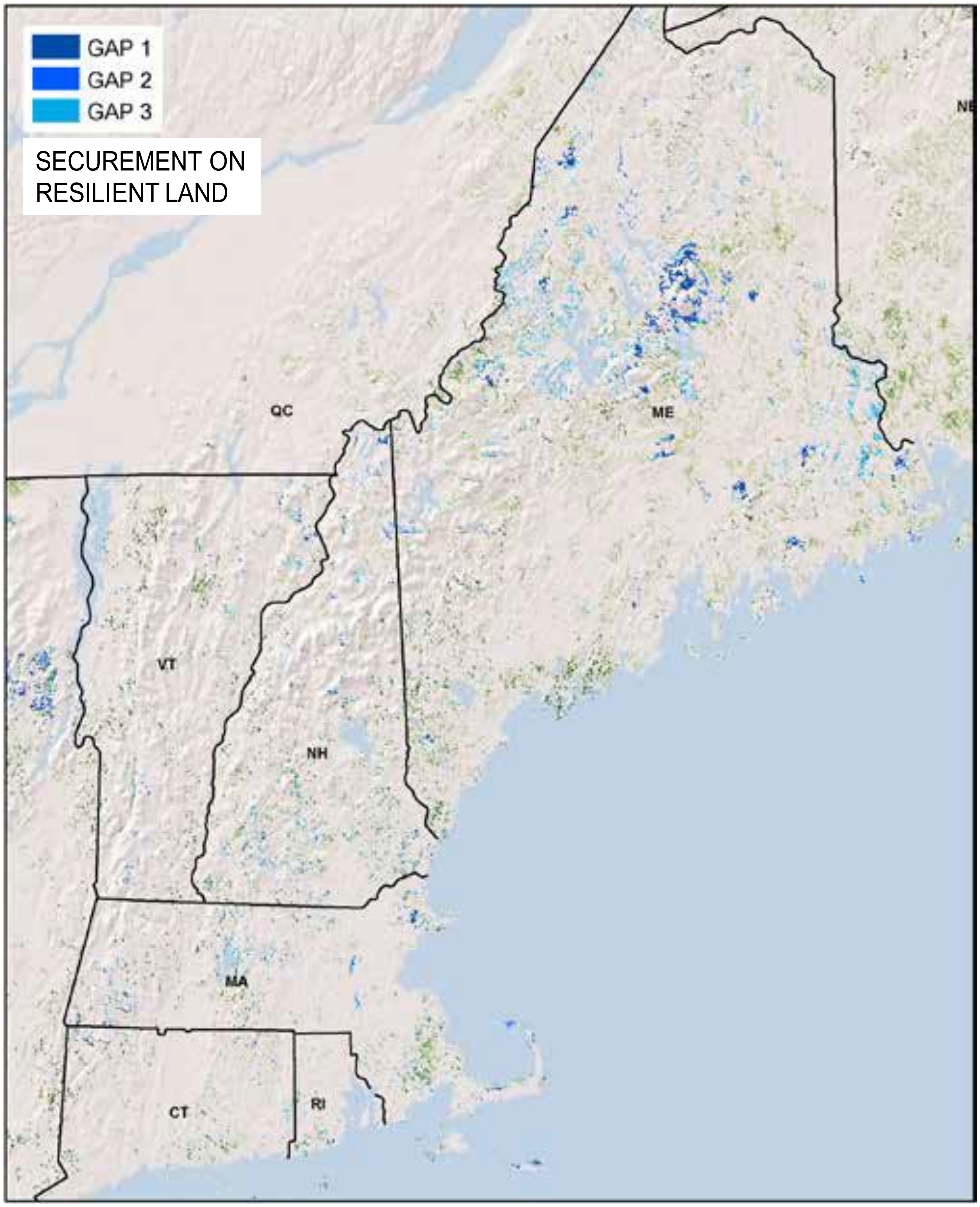


Predicted Loss to Development by 2050

Low 2%

This community is somewhat threatened by development, with 12,556 acres (2%) likely to be lost over the next 30 years.

Laurentian-Acadian Wet Meadow-Shrub Swamp




© Maine Natural Areas Program

LOCATION	TOTAL ACRES	% SECURED
New England	492,741	22%
CT	22,747	22%
MA	75,212	31%
ME	289,424	20%
NH	58,432	28%
RI	5,028	37%
VT	41,898	16%

LOCATION	RESILIENT ACRES	% SECURED
New England	292,438	27%
CT	8,619	29%
MA	27,185	39%
ME	197,211	24%
NH	34,525	32%
RI	2,135	47%
VT	22,764	23%

Rare or Uncommon Plants Associated with this Habitat

bog Jacob's-ladder
(*Polemonium van-bruntiae*)

Long's bulrush
(*Scirpus longii*)

wheat sedge
(*Carex atherodes*)

Barratt's sedge
(*Carex barrattii*)

white-edged sedge
(*Carex debilis* var. *debilis*)

blue sedge
(*Carex glaucodea*)

wiry panicgrass
(*Panicum flexile*)

field beadgrass
(*Paspalum laeve*)

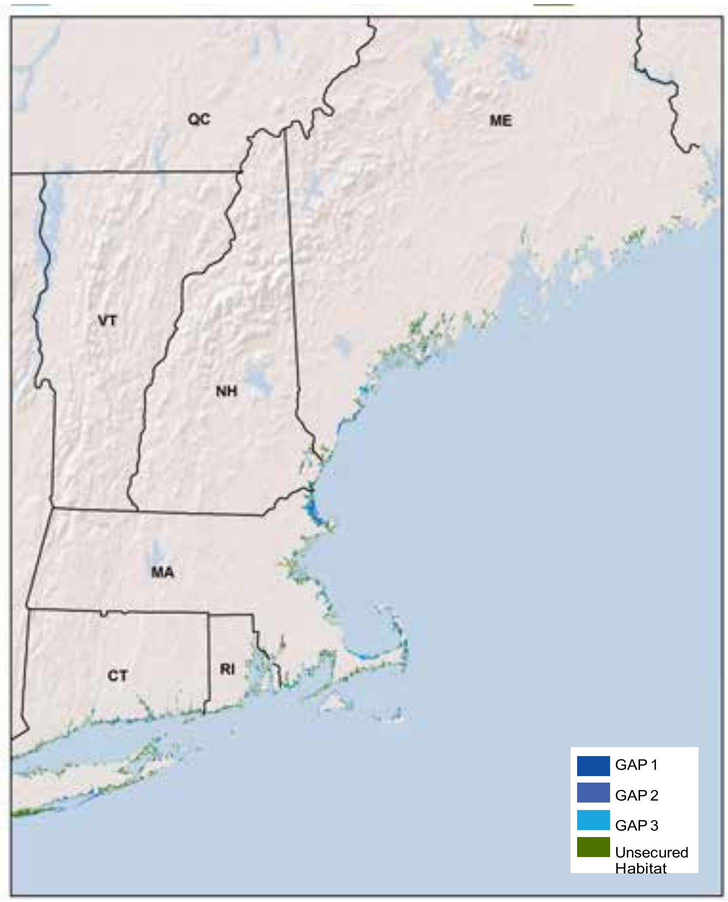
bristly smartweed
(*Persicaria setacea*)

orange fringed bog-orchid
(*Platanthera ciliaris*)

crested orange bog-orchid
(*Platanthera cristata*)

water-plantain crowfoot
(*Ranunculus ambigens*)

MACROGROUP
TIDAL MARSH



Tidal Marsh

Here two habitats, Acadian Coastal Salt & Estuary Marsh (ME only) and North Atlantic Coastal Plain Tidal Salt Marsh (CT, ME, NH, MA, RI), are treated as one.

Acres in New England

111,748

Percent Secured

GAP 1 = 2%

GAP 2 = 15%

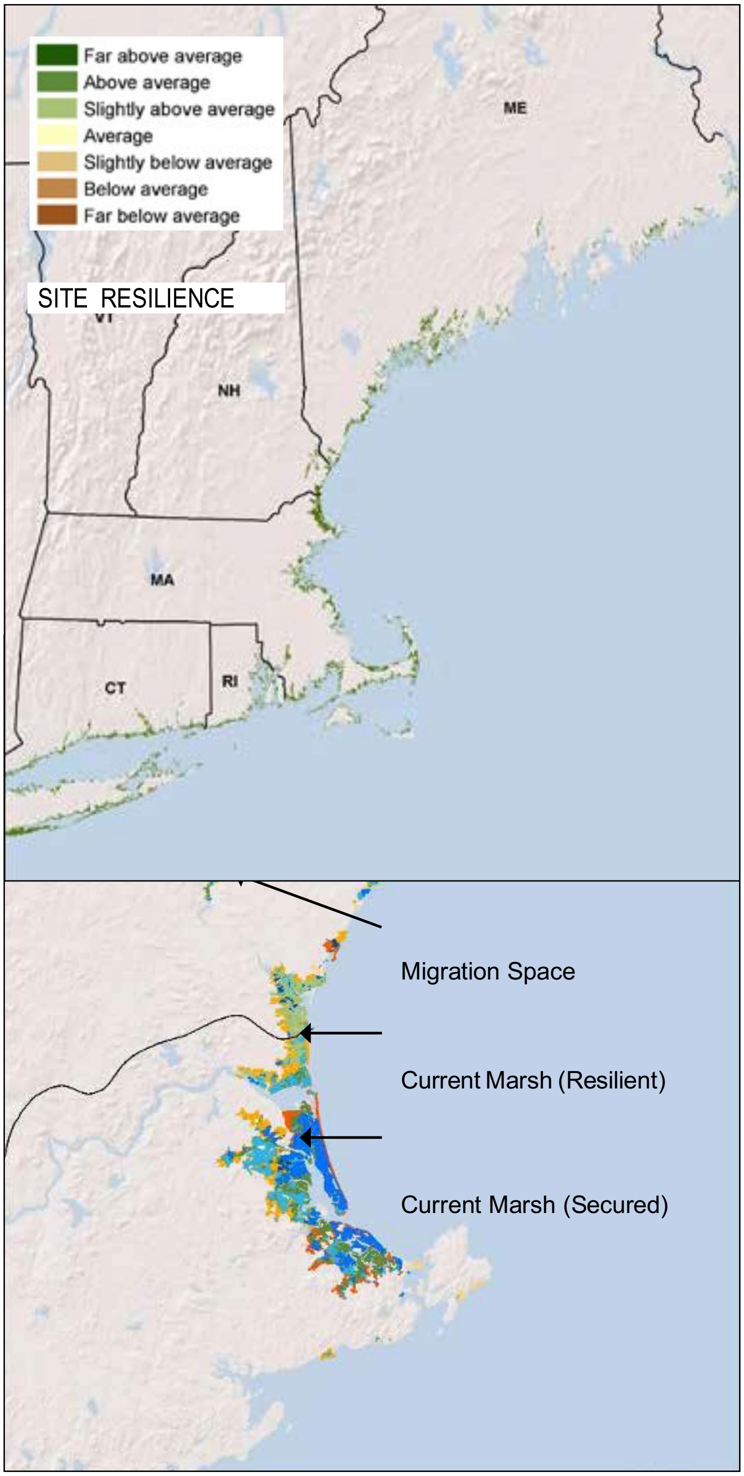
GAP 3 = 24%

Predicted Loss

Although the land on which they occur is fairly well protected, these marshes are succumbing to sea-level rise, which inundates the marsh and causes die-off.

						IMPORTANT PLANT AREAS			
	ACRES	GAP 1	GAP 2	GAP 3	UNSECURED	TOTAL	P	S	U
Tidal Marsh	**111,748**	**2%**	**15%**	**24%**	**58%**	**15**		**1**	**14**
Connecticut	15,084	4%	15%	24%	58%	2			2
Massachusetts	57,071	2%	16%	29%	53%	11			11
Maine	26,907	1%	16%	17%	66%				
New Hampshire	6,443	4%	4%	17%	74%				
Rhode Island	6,244	3%	16%	17%	65%	2		1	1
New England	**111,748**	**2,427**	**17,002**	**26,958**	**65,361**	P = Protected S = Secured U = Unsecured			

TIDAL MARSH



© Josh Royte (The Nature Conservancy, Maine)

Description

A complex of tidally influenced marshes from the coastal shoreto the tidal rivers. This habitat includes salt marsh, brackish marsh, and freshwater tidal marsh. A salt marsh profile features a low, regularly flooded marsh dominated by salt marsh cordgrass; a higher irregularly flooded marsh dominated by salt meadow cordgrass and saltgrass; low hypersaline pannes characterized by saltwort; and a salt scrub ecotone characterized by marsh elder, groundsel-tree, and switchgrass. Brackish areas support salt marsh cordgrass, giant cordgrass, narrowleaf cattail, and bulrush.

Associated Herbs & Shrubs

American sea-blite (*Suaeda calceoliformis*), dwarf glasswort (*Salicornia bigelovii*), big cordgrass (*Spartina cynosuroides*), saltmarsh tuber-bulrush (*Schoenoplectus maritimus*), saltmarsh agalinis (*Agalinis maritima*), sea pink (*Sabatia stellaris*), sea coast Angelica (*Angelica lucida*)

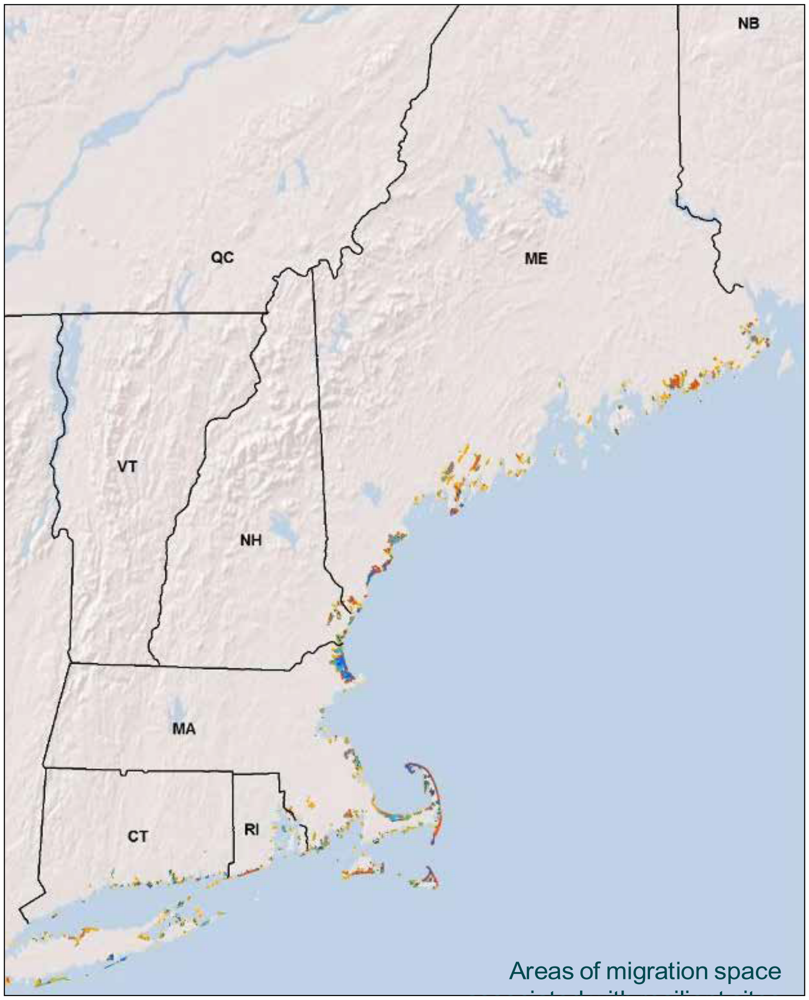
Migration Space

A key concept for estimating the resilience of tidal habitatsis whether they have:

1) Migration space: available adjacent lowlands suitable for the formation of future marsh under rising sea levels

2) Intact processes: the processes needed to facilitate migration: sediments, freshwater, and an absence of barriers.

TIDAL MARSH



Rare or Uncommon Plants Associated with this Habitat

Eaton's beggar-ticks (*Bidens eatonii*)

Long's bitter-cress (*Cardamine longii*)

tidal spikesedge (*Eleocharis aestuum*)

Parker's pipewort (*Eriocaulon parkeri*)

herbaceous sea-blite (*Suaeda maritima* ssp. *richii*)

New England tuber-bulrush (*Bolboschoenus novae-angliae*)

American waterwort (*Elatine americana*)

beaked spikesedge (*Eleocharis rostellata*)

whorled marsh-pennywort (*Hydrocotyle verticillata*)

Torrey's rush (*Juncus torreyi*)

bearded sprangletop (*Leptochloa fusca* ssp. *fascicularis*)

immigrant pond-lily (*Nuphar advena*)

golden-club (*Orontium aquaticum*)

swamp lousewort (*Pedicularis lanceolata*)

awl-leaved arrowhead (*Sagittaria subulata*)

Annual sea-purslane (*Sesuvium maritimum*)

hairy hedge-nettle (*Stachys pilosa* var. *arenicola*)

yellow thistle
(*Cirsium horridulum* var. *horridulum*)

winged monkey-flower (*Mimulus alatus*)

SITE RESILIENCE	RESILIENT	ACRES	GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	11%	15,031	0%	2%	4%	7%	5%
Above average	42%	55,630	1%	7%	8%	16%	27%
Slightly above average	18%	24,064	0%	1%	3%	4%	14%
Average	18%	23,415	0%	1%	3%	4%	14%
Slightly below average	3%	4,076	0%	0%	0%	0%	3%
Below average	3%	3,724	0%	0%	0%	0%	2%
Far below average	[illegible]	5,552	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL	[illegible]	**131,492**	**2%**	**12%**	**19%**	**33%**	**67%**

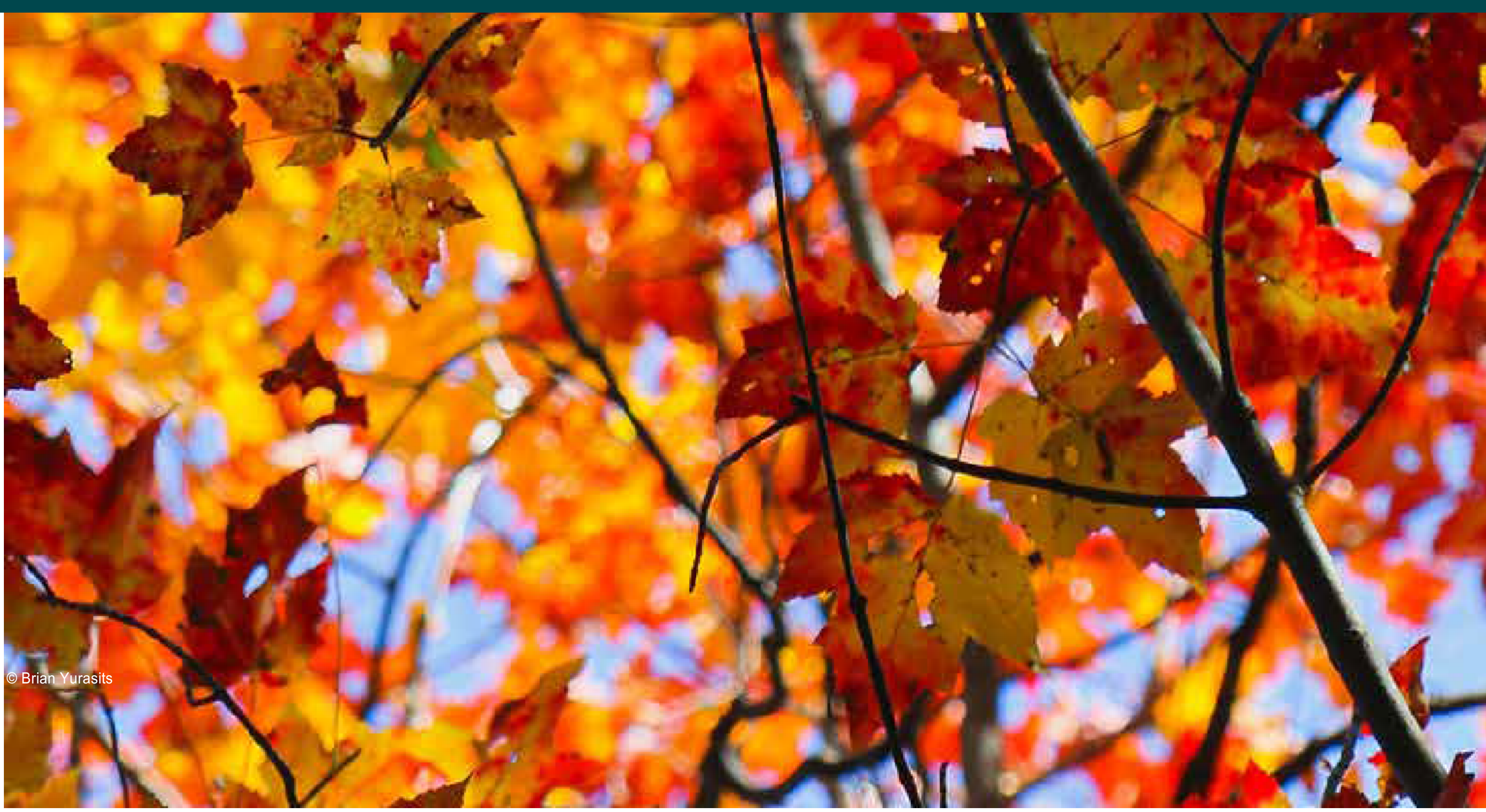
MIGRATION SPACE	RESILIENT	ACRES	GAP 1	GAP 2	GAP 3	TOTAL SECURED	TOTAL UNSECURED
Far above average	35%	24,496	0%	8%	6%	15%	20%
Above average	33%	23,432	1%	5%	5%	11%	23%
Slightly above average	12%	8,690	0%	1%	2%	4%	9%
Average	15%	10,467	0%	1%	2%	3%	12%
Below average	2%	1,138	0%	0%	0%	0%	1%
Far below average	0%	132	0%	0%	0%	0%	0%
TOTAL	**100%**	**70,429**	**2%**	**15%**	**16%**	**33%**	**67%**

Total Acres of Tidal Complex = 131,492 Resilient Tidal Complex = 94,724 (72%) Total Acres Migration Space = 70,429 acres Resilient Migration Space = 56,618 acres (80%)Secured Resilient Tidal Complex = 23% Secured Resilient Migration Space = 29%

These statistics are from "Resilient Sites for Coastal Conservation in the Northeast" (Anderson and Barnett 2017). They summarize the area of Tidal Complex, a slightly broader habitat than tidal marsh that includes brackish marsh and tidal flat. See the full study and web tool here.

SUPPORTING MATERIAL

PART THREE



Bibliography

Alban, D. H. & Berry, E.C. (1994). Effects of earthworm invasion on morphology, carbon andnitrogen of a forest soil. *Applied Soil Ecology*., 1:243–49.

Anderson, M.G. (2008). Conserving Forest Ecosystems: Guidelines for Size, Condition and Landscape Requirements, in Askins, B. ed. *Saving Biological Diversity: Balancing Protection of Endangered Species and Ecosystems*. Berlin, DE: Springer-Verlag.

Anderson, M.G. & Barnett, A. (2017). *Resilient Coastal Sites for Conservation in the Northeast and Mid-Atlantic US*. The Nature Conservancy, Eastern Conservation Science. Boston, MA https://www.nature.org/resilientcoasts

Anderson, M.G., Barnett, A., Clark, M., Prince, J., Olivero Sheldon, A. & Vickery B. (2016). *Resilient and Connected Landscapes for Terrestrial Conservation.* The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA.

Anderson, M.G., Clark, M., & Olivero Sheldon, A. (2012). *Resilient Sites for Terrestrial Conservation in the Northeast and Mid-Atlantic Region*. The Nature Conservancy, Eastern Conservation Science. 168pp.

Anderson, M.G., Clark, M., Olivero Sheldon, A. (2014). Estimating Climate Resilience forConservation across Geophysical Settings. *Conservation Biology* 28 (4) 1523-1739. http://dx.doi.org/10.1111/cobi.12272

Anderson, M.G., Vickery, B., Gorman, M., Gratton, L., Morrison, M., Mailet, et al. (2006). *The Northern Appalachian / Acadian Ecoregion: Ecoregional Assessment, Conservation Status and Resource CD.* The Nature Conservancy. Boston, MA.

Ashcroft, M.B. (2010). Identifying refugia from climate change. *Journal of Biogeography 37*, 1407–1413

Ballesteros, D., et al. (2012). Effects of Temperature and Desiccation on Ex Situ Conservation ofNongreen Fern Spores. *American Journal of Botany, vol. 99, no. 4*, 2012, pp. 721–729. JSTOR, Accessed 1 Mar. 2020. www.jstor.org/stable/41415613.

Barney, J. N., & Whitlow, T.H. (2008). A unifying framework for biological invasions:The state factor model. *Biological Invasions 10*: 259 – 272.

Bastolla U., Fortuna M.A., Pascual-Garcia A., Ferrera A., Luque B., Bascompte J. (2009). The architecture of mutualistic networks minimizes competition and increases biodiversity. *Nature 458*:1018–1021

Beckage, B., Osborne, B., Gavin, D.G., Pucko, C., Siccama, T., and Perkins, T. (2008). A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont. *PNAS, 105*, 4197-4202.

Beer, C., Reichstein, M., Tomelleri, E., et al. (2010). Terrestrial gross carbon dioxide uptake:global distribution and covariation with climate. *Science 329:* 834–838.

Beier, P., Hunter, M.L., Anderson, M.G. (2015). Special Section: Conserving Nature's Stage. *Conservation Biology 29* (3) 1523-1739. http://dx.doi.org/10.1111/cobi.12511.

Bischoff, A., Steinger, T., Müller-Schärer, H. (2010). The Importance of Plant Provenance and Genotypic Diversity of Seed Material Used for Ecological Restoration. *Restoration Ecology 18*.338 - 348. 10.1111/j.1526-100X.2008.00454.x.

Bureau of Land Management (BLM). (2019). *Plant and Seed Material Development: Collection.* Accessed 7 Oct. 2019, www.blm.gov/programs/natural-resources/native-plant-communities/ native-plant-and-seed-material-development/collection

Bohlen, P. J., Scheu, S., Hale, C.M., McLean, M., Migge, S., Groffman, P.M. (2004). Invasive earthworms as agents of change in north temperate forests. *Frontiers in Ecology and the Environment 8*: 427–435.

Bois, S.T., Silander, J.A.., Mehrhoff, L.J. Invasive Plant Atlas of New England: The Role of Citizens in the Science of Invasive Alien Species Detection. *BioScience, Volume 61, Issue 10*, October 2011, Pages 763–770, https://doi.org/10.1525/bio.2011.61.10.6 Published: 01 October 2011

Botanic Gardens Conservation International (BGCI). *The Global Strategy for Plant Conservation.* Botanic Gardens Conservation International. (2012). Accessed on 15 February 2020. www.bgci.org/our-work/policy-and-advocacy/the-global-strategy-for-plant-conservation/

Brumback, W. & Gerke, J. (2013). Flora Conservanda: New England 2012. The New England Plant Conservation Program (NEPCoP). *Rhodora 115*: 315-4084

Buzhdygan, O.Y., Meyer, S.T., Weisser, W.W. et al. (2020). Biodiversity increases multitrophic energy use efficiency, flow and storage in grasslands. *Nat Ecol Evol* 4, 393–405 (2020). https://doi.org/10.1038/s41559-020-1123-8

Catanzaro, P and D'Amato, A. (2019). *Forest Carbon: An essential natural solution for climate change.* University of Massachusetts, Amherst. 24 pp.

Convention on Biological Diversity. (2016). Progress in implementation of the targets of the Global Strategy for Plant Conservation 2011-2020. UNEP/CBD/SBI/1/INF/32, 23 March 2016. Accessed on 13 February 2020. https://www.cbd.int/doc/meetings/sbi/sbi-01/information/sbi-01-inf-32-en.doc

Chardon, N.I., Wipf, S., Rixen, C., Beilstein, A., Doak, DF. (2018). Local trampling disturbance effects on alpine plant populations and communities: Negative implications for climate change vulnerability. *Ecol Evol. 8*: 7921–7935. https://doi.org/10.1002/ece3.4276

Compton, B. W., McGarigal, K., Cushman, S.A., & Gamble, L.R. (2007). A resistant-kernel model of connectivity for amphibians that breed in vernal pools. *Conservation Biology 21*: 788-799.

Convention on Biological Diversity. 2012. *Global Strategy for Plant Conservation: 2011-2020*. Botanic Gardens Conservation International, Richmond, UK.

Cook-Patton, S., McArt, S., Parachnowitsch, A., Thaler, J., Agrawal, A. (2011). A direct comparison of the consequences of plant genotypic and species diversity on communities and ecosystem function. *Ecology 92*. 915-23. 10.2307/41151215.

Costanza, R., De Groot, R., Sutton, P., et al. (2014). Changes in the global value of ecosystem services. *Global Environmental Change 26*: 152–158.

Cronon, W. (2003). *Changes in the Land: Indians, Colonists, and the Ecology of New England*. New York, NY: Hill and Wang.

DeFrenne, P., F. Rodriguez-Sanchez, D. A. Coomes, L. Baeten, G. Verstraeten, M. Vellend, et al. (2013). *Microclimate moderates plant responses to macroclimate warming. Proceedings of the National Academy of Sciences of the United States of America (PNAS-USA)* 110: 18561-18565.

Dinerstein, E., et al. (2019). A Global Deal for Nature: Guiding principles, milestones, and targets.
Sci. Adv. 5, eaaw2869 2019.

Dobkin, D. S., Olivieri, L. & Erlich, P.R. (1987). Rainfall and the interaction of microclimate withlarval resources in the population dynamics of checkerspot butterflies (Euphydryas editha) inhabiting serpentine grassland. *Oecologia 71*: 161-166.

Dobrowski, S. Z. (2011). A climatic basis for microrefugia: the influence of terrain on climate.
Global Change Biology 17: 1022-1035.

Duffy, J.E. (2008). Why biodiversity is important to the functioning of real-world ecosystems.
VIMS Articles 1747. https://scholarworks.wm.edu/vimsarticles/1747

Dupigny-Giroux, et al. (2018). *Northeast - Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel,
K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. 2018. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18

Dupré, C., & Ehrlén, J. (2002). Habitat Configuration, Species Traits and Plant Distributions.
Journal of Ecology, vol. 90, no. 5, 2002, pp. 796–805. JSTOR, www.jstor.org/stable/3072249.
Accessed 27 Feb. 2020.

Eastman, J. (1995). *The Book of Swamp and Bog.* Harrisburg, PA: Stackpole. 523 pp.

Eisenhauer, N., et al. (2013). Plant Diversity Effects on Soil Food Webs Are Stronger Than Those of Elevated CO_2 and N Deposition in a Long-Term Grassland Experiment. *Proceedings of the National Academy of Sciences of the United States of America, vol. 110, no. 17*, 2013, pp. 6889–6894. JSTOR, www.jstor.org/stable/42590534. Accessed 16 June 2020.

Enright, N.J., et al. (2014). Resistance and Resilience to Changing Climate and Fire Regime Depend on Plant Functional Traits. *Journal of Ecology, vol. 102, no. 6*, 2014, pp. 1572–1581., www.jstor.org/stable/24541607. Accessed 16 June 2020.

Facon, B., Genton, B.J., Shykoff, J., et al. (2006). A general eco-evolutionary framework for understanding bioinvasions. *Trends in Ecology and Evolution 21*: 130 – 135.

Farnsworth, E. J. (2004). Patterns of plant invasions at sites with rare plant species throughoutNew England. Rhodora 106: 97 – 117.

Farnsworth, E.J. (2015). State of the Plants: Challenges and Opportunities for Conserving NewEngland's Native Flora. Native Plant Trust, Framingham, MA.

Farnsworth, E.J., & DiGregorio, M.J. (2002). Asclepias purpurascens L. *(Purple milkweed) Conservation and Research Plan.* New England Plant Conservation Program, Framingham, Massachusetts, USA.

Fei, S. & Steiner, K.C. (2007). Evidence for Increasing Red Maple Abundance in the Eastern UnitedStates. Forest Science 53 (4) 473-477.

Fei, S., Desprez, J.M., Potter, K.M., Jo, I., Knott, J.A., Oswalt, C.M. (2017). Divergence of speciesresponses to climate change. *ScienceAdvances* 2017;3: e1603055

Ferree, C. & Anderson, M.G. (2015). *A Terrestrial Habitat Map for the Northeastern United States andAtlantic Canada.* The Nature Conservancy, Eastern Conservation Science. Boston, MA, USA.

Food and Agriculture Organization of the United Nations. (1995). *Dimensions of need: An atlas offood and agriculture.* Rome, Italy. http://www.fao.org/docrep/u8480e/u8480e00.htm

Foster, D. R. (2012). Wildlands and Woodlands Update. Harvard Forest, Petersham, MA.

Foster, D. R., Motzkin, G., Bernardos, D., et al. (2002). Wildlife dynamics in the changing New En-gland landscape. *Journal of Biogeography 29*: 1337-1357.

Frainer, André, et al. (2014). When Does Diversity Matter? Species Functional Diversity and Eco- system Functioning across Habitats and Seasons in a Field Experiment. *Journal of Animal Ecology,vol. 83, no. 2*, 2014, pp. 460–469. Accessed 16 June 2020, www.jstor.org/stable/24034609

Goodwin pers com. (2019). Gus Goodwin Personal Communication and Powerpoint

Gremmen, N., Smith, V.R., van Tongeren, O. (2003). Impact of Trampling on the Vegetation ofSubantarctic Marion Island. *Arctic, Antarctic, and Alpine Research, 35(4)*, 442-446,
(1 November 2003)

Grifo, F. and Rosenthal, J. (1997). Biodiversity and Human Health. Washington, D.C.: Island Press

Groves, C.R., (2003). *Drafting a conservation blueprint: a practitioners' guide to planning for biodiversity.* Island Press. Washington D.C.

Guerrant, Edward O., et al. (2004). Ex Situ Plant Conservation: Supporting Species Survival in theWild. Island Press.

Gundale, J. M. (2002). Influence of exotic earthworms on the soil organic horizon and the rare fernBotrychium mormo. *Conservation Biology 16*: 1555–1561.

Havens, K., et al. (2006). Ex Situ Plant Conservation and Beyond. *BioScience, vol. 56, no. 6*, 2006,pp. 525–531. JSTOR, www.jstor.org/stable/10.1641/0006-3568(2006)56[525:espcab]2.0.co;2.
Accessed 1 Mar. 2020.

Havens, K., et al. (2014). Getting Plant Conservation Right (or Not): The Case of the United States. *International Journal of Plant Sciences, vol. 175, no. 1*, 2014, pp. 3–10. JSTOR, Accessed 27 Feb. 2020.www.jstor.org/stable/10.1086/674103

Havens, K., et al. (1999). Strategies for Survival: Ex Situ Plant Conservation - Report of a ResearchSymposium Held at the Chicago Botanic Garden. *Botanic Gardens Conservation News, vol. 3, no. 3,* 1999, pp. 43–44. JSTOR, Accessed 27 Feb. 2020. www.jstor.org/stable/24753885

Hird, A., & Kramer, A. (2013). Achieving Target 8 of the Global Strategy for Plant Conservation:Lessons learned from the North American collections assessment. *Annals of the Missouri Botanical Garden, vol. 99, no. 2*, 2013, pp. 161–166. JSTOR, Accessed 1 Mar. 2020.
www.jstor.org/stable/42703719

Hoegh-Guldberg O., Hughes L., McIntyre S., et al. (2008). Assisted colonization and rapid climatechange. *Science 321*: 345–46.

Holdsworth, A. R., Frelich, L. E., Reich, P.B. (2007). Effects of earthworm invasion on plant speciesrichness in northern hardwood forests. *Conservation Biology, 21*: 997–1008.

Hopfensperger, K.,Leighton, G., & Fahey, T. (2011). Influence of Invasive Earthworms on Above andBelowground Vegetation in a Northern Hardwood Forest. *TheAmerican Midland Naturalist, 166.* 53-62. 10.1674/0003-0031-166.1.53.

Hulme P.E. (2005).Adapting to climate change: is there scope for ecological management in theface of a global threat? *Journal ofApplied Ecology, 42*: 784–94.

Hunter ML. (2007). Climate change and moving species: furthering the debate on assistedcolonization. *Conservation Biology 21*: 1356–58.

McCarthy, J. J., Canziani, O. F., Leary, N.A., Dokken D. J., & White, K. S. (eds). (2001). *Climate change 2001: impacts, adaptation and vulnerability.* Intergovernmental Panel on Climate Change, Working Group II. Cambridge, United Kingdom: Cambridge University Press

Janousek, C.N. & Folger, C.L. (2014). Variation in tidal wetland plant diversity and composition withinandamongcoastalestuaries: assessingtherelativeimportanceofenvironmentalgradients.*Journal ofVegetation Science, 25*: 534-545. doi:10.1111/jvs.12107

Joly, J.L. & Fuller, N. (2009). Advising Noah: a legal analysis of assisted migration.
Environmental Law Reporter 39: 10413–25.

Jones, M., Willey, L., Waterman, L., Hermanutz, L., Charney, N., Martin, J-P., et al. (2018). *Eastern Alpine Guide: Natural History and Conservation of Mountain Tundra East of the Rockies.* Lebanon, NH: University Press of New England.

Jules, E.S., & Shahani, P. (2003). A Broader Ecological Context to Habitat Fragmentation: Why Matrix Habitat Is More Important than We Thought. *Journal ofVegetation Science, vol. 14, no. 3,* 2003, pp. 459–464. JSTOR, Accessed 27 Feb. 2020. www.jstor.org/stable/3236524

Kotowska, A., Cahill, J., & Keddie, B. (2009). Plant genetic diversity yields increased plantproductivity and herbivore performance. *Journal of Ecology, 98.* 237 - 245. 10.1111/j.1365- 2745.2009.01606.x.

Krosby, M., Tewksbury, J., Haddad, N. M., & Hoekstra, J. (2010). Ecological connectivity for a changingclimate. *Conservation Biology, 24 (6),* 1686-1689. doi: 10.1111/j.1523-1739.2010.01585.x

Kruckeberg A.R. (2002). *Geology and Plant Life.* Seattle, WA: University of Washington Press. 362 p.

Langdonetal.(2018).(Inprep)

Lautzenheiser, T.E., Collins, J., Ricci, E., & Clarke, J. (2014). *Losing Ground: Planning for Resilience.* Massachusetts Audubon Society, Inc. Lincoln, Massachusetts. 32 pp.

Lawler, J., & Olden, J. (2011). Reframing the Debate over Assisted Colonization. *Frontiers in Ecology and the Environment, vol. 9, no. 10*, 2011, pp. 569–574. JSTOR, Accessed 27 Feb. 2020. www.jstor. org/stable/41479961

Lawrence, B., Fisk, M., Fahey, T., & Sua'Rez, E. (2003). Influence of nonnative earthworms onmycorrhizal colonization of sugar maple (Acer saccharum). *New Phytologist, 157*: 145–153.

Leopold, A. (1949). *A Sand County Almanac.* Oxford, England: Oxford University Press, 240 pp.

Li, X., Fisk, M., Fahey, T., & Bohlen, P. (2002). Influence of earthworm invasion on soil microbial biomass and activity in a northern hardwood forest. *Soil Biology and Biochemistry, 34*: 1929–1937.

Lichvar, R., Banks, D., Kirchner, W., and Melvin, N. (2016). The National Wetland Plant List: 2016wetland ratings. *Phytoneuron* 2016-30: 1-17. Published 28 April 2016. ISSN 2153 733X

NHESP - Natural Heritage and Endangered Species Program - Massachusetts Division of Fisheries& Wildlife. (2015). - *Purple Milkweed* (Asclepias Purpurascens L.). Accessed: 10 Feb. 2020. https://www.mass.gov/Files/Documents/2016/08/No/Asclepias-Purpurascens.pdf

Manomet Center for Conservation Sciences and National Wildlife Federation. (2012). *The Vulnerabilities of Fish and Wildlife Habitats in the Northeast to Climate Change:A report to the Northeastern Association of Fish and Wildlife Agencies and the North Atlantic Landscape Conservation Cooperative.* Manomet, MA.

Martin, A., Zim, H., & Nelson, A. (1951). *American Wildlife and Plants.* New York, NY: Dover. 500 p.

McCann, K. (2000). The diversity–stability debate. *Nature 405*, 228–233 (2000).https://doi.org/10.1038/35012234

McClanahan T., Cinner J., Maina J., et al. (2008). Conservation action in a changing climate. *Conservation Letters 1*: 53–59.

McLaughlin, B., Ackerly, D., Klos, P., Natali, J., Dawson, T.E. & Thompson, S. (2017). Hydrologic refugia, plants, and climate change. *Global Change Biology 23,* 2941–2961, doi: 10.1111/gcb.13629

McLaughlin, J. F., Hellmann J., Boggs, C.L., & Ehrlich, P. (2002). Climate change hastens population extinctions. *Proceedings of the National Academy of Sciences of the United States of America 99*: 6070– 6074.

Meiklejohn, K., Ament, R., & Tabor, G. (2010). Habitat corridors and landscape connectivity: clarifying the terminology. Bozeman, MT. *Center for Large Landscape Conservation.* 6 pp.

Miller-Rushing, A.J., & Primack, R. (2008). Global Warming and Flowering Times in Thoreau'sConcord: A Community Perspective. *Ecology, vol. 89, no. 2*, 2008, pp. 332–341.

Moles,A. T., Gruber, M., & Bonser, S.P. (2008). A new framework for predicting invasive plantspecies. *Journal of Ecology 96:* 13 – 17.

Morelli.T.L. et al. (2018). Climate-change refugia: biodiversity in the slow lane. *Frontiers of Ecology and the Environment, 18* (5):228–234. doi:10.1002/fee.2189

Mounce R., Smith P., Brockington S. (2017). Ex situ conservation of plant diversity in the world'sbotanic gardens. *Nature Plants,* 2017; DOI: 10.1038/s41477-017-0019-3

Nantel, P., et al. (1996). Population Viability Analysis of American Ginseng and Wild Leek Harvested in Stochastic Environments. *Conservation Biology, vol. 10, no. 2*, 1996, pp. 608–621. JSTOR, Accessed 6 Mar. 2020. www.jstor.org/stable/2386876

Native Plant Materials Development Program (NPMDP). (2009). *2009 Native Plant Materials Development Program - Progress report for FY2001-2007.* Bureau of Land Management National Operations Center, Lakewood, CO.

Noto, A. & Shurin, J. (2017). Mean conditions predict salt marsh plant community diversity andstability better than environmental variability, *Oikos, 126*, 9, (1308-1318), 2017.

National Vegetation Classification (NVC). (2008). NATIONAL VEGETATION CLASSIFICATIONSTANDARD, VERSION 2. 2008. Vegetation Subcommittee Federal Geographic Data Committee February 2008

O'Donnell, K., Sharrock, S. (2015). Seed banking in botanic gardens: Can botanic gardens achieveGSPC Target 8 by 2020? *BGjournal, vol. 12, no. 1*, 2015, pp. 3–8. JSTOR, Accessed 1 Mar. 2020. www.jstor.org/stable/bgj.12.1.3

Okuyama T., Holland J. (2008). Network structural properties mediate the stability of mutualisticcommunities. *Ecology Letters 11:* 208–216

Oldfield, S. (2015). Botanic gardens and seed banks. *BGjournal, vol. 12, no. 1*, 2015, pp. 2–2. JSTOR,Accessed 1 Mar. 2020. www.jstor.org/stable/bgj.12.1.2

Reich, P., Tilman, D., Isbell,F., Mueller,K., Hobbie,S., Flynn,D. et al. (2012). Impacts of BiodiversityLoss Escalate Through Time as Redundancy Fades. *Science*, 2012; 336 (6081): 589 DOI: 10.1126/ science.1217909

Pailett, F. (2002). Chestnut: history and ecology of a transformed species.
Journal of Biogeography, 29, 1517–1530

Parks, K. (1993). The New England Plant Conservation Program: A Regional Model for Integrated Conservation Efforts. *Maine Naturalist, vol. 1, no. 2*, 1993, pp. 35–40. JSTOR, Accessed 27 Feb. 2020www.jstor.org/stable/3858225

Perschel, R., Giffen,R., & Lowenstein, F. (2014). *New England Forests: The Path to Sustainability.* New England Forestry Foundation, Littleton, MA. This report is a summary of R. A. Giffen, editor.2014. New England Forests: The Path to Sustainability, Technical Reports. New England Forestry Foundation, Littleton, MA.

Pettorelli, J., Côté, S. (2006). Long term effects of deer browsing and trampling on the vegetation ofpeatlands. *Biological Conservation 128.* 316-326. 10.1016/j.biocon.2005.09.039.

Poiani, K., Richter, B.D., Anderson, M.G., & Richter, H.E. (2000). Biodiversity conservation at mul-tiple scales: Functional sites, landscapes, and networks. *BioScience 50(2)*: 133-146.

Randin, C. F., Engler, R, Normand, S., Zappa, M., Zimmermann, N.E., Pearman, P.B., et al. (2009).Climate change and plant distribution: local models predict high-elevation persistence.
Global Change Biology 15: 1557-1569.

Reside, A.E., VanDerWal, J., Phillips, B., Shoo, L.P., Rosauer, D.F., Anderson, B.A., et al. (2013). *Climate change refugia for terrestrial biodiversity: Defining areas that promote species persistence and ecosystem resilience in the face of global climate change.* National Climate Change Adaptation Research Facility, Gold Coast, pp. 216.

Ricciardi A., Simberloff D. (2009).Assisted colonization is not a viable conservation strategy.Trends *Ecol Evol 24*: 248–53.

Richardson D.M., Hellmann, J.J., McLachlan, J.S., et al. (2009). Multidimensional evaluation ofmanaged relocation. *PNAS 106*: 9721–24.

Root, T. L., Price, J.T., Hall, K.R., Schneider S.H., Rosenzweig, C., & Pounds, J.A. (2003). Fingerprints of global warming on wild animals and plants. *Nature 421*: 57– 60.

Sandler, R. (2010). The value of species and the ethical foundations of assisted colonization.
Conservation Biology 24: 424–31.

Sax, D.F., Smith, K.F., Thompson, A.R. (2009). Managed relocation: a nuanced evaluation isneeded. Trends *Ecol Evol 24*: 472–73.

Schuldt, A, et al. (2014). Functional and Phylogenetic Diversity of Woody Plants Drive Herbivory ina Highly Diverse Forest. *The New Phytologist, vol. 202, no. 3*, 2014, pp. 864–873. JSTOR, Accessed 16 June 2020. www.jstor.org/stable/newphytologist.202.3.864

Schuldt, A., Ebeling, A., Kunz, M. et al. (2019). Multiple plant diversity componentsdrive consumer communities across ecosystems. *Nat Commun 10,* 1460 (2019). https://doi.org/10.1038/s41467-019-09448-8

Seddon, P.J., Armstrong, D.P., Soorae, P., et al. (2009). The risks of assisted colonization.
Conservation Biology 23: 788–89.

Sharrock, S, Hoft, R., De Souza, F., Dias, B. (2018). An overview of recent progress in the imple-mentation of the Global Strategy for Plant Conservation - a global perspective. *Rodriguésia.* 69. 1489-1511. 10.1590/2175-7860201869401.

Siemann, E., et al. (1998). Experimental Tests of the Dependence of Arthropod Diversity on Plant Diversity. *The American Naturalist, vol. 152, no. 5*, 1998, pp. 738–750. JSTOR, Accessed 20 Apr.
2020. www.jstor.org/stable/10.1086/286204

Simsek, C.K. & Odul, H. (2018). Investigation of the effects of wetlands on micro-climate.
Applied Geography 97, pp 48-60

Suggitt A.J., Wilson, R.J., Isaac, N.J.B., et al. (2018). Extinction risk from climate change is reduced by microclimatic buffering. *Nat Clim Change 8*: 713–17.

Tayyebi, A., Burak, K., Pekin, B., Pijanowski, C., Plourde, J.D., Doucette,J.S., & Braun, D. (2012).Hierarchical modeling of urban growth across the conterminous USA: developing meso-scale quantity drivers for the Land Transformation Model. *Journal of Land Use Science, Vol. 8:4*

Thébault E, Fontaine C. (2010). Stability of ecological communities and the architecture ofmutualistic and trophic interactions. *Science 329*: 853–856

Thomas, C. D., et al. (2004). Extinction risk from climate change. *Nature 427*: 145– 148.Thompson, J., Lambert, K.F., Foster, D., et al. (2014). Changes to the land:

Four scenarios for the future of Massachusetts. Harvard Forest, Petersham, MA.
http://harvardforest.fas.harvard.edu/changes-to-the-land

Tilman, D. (1999). The Ecological Consequences of Changes in Biodiversity: A Search for GeneralPrinciples. *Ecology 80*: 1455-74.

USFS - Eastern Region. (2003). Conservation Assessment for American Ginseng(*Panax quinquefolius* L.). FS USDA - Conservation Assessment.

USDA – Forest Service Eastern Region. 2003. Conservation Assessment for Purple Milkweed (*Asclepias purpurascens* L.). *FS USDA* - Conservation Assessment.

Villard, M., & Metzger, J.P. (2014). Beyond the Fragmentation Debate: a Conceptual Model to Predict When Habitat Configuration Really Matters. *Journal of Applied Ecology, vol. 51, no. 2,* 2014, pp. 309–318. JSTOR, Accessed 27 Feb. 2020. www.jstor.org/stable/24032362

Wardle, D. (2002). *Communities and ecosystems: linking the aboveground and belowground components.* Princeton, New Jersey: Princeton University Press.

Weiss, S. B., Murphy, D. D., & White, R. R. (1988). Sun, slope, and butterflies: topographicdeterminants of habitat quality for Euphydryas editha. *Ecology, 69(5)*, 1486-1496. doi: 10.2307/1941646

Willis, K. J., & Bhagwat, S.A. (2009). Biodiversity and climate change. *Science, 326* (5494), 806-807.

Woolsey, H., Finton, A., DeNormandie, J. (2010). *BioMap2: Conserving the Biodiversity of Massachusetts in a Changing World.* MA Department of Fish and Game/Natural Heritage & Endangered Species Program and The Nature Conservancy/Massachusetts Program. http://www.mass.gov/dfwele/dfw/nhesp/land_protection/biomap/biomap2_summary_report.pdf

Yeakley, J. A., Swank, W. T., Swift, L. W., Hornberger, G. M., & Shugart, H. H. (1998). Soil moisture gradients and controls on a southernAppalachian hillslope from drought through recharge. *Hydrology and Earth System Sciences, 2(1)*, 41-49. doi: doi.org/10.5194/hess-2-41-1998.

Appendices

APPENDIX 1

Divisions of Flora Conservanda (Brumback and Gerke 2013)

Flora Conservanda is divided into five Divisions.

Division 1: Globally Rare Taxa occurring in New England.

Taxa included in this Division have a global conservation status rank (GRank) of G1 through G3 or T1 through T3 (see Appendix 2); they are critically imperiled, imperiled, or vulnerable (NatureServe 2012). Usually only a few occurrences of these taxa exist within our region, but for some species, the majority of occurrences of these highly ranked taxa occur in New England. GRanks fortaxa in this Division appear under each relevant taxon in the list.

Division 2: Regionally Rare Taxa.

Within New England, these taxa have 20 or fewer current (observed within the last 20–25 years) occurrences. This Division includes taxa that are rare or uncommon throughout their entire range as well as taxa that reach the edge of their distributional range in our region. It is important to conserve these edge-of-range occurrences as part of New England's natural heritage as well as to avoid shrinkage of these species' ranges. All taxa in Division 2 have G Ranks of G4 or G5 (appar- ently secure to secure globally). A taxon with slightly more than 20 occurrences in New England might also be included in Division 2 if it is vulnerable to extirpation due to other important factors(population size and trends, area of occupancy, overall viability, geographic distribution, habitat rarity and integrity, and/or degree of protection). These taxa are denoted as 2(a).

Division 3: Locally Rare Taxa

These taxa may be declining in a significant part of their range in New England, or may have one ormore occurrences of biological, ecological, or possible genetic significance. Division 3(a) includes those taxa that have declined in a substantial portion of their range in New England (e.g., southern New England). Each state in the declining portion of the range is listed following the Division designation in the List (e.g., MA, NH). Division 3(b) taxa are those that, based on their biology and geography within New England, have populations that are disjunct to such a degree that genetic isolation is suspected. Each state with one or more disjunct occurrence is noted following the Division designation in the List, and the county of each disjunct occurrence is listed in the notes under the taxon. For Division 3(b), only selected occurrences in a particular state are of conser- vation concern for the purposes of the Flora Conservanda list, not all occurrences of the taxon throughout New England. A taxon may be listed as Division 3 in one or more states (designated by an asterisk following the state data), but not considered to be regionally rare.

Division 4: Historic Taxa

This Division consists of taxa that once existed in New England but have not been observed in natural occurrences on the landscape in the last 20–25 years (depending upon each NHPs meth- odology). The purposes of this division are to generate interest in re-locating these taxa if they stillexist and to illustrate the level at which species have been lost from the region.

Division Indeterminate (IND.): Presumed Rare but Confirmation Required

These taxa are under review for inclusion in one of the above divisions, but due to issues of taxonomy (at least for New England occurrences) or nomenclature, or because their status inthe wild is not confidently understood, they cannot yet be designated to a particular division. The purpose of this division is to stimulate interest in taxonomic research and/or field surveysfor these taxa to bolster our knowledge and understanding.

APPENDIX 2
Definitions of Conservation Status Ranks per NatureServe (2014)

The conservation rank of an element known or assumed to exist within a jurisdiction is designatedby a whole number from 1 to 5, pre-ceded by a G (Global), N (National), or S (Subnational) as appropriate. The numbers have the following meaning:

1 = critically imperiled2 = imperiled
3 = vulnerable to extirpation or extinction4 = apparently secure
5 = demonstrably widespread, abundant, and secure.

G1, for example, indicates critical imperilment on a range-wide basis—that is, a great risk of extinction. S1 indicates critical imperilment within a particular state, province, or other subnationaljurisdiction—i.e., a great risk of extirpation of the element from that subnation, regardless of its status elsewhere.

Species known in an area only from historical records are ranked as either H (possiblyextirpated/possibly extinct; not having been observed for the past 20–25 years) or X (presumed extirpated/presumed extinct). Certain other codes, rank variants, and qualifiers are also allowed in order to add information about the element or indicate uncertainty.

Elements that are imperiled or vulnerable everywhere they occur will have a global rank of G1, G2, or G3 and equally high or higher national and subnational ranks (the lower the number, the"higher" the rank, and therefore the conservation priority). On the other hand, it is possible for an element to be rarer or more vulnerable in a given nation or subnation than it is range-wide. In
that case, it might be ranked N1, N2, or N3, or S1, S2, or S3 even though its global rank is G4 or G5.The three levels of the ranking system give a more complete picture of the conservation status of a species or community than either a range-wide or local rank by itself. They also make it easier to set appropriate conservation priorities in different places and at different geographic levels. In an
effort to balance global and local conservation concerns, global as well as national and subnational(provincial or state) ranks are used to select the elements that should receive priority for researchand conservation in a jurisdiction.

bearberry willow *(Salix uva-ursi)*
Liza Green © Native Plant Trust

Use of standard ranking criteria and definitions makes Natural Heritage ranks comparable across element groups; thus, G1 has the same basic meaning whether applied to a salamander, a moss, ora forest community. Standardization also makes ranks comparable across jurisdictions, which in turn allows scientists to use the national and subnational ranks assigned by local data centers to determine and refine or reaffirm global ranks.

Ranking is a qualitative process: it takes into account several factors, including total number, range, and condition of element occurrences, population size, range extent and area of occupancy, short- and long-term trends in the foregoing factors, threats, environmental specificity, and fragility.These factors function as guidelines rather than arithmetic rules, and the relative weight given tothe factors may differ among taxa. In some states, the taxon may receive a rank of SR (where the element is reported but has not yet been reviewed locally) or SRF (where a false, erroneous report exists and persists in the literature). A rank of S? denotes an uncertain or inexact numeric rank forthe taxon at the state level.

Within states, individual occurrences of a taxon are sometimes assigned element occurrence ranks.

Element occurrence (EO) ranks, which are an average of four separate evaluations of quality (sizeand productivity), condition, viability, and defensibility, are included in site descriptions to providea general indication of site quality. Ranks range from: A (excellent) to D (poor); a rank of E is provided for element occurrences that are extant, but for which information is inadequate to provide a qualitative score. An EO rank of H is provided for sites for which no observations have made for more than 20 years. An X rank is utilized for sites that are known to be extirpated. Not all EOs have received such ranks in all states, and ranks are not necessarily consistent amongstates as yet.

APPENDIX 3

Important Plant Areas by State and Protection Status

IPA ID	MAJORITY STATE	# FLOCO SPECIES	ACRES	APPROXIMATE SITE NAME	PROTECT CODE	PROTECTED (GAP 1–2)	MULTIPLE USE (GAP 3)	SECURED (GAP 1–3)	NE TARGET 30 / 75
MATRIX FOREST									
Boreal Upland Forest									
Acadian Low-Elevation Spruce-Fir-Hardwood Forest									
81632	ME	2	2,681	Soubunge Mountain	S	0%	100%	100%	
90329	ME	2	13,237	No Name	U	0%	0%	0%	
52265	ME	6	25,411	White Pond Acidic Fen	U	3%	54%	57%	
106862	ME	2	6,734	Horan Head	U	3%	23%	26%	
44810	ME	2	37,997	Gardner Brook	U	0%	41%	41%	
77427	ME	6	194	Name Excluded	U	16%	0%	16%	
38769	ME	5	286	Name Excluded	S	0%	77%	77%	
89343	ME	5	43,820	Dwinal Pond	U	2%	6%	9%	
35477	ME	4	11,889	No Name	U	2%	7%		
59487	ME	4	21,269	Burntland Bend	P	99%	0%	99%	1
138016	ME	3	3,530	Cadillac Mountain South And East	P	99%	0%	99%	1
73227	ME	3	13,666	Marble Pond Fen	U	4%	0%	4%	
49075	ME	3	71,551	Dead Horse Bog	U	1%	1%	1%	
40218	ME	2	41	Name Excluded	U	0%	0%	0%	
64291	ME	2	93	Name Excluded	P	100%	0%	100%	1
53841	ME	2	5,454	Sixmile Brook, St. John River	U	21%	51%	71%	
68704	ME	2	9,359	Eagle Lake	S	20%	70%	90%	
32792	ME	2	22,557	Deer Lake Fen	U	0%	8%	8%	
64224	ME	2	36,111	Bluffer Preserve	U	2%	65%	67%	
Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest									
166592	NH	24	106,908	Mt Eisenhower/Jackson/ Crawford/Webster	S	62%	32%		1
177296	NH	12	142,457	Mt Lincoln/Lafayette	S	73%	26%	99%	1
Central Oak-Pine Forest									
North Atlantic Coastal Plain Hardwood Forest									
430026	CT	2	1,707	Pequot Swamp Pond	U	0%	21%		
423446	CT	3	682	No Name	U	38%	0%	38%	
439507	CT	3	1,287	Old Quarry Road	U	16%	13%	29%	
425573	CT	2	2,039	No Name	U	26%	14%	40%	
425882	CT	2	117	Name Excluded	U	15%	2%	16%	
427590	CT	2	570	Lieutenant River	U	23%	0%		
314974	MA	2	365	Name Excluded	S	0%	97%	97%	
337564	MA	2	116	Name Excluded	U	0%	28%	28%	
401894	MA	2	1,604	No Name	U	2%	6%	8%	
411365	RI	2	222	Name Excluded	U	47%	0%	47%	

IPA ID	MAJORITY STATE	# FLOCO SPECIES	ACRES	APPROXIMATE SITE NAME	PROTECT CODE	PROTECTED (GAP 1–2)	MULTIPLE USE (GAP 3)	SECURED (GAP 1–3)	NE TARGET 30 / 75
407472	RI	5	1,364	Hot House Pond, Strange Pond	U	31%	6%	37%	
411644	RI	2	1,589	No Name	U	0%	2%	2%	
North Atlantic Coastal Plain Maritime Forest									
391895	MA	3	500	Name Excluded	U	0%	0%		
423756	CT	3	543	Mumford Cove, Bluff Point Coastal Reserve	P	84%	0%	84%	1
North Atlantic Coastal Plain Pitch Pine Barrens									
320209	MA	2	344	Name Excluded	P	100%	0%		1
338857	MA	2	5	Name Excluded	U	0%	0%	0%	
370398	MA	2	74	Name Excluded	U	0%	43%	43%	
347201	MA	3	9	Name Excluded	U	0%	33%	33%	
337417	MA	2	3	Name Excluded	U	0%	0%	0%	
339917	MA	2	119	Name Excluded	S	0%	100%	100%	
345735	MA	2	72	Name Excluded	S	0%	84%	84%	
Northeastern Interior Dry-Mesic Oak Forest									
422809	CT	5	1,163	Eightmile River	U	7%	50%	58%	
392816	CT	3	1,564	Daphne Swamp	U	19%	3%	21%	
423955	CT	3	831	No Name	U	5%	8%	13%	
426168	CT	3	2,308	No Name	U	8%	2%	10%	
445892	CT	3	422	Name Excluded	U	61%	13%	74%	
396247	CT	2	192	Name Excluded	U	0%	0%	0%	
411029	CT	2	335	Name Excluded	U	0%	0%	0%	
419559	CT	2	72	Name Excluded	U	0%	0%	0%	
420874	CT	2	408	Name Excluded	U	14%	0%	14%	
428347	CT	2	459	Name Excluded	P	95%	0%	95%	1
317574	MA	2	14	Name Excluded	S	0%	100%	100%	
352810	MA	2	2,427	No Name	U	0%	19%	19%	
Northern Hardwood & Conifer Forest									
Appalachian (Hemlock)-Northern Hardwood Forest									
381217	CT	5	1,488	Toms Hill	U	5%	0%	5%	
385916	CT	4	10,866	Bear Swamp, Great Mountain Forest	U	6%	7%	14%	
383349	CT	5	8,548	Canaan Mountain	U	20%	33%	53%	
408686	CT	4	14,405	Bulls Bridge	U	18%	2%	21%	
430052	CT	3	124	Name Excluded	U	0%	0%	0%	
390426	CT	2	1,784	Beebe Hill Swamp	U	3%	23%	26%	
442665	CT	2	1,672	Lees Brook Valley	U	24%	23%	46%	
387603	CT	2	572	Wangum Lake Brook	U	0%	24%	24%	
416346	CT	2	460	Name Excluded	P	78%	7%	85%	1
299057	MA	2	4,656	No Name	U	0%	4%	4%	
315708	MA	7	4,292	No Name	U	3%	34%	37%	
379959	MA	4	496	Name Excluded	U	3%	0%	3%	
332418	MA	12	3,445	No Name	S	48%	27%	75%	1
331473	MA	11	4,068	No Name	U	41%	31%	71%	

IPA ID	MAJORITY STATE	# FLOCO SPECIES	ACRES	APPROXIMATE SITE NAME	PROTECT CODE	PROTECTED (GAP 1–2)	MULTIPLE USE (GAP 3)	SECURED (GAP 1–3)	NE TARGET 30 / 75
347186	MA	6	663	No Name	U	0%	64%	64%	
339393	MA	6	535	No Name	U	0%	64%	64%	
301208	MA	4	11,117	No Name	U	12%	8%	20%	
317672	MA	4	704	No Name	U	0%	64%	64%	
379783	MA	4	44	Name Excluded	U	58%	0%	58%	
330110	MA	3	12,966	No Name	U	18%	41%	59%	
348273	MA	3	1,438	No Name	U	0%	34%	34%	
350275	MA	3	974	No Name	U	0%	49%	49%	
317150	MA	3	240	Name Excluded	S	0%	100%	100%	
317566	MA	3	92	Name Excluded	U	0%	37%	37%	
352768	MA	2	5,844	No Name	U	12%	55%	67%	
313220	MA	2	3,353	No Name	U	0%	17%	17%	
353161	MA	2	2,105	No Name	U	0%	67%	67%	
376472	MA	2	632	No Name	U	31%	7%	38%	
303191	MA	2	614	No Name	S	0%	94%	94%	
369688	MA	2	493	Name Excluded	U	8%	0%	8%	
312622	MA	2	337	Name Excluded	U	0%	24%	24%	
304784	MA	2	322	Name Excluded	U	13%	47%	60%	
316503	MA	2	309	Name Excluded	U	0%	8%	8%	
375762	MA	2	302	Name Excluded	U	0%	0%	0%	
339530	MA	2	271	Name Excluded	S	24%	75%	99%	
308362	MA	2	185	Name Excluded	U	0%	21%	21%	
316633	MA	2	175	Name Excluded	S	0%	100%	100%	
320576	MA	2	158	Name Excluded	U	0%	21%	21%	
337093	MA	2	49	Name Excluded	U	28%	0%	28%	
299544	MA	2	8	Name Excluded	U	0%	0%	0%	
184692	ME	2	5,861	Pleasant Mountain	U	31%	18%	49%	
218520	ME	2	5,407	Abbott Mountain	U	4%	51%	56%	
209171	ME	3	3,705	Cedar Mountain	U	0%	45%	45%	
241174	NH	3	103	Name Excluded	U	0%	60%	60%	
223024	NH	2	16,052	No Name	U	0%	29%	29%	
266278	NH	2	3,529	No Name	U	0%	23%	23%	
175457	VT	2	1,115	Adlum's Ridge	U	23%	25%	48%	
214100	VT	2	212	Name Excluded	U	0%	0%	0%	
243370	VT	9	3,506	Massachusetts Ledge	U	13%	0%	13%	
245357	VT	8	6,792	Bald Mountain-West Haven	U	50%	6%	56%	
300520	VT	6	339	Name Excluded	U	28%	0%	28%	
168001	VT	5	1,315	Eagle Mountain	U	17%	0%	17%	
304216	VT	4	633	Waterleaf Cliffs	U	0%	0%	0%	
234854	VT	3	23,691	Hubbardton Battlefield Wma	U	9%	7%	16%	
296065	VT	3	5,928	Pownal Hills-Peckham Hill	U	0%	0%	0%	
239529	VT	3	852	Doughty Hill	U	0%	0%	0%	
202063	VT	2	9,069	Baldwin Creek	U	1%	0%	1%	
216316	VT	2	3,040	Rivers	U	3%	29%	31%	

IPA ID	MAJORITY STATE	# FLOCO SPECIES	ACRES	APPROXIMATE SITE NAME	PROTECT CODE	PROTECTED (GAP 1–2)	MULTIPLE USE (GAP 3)	SECURED (GAP 1–3)	NE TARGET 30 / 75
242530	VT	2	2,408	Red Rock Bay Cobble	U	11%	0%	11%	
171199	VT	2	2,049	Bear Trap Road Site	U	0%	20%	20%	
246074	VT	2	1,989	Coggman Creek Marsh	U	0%	0%	0%	
205580	VT	2	1,001	Shellhouse Mountain	U	0%	12%	12%	
253247	VT	2	743	Connecticut River	U	0%	0%	0%	
230403	VT	2	647	Burnell Pond Marsh	U	0%	0%	0%	
241098	VT	2	299	Name Excluded	U	10%	0%	10%	
251930	VT	2	119	Name Excluded	P	97%	0%	97%	1
Laurentian-Acadian Northern Hardwood Forest									
371951	CT	4	14,813	Bear Mountain	U	41%	26%	66%	
319131	MA	2	2,814	No Name	U	40%	24%	64%	
309129	MA	5	6,734	No Name	U	31%	40%	71%	
314533	MA	3	7,197	No Name	U	0%	4%	4%	
319905	MA	2	10,129	No Name	U	42%	26%	68%	
309928	MA	2	7,762	No Name	U	48%	14%	62%	
315599	MA	2	2,956	No Name	U	33%	30%	63%	
336454	MA	2	2,038	No Name	U	37%	27%	64%	
316630	MA	2	1,182	No Name	S	3%	88%	90%	
317868	MA	2	517	No Name	S	0%	79%	79%	
39751	ME	12	101,523	St John River-Basford Rips-Blue Brook	U	2%	12%	14%	
149027	ME	4	107,173	Carlo Col, Mount Carlo	U	18%	21%	39%	
38277	ME	3	52	Name Excluded	U	0%	0%	0%	
32946	ME	2	35,653	Pinette Brook	U	0%	1%	1%	
88239	ME	2	26,662	Carry Bog	S	0%	99%	99%	
74690	ME	20	231,550	Mt Katahdin	P	86%	6%	92%	1
49094	ME	8	28,493	St John River-Blue Brook	U	2%	0%	2%	
106397	ME	7	208,662	Bigelow Brook	U	2%	10%	12%	
35309	ME	6	133,530	St Francis Rd	U	5%	10%	15%	
40193	ME	5	64	Name Excluded	U	0%	0%	0%	
162195	ME	4	106,857	East Royce Mountain	S	52%	38%	90%	1
160733	ME	3	61,632	Kneeland Pond Road	U	26%	42%	68%	
44904	ME	3	5,967	175 T14 Rno Name7 Wels	U	0%	0%	0%	
83560	ME	3	4,290	Ripogenus Gorge	S	0%	97%	97%	
36490	ME	3	123	Name Excluded	U	0%	0%	0%	
95716	ME	2	268	Name Excluded	U	64%	0%	64%	
42855	ME	2	2	Name Excluded	U	0%	0%	0%	
157380	NH	2	5,457	No Name	U	6%	33%	39%	
195019	NH	4	108,760	Bolles Preserve	S	58%	34%	92%	1
208723	NH	2	34,044	Bald Knob	U	24%	34%	58%	
187968	NH	2	23,812	Albany Haystack	S	45%	45%	90%	1
376250	MA	3	14,737	Alander Mountain	U	30%	37%	67%	
153805	VT	12	3,664	Mount Pisgah	U	0%	37%	37%	
221314	VT	3	14,850	Bryant Mountain Hollow	U	1%	72%	73%	
222323	VT	2	34,860	Monastery Mountain	S	36%	45%	81%	1

IPA ID	MAJORITY STATE	# FLOCO SPECIES	ACRES	APPROXIMATE SITE NAME	PROTECT CODE	PROTECTED (GAP 1–2)	MULTIPLE USE (GAP 3)	SECURED (GAP 1–3)	NE TARGET 30 / 75
215104	VT	2	12,577	East Middlebury	U	5%	55%	60%	
170730	VT	14	62,857	Mount Mansfield	U	23%	33%	56%	
150311	VT	6	21,853	Bald Mountain-Westmore	U	0%	9%	9%	
267687	VT	4	38,738	Mount Equinox-Cook's Hollow	U	7%	9%	16%	
153262	VT	4	30,408	Belvidere Quarry	U	30%	6%	36%	
166123	VT	4	29,210	Smugglers' Notch, Elephants Head	U	8%	37%	45%	
154635	VT	4	6,072	Kings Pond Marsh	S	0%	84%	84%	
190680	VT	3	51,386	Beaver Meadow-Duxbury	U	18%	29%	47%	
159626	VT	3	8,302	No Name	U	8%	1%	9%	
152921	VT	3	1,661	No Name	U	6%	0%	6%	
209810	VT	2	43,732	Blue Banks South Introduction	S	57%	29%	87%	1
255356	VT	2	37,989	Mount Tabor Floodplain Swamps	S	50%	32%	83%	1
Laurentian-Acadian Pine-Hemlock-Hardwood Forest									
167837	ME	5	10,134	Abagadasset Point	U	0%	22%	22%	
179940	ME	2	6,035	Back River Marshes	U	12%	14%	26%	
174376	ME	4	2,280	West Chops Point	U	0%	0%	0%	
171660	ME	3	3,553	No Name	U	0%	9%	9%	
114663	ME	3	221	Name Excluded	U	0%	0%	0%	
164059	ME	2	306	Name Excluded	U	0%	2%	2%	
160450	ME	2	239	Name Excluded	U	0%	6%	6%	
175039	ME	2	212	Name Excluded	U	0%	73%	73%	
222095	NH	2	5,537	No Name	U	15%	5%	21%	
235577	VT	3	2,552	Quechee Gorge	U	0%	13%	13%	
152156	VT	2	963	Benedictine Cliffs	U	0%	0%	0%	
Northeastern Coastal & Interior Pine-Oak Forest									
319602	MA	2	468	Name Excluded	S	0%	79%	79%	
32875	ME	3	9	Name Excluded	U	0%	0%	0%	
229555	NH	2	2,612	No Name	U	6%	17%	23%	
207218	VT	3	2	Name Excluded	U	0%	0%	0%	
PATCH-FORMING HABITATS									
Grassland & Shrubland									
Agricultural Grassland									
376942	MA	2	94	Name Excluded	U	0%	0%	0%	
374696	MA	2	173	Name Excluded	U	0%	0%	0%	
379181	MA	2	7	Name Excluded	U	0%	0%	0%	
40304	ME	2	14	Name Excluded	U	0%	0%	0%	
36003	ME	2	68	Name Excluded	U	0%	0%	0%	
234649	VT	3	2,546	Catfish Bay	U	18%	6%	24%	
202478	VT	2	1,273	Mountain Road-Monkton	U	14%	2%	16%	

IPA ID	MAJORITY STATE	# FLOCO SPECIES	ACRES	APPROXIMATE SITE NAME	PROTECT CODE	PROTECTED (GAP 1–2)	MULTIPLE USE (GAP 3)	SECURED (GAP 1–3)	NE TARGET 30 / 75
Atlantic Coastal Plain Beach & Dune									
394361	MA	2	1,183	No Name	U	15%	9%	24%	
382776	MA	3	77	Name Excluded	U	0%	0%	0%	
394810	MA	2	244	Name Excluded	U	28%	9%	37%	
North Atlantic Coastal Plain Heathland & Grassland									
395136	MA	2	892	No Name	S	0%	97%	97%	
393508	MA	3	166	Name Excluded	P	100%	0%	100%	1
398403	MA	2	1,599	No Name	U	8%	7%	15%	
WETLAND HABITATS									
Central Hardwood Swamp									
North-Central Interior Wet Flatwoods									
378199	MA	3	67	No Name	U	0%	0%	0%	
Freshwater Marsh & Shrub Swamp									
Laurentian-Acadian Freshwater Marsh									
425408	CT	2	126	Name Excluded	U	6%	3%	9%	
392122	MA	2	663	No Name	U	20%	3%	23%	
370503	MA	2	356	Name Excluded	U	25%	23%	47%	
320161	MA	2	403	Name Excluded	U	0%	18%	18%	
395521	MA	2	901	No Name	U	47%	24%	71%	
128579	ME	3	32	Name Excluded	U	71%	0%	71%	
Laurentian-Acadian Wet Meadow-Shrub Swamp									
321861	MA	2	254	Name Excluded	S	9%	82%	91%	
391424	CT	2	93	Name Excluded	U	0%	0%	0%	
Large River Floodplain									
North-Central Appalachian Large River Floodplain									
334496	MA	2	52	Name Excluded	U	0%	70%	70%	
270532	MA	2	113	Name Excluded	U	0%	16%	16%	
368302	MA	2	56	Name Excluded	S	0%	89%	89%	
Northern Peatland									
Boreal-Laurentian Bog									
119055	ME	2	12,990	Great Heath	U	37%	1%	38%	
Northern Swamp									
North-Central Appalachian Acidic Swamp									
382379	MA	17	4,675	No Name	U	53%	4%	57%	
391955	MA	5	404	Name Excluded	U	30%	8%	38%	
313428	MA	2	12	Name Excluded	S	0%	100%	100%	
404439	RI	2	2,064	Queen's River	U	5%	66%	71%	
409738	RI	2	632	Woodville	U	0%	34%	34%	
411379	RI	4	1,393	No Name	U	19%	49%	67%	
431453	CT	3	22	Name Excluded	U	0%	0%	0%	
North-Central Interior & Appalachian Rich Swamp									
374009	MA	3	139	Name Excluded	U	0%	32%	32%	
374680	MA	2	77	Name Excluded	S	0%	76%	76%	
375896	MA	2	1,184	No Name	U	34%	12%	46%	

IPA ID	MAJORITY STATE	# FLOCO SPECIES	ACRES	APPROXIMATE SITE NAME	PROTECT CODE	PROTECTED (GAP 1–2)	MULTIPLE USE (GAP 3)	SECURED (GAP 1–3)	NE TARGET 30 / 75
Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp									
40429	ME	2	1,420	Salmon Brook Lake	U	48%	9%	57%	
Tidal Marsh									
North Atlantic Coastal Plain Tidal Salt Marsh									
437555	CT	2	1,126	Hammonasset State Park	U	65%	1%	66%	
453068	CT	2	470	Name Excluded	U	0%	71%	71%	
277479	MA	2	290	Name Excluded	U	2%	3%	6%	
354799	MA	2	165	Name Excluded	U	0%	42%	42%	
317423	MA	4	876	No Name	U	2%	30%	32%	
340769	MA	2	721	No Name	U	2%	59%	61%	
349758	MA	2	768	No Name	U	0%	22%	22%	
348863	MA	4	6,515	No Name	U	1%	69%	70%	
381361	MA	4	4,657	No Name	U	6%	40%	46%	
275986	MA	3	5,660	No Name	U	42%	14%	56%	
270568	MA	2	4,777	No Name	U	66%	4%	70%	
335351	MA	2	554	No Name	U	14%	36%	50%	
346911	MA	2	2,164	No Name	U	0%	48%	48%	
412715	RI	3	290	Name Excluded	U	70%	0%	70%	
380956	RI	2	667	Nbnerr North Prudence Unit	S	16%	65%	81%	

APPENDIX 4

Flora Conservanda Taxa on Secured Lands

SCIENTIFIC NAME	DIVISION	G RANK	TOTAL EOs IN GAP STUDY	GAP 1	GAP 2	GAP 3	% SECURED	% UNSECURED
Adiantum viridimontanum	1	G2	7	14%			14%	86%
Agalinis acuta	1	G1	49	4%	16%	37%	57%	43%
Amelanchier nantucketensis	1	G3	99	3%	15%	22%	40%	60%
Astragalus alpinus var. brunetianus	1	G3	20			5%	5%	95%
Astragalus robbinsii var. jesupii	1	G1	5		40%	20%	60%	40%
Bidens eatonii	1	G2	40			10%	10%	90%
Carex oronensis	1	G2	61	2%	3%	7%	11%	89%
Carex polymorpha	1	G3	72		1%	11%	13%	88%
Carex schweinitzii	1	G3	39	3%	5%	26%	33%	67%
Coreopsis rosea	1	G3	113	4%	3%	26%	32%	68%
Cystopteris laurentiana	1	G3	2			100%	100%	
Eleocharis aestuum	1	G3	2		50%		50%	50%
Eleocharis diandra	1	G1	11			9%	9%	91%
Eriocaulon parkeri	1	G3	53		2%	11%	13%	87%
Geum peckii	1	G2	38	61%	21%	13%	95%	5%
Hieracium robinsonii	1	G2	2				0%	100%
Hypericum adpressum	1	G2	22	9%	41%	14%	64%	36%
Isoetes acadiensis	1	G3	11	18%		55%	73%	27%
Isoetes prototypus	1	G2	4		25%		25%	75%
Isotria medeoloides	1	G2	112	4%	1%	26%	30%	70%
Malaxis bayardii	1	G1	6	17%		33%	50%	50%
Mimulus ringens var. colpophilus	1	G45	22		5%	9%	14%	86%
Minuartia marcescens	1	G2	1	100%			100%	
Panax quinquefolius	1	G3	382	10%	9%	31%	50%	50%
Pedicularis furbishiae	1	G1	46		7%		7%	93%
Pityopsis falcata	1	G3	21			29%	29%	71%
Platanthera leucophaea	1	G2	1	100%			100%	
Polemonium vanbruntiae	1	G3	15	7%		40%	47%	53%
Polygonum glaucum	1	G3	41	10%	10%	10%	29%	71%
Potamogeton hillii	1	G3	80	5%		11%	16%	84%
Potamogeton ogdenii	1	G1	14	7%			7%	93%
Potentilla robbinsiana	1	G1	2	100%			100%	
Pycnanthemum torrei	1	G2	4	25%	50%		75%	25%
Sabatia kennedyana	1	G3	212	2%	1%	19%	22%	78%
Sagittaria teres	1	G3	103	3%	3%	17%	22%	78%
Scirpus ancistrochaetus	1	G3	39		3%	15%	18%	82%
Scirpus longii	1	G2	74	1%	32%	38%	72%	28%
Suaeda maritima ssp. richii	1	G45	20		20%	15%	35%	65%
Symphyotrichum anticostense	1	G2	3				0%	100%

SCIENTIFIC NAME	DIVISION	G RANK	TOTAL EOs IN GAP STUDY	GAP 1	GAP 2	GAP 3	% SECURED	% UNSECURED
Triglochin gaspensis	1	G3	6			33%	33%	67%
Trollius laxus	1	G45	6	17%	17%		33%	67%
Adiantum aleuticum	2	G45	3	33%		33%	67%	33%
Agalinis neoscotica	2	G2	6	17%	67%		83%	17%
Agastache nepetoides	2	G45	6		17%		17%	83%
Agastache scrophulariifolia	2	G4	10			40%	40%	60%
Ageratina aromatica	2	G45	18	6%	17%	44%	67%	33%
Agrimonia parviflora	2	G45	38		13%	13%	26%	74%
Amaranthus tuberculatus	2	G4	6			17%	17%	83%
Amerorchis rotundifolia	2	G45	15	13%		7%	20%	80%
Aplectrum hyemale	2	G45	14	21%	7%	29%	57%	43%
Aristida tuberculosa	2	G45	29		10%	14%	24%	76%
Asclepias purpurascens	2	G45	45	4%	11%	22%	38%	62%
Asclepias viridiflora	2	G45	2				0%	100%
Asplenium montanum	2	G45	27	4%	26%	26%	56%	44%
Astragalus robbinsii var. minor	2	G45	7	29%		43%	71%	29%
Betula glandulosa	2	G45	13	100%			100%	
Betula minor	2	G3	23	70%	22%	9%	100%	
Blephilia ciliata	2	G45	13	8%		62%	69%	31%
Botrychium lunaria	2	G45	6		17%	33%	50%	50%
Botrychium oneidense	2	G4	14	7%	14%	29%	50%	50%
Calamagrostis stricta ssp. stricta	2	GU	16	6%		6%	13%	88%
Cardamine douglassii	2	G45	22	9%	5%	9%	23%	77%
Cardamine longii	2	G3	28			18%	18%	82%
Carex adusta	2	G45	13		38%	8%	46%	54%
Carex alopecoidea	2	G45	48		17%	15%	31%	69%
Carex atherodes	2	G45	10				0%	100%
Carex atratiformis	2	G45	23	22%	9%	4%	35%	65%
Carex barrattii	2	G3	2		50%		50%	50%
Carex bicknellii	2	G45	15	7%		27%	33%	67%
Carex capillaris ssp. capillaris	2	GU	3	100%			100%	
Carex capillaris ssp. fuscidula	2	TNR	2	100%			100%	
Carex collinsii	2	G4	4			50%	50%	50%
Carex crawei	2	G45	9	22%	11%		33%	67%
Carex davisii	2	G4	52	2%	17%	15%	35%	65%
Carex debilis var. debilis	2	T5	2		50%		50%	50%
Carex gracilescens	2	G5	4			50%	50%	50%
Carex gynocrates	2	G45	15	13%	7%	20%	40%	60%
Carex livida	2	G45	11	36%	18%	27%	82%	18%
Carex mitchelliana	2	G3	31	3%		45%	48%	52%
Carex molesta	2	G4	3				0%	100%
Carex oligocarpa	2	G4	18	6%	6%	11%	22%	78%
Carex richardsonii	2	G45	2	100%			100%	
Carex rostrata	2	G5	15	33%		27%	60%	40%

SCIENTIFIC NAME	DIVISION	G RANK	TOTAL EOs IN GAP STUDY	GAP 1	GAP 2	GAP 3	% SECURED	% UNSECURED
Carex saxatilis	2	GU	2	100%			100%	
Carex striata	2	(blank)	19		11%		11%	89%
Carex tenuiflora	2	G45	34	6%	12%	35%	53%	47%
Carex vacillans	2	GNR	7			29%	29%	71%
Castilleja coccinea	2	G45	27	4%		7%	11%	89%
Ceanothus herbaceus	2	G45	1				0%	100%
Chamaelirium luteum	2	G45	13	8%	8%	15%	31%	69%
Cheilanthes lanosa	2	G45	2		50%		50%	50%
Chenopodium foggii	2	G2	9		11%	56%	67%	33%
Chrysopsis mariana	2	G45	1		100%		100%	
Claytonia virginica	2	G45	36	3%	19%	36%	58%	42%
Corydalis aurea	2	G45	18	11%		11%	22%	78%
Corydalis flavula	2	G45	4			25%	25%	75%
Crataegus bicknellii	2	G1	8	13%	13%		25%	75%
Crataegus schizophylla	2	G1G2	6			17%	17%	83%
Cryptogramma stelleri	2	G45	31	6%	6%	39%	52%	48%
Cuscuta coryli	2	G45	8	13%	13%	38%	63%	38%
Cuscuta polygonorum	2	G45	1			100%	100%	
Cypripedium arietinum	2	G3	65	8%	9%	14%	31%	69%
Cypripedium parviflorum var. makasin	2	T4	9	22%		44%	67%	33%
Desmodium cuspidatum	2	G45	44	27%	2%	36%	66%	34%
Desmodium glabellum	2	G45	23		4%	57%	61%	39%
Desmodium sessilifolium	2	G45	6			17%	17%	83%
Dichanthelium scabriusculum	2	G4	4			75%	75%	25%
Diospyros virginiana	2	G45	1			100%	100%	
Diphasiastrum sitchense	2	G45	5	40%	40%	20%	100%	
Doellingeria infirma	2	G45	15			67%	67%	33%
Draba cana	2	G45	4	75%		25%	100%	
Draba glabella	2	G4	10			30%	30%	70%
Draba reptans	2	G45	12		25%	8%	33%	67%
Drosera anglica	2	G5	3	67%		33%	100%	
Drosera linearis	2	GU	1	100%			100%	
Elatine americana	2	G4	14			36%	36%	64%
Eleocharis equisetoides	2	G4	12		8%	25%	33%	67%
Eleocharis microcarpa var. filiculmis	2	(blank)	4			25%	25%	75%
Eleocharis nitida	2	GU	3			33%	33%	67%
Eleocharis quadrangulata	2	G45	2				0%	100%
Eleocharis rostellata	2	G45	20		15%	30%	45%	55%
Eleocharis tricostata	2	G4	4		50%		50%	50%
Elymus macgregorii	2	GNR	3				0%	100%
Epilobium anagallidifolium	2	G5	2	100%			100%	
Erigeron hyssopifolius	2	G45	25	4%	4%	24%	32%	68%
Euphrasia oakesii	2	G4	4	100%			100%	
Festuca prolifera	2	GU	1	100%			100%	

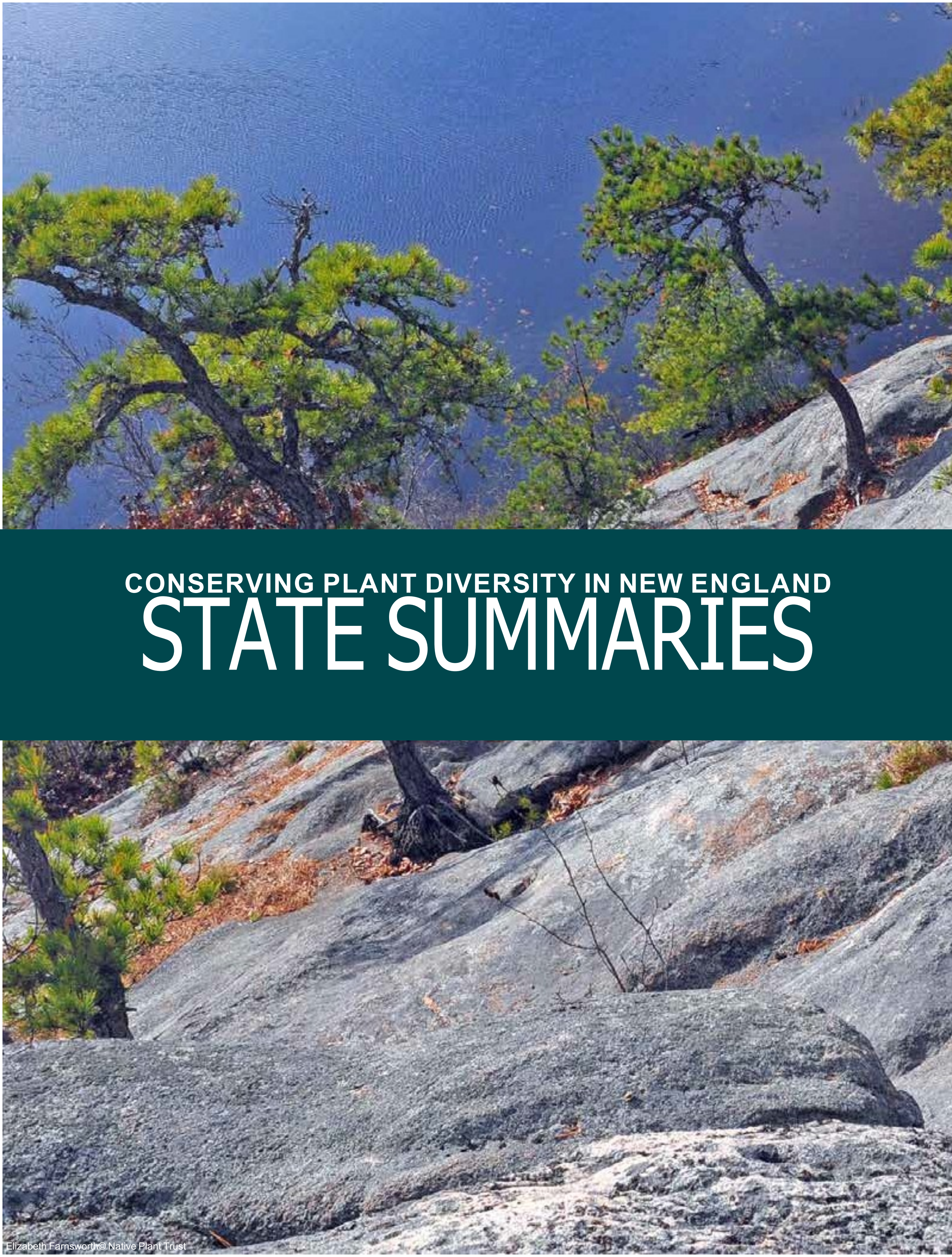
SCIENTIFIC NAME	DIVISION	G RANK	TOTAL EOs IN GAP STUDY	GAP 1	GAP 2	GAP 3	% SECURED	% UNSECURED
Floerkea proserpinacoides	2	G45	6		33%	17%	50%	50%
Gentiana andrewsii var. andrewsii	2	T5	3				0%	100%
Gentianella amarella ssp. acuta	2	T5	1			100%	100%	
Goodyera oblongifolia	2	G5	16			19%	19%	81%
Hieracium umbellatum	2	G45	1			100%	100%	
Huperzia selago	2	G45	16	25%	13%	38%	75%	25%
Hybanthus concolor	2	G45	1			100%	100%	
Hydrastis canadensis	2	G4	12	8%	8%		17%	83%
Hydrocotyle verticillata	2	G45	24		13%	8%	21%	79%
Hydrophyllum canadense	2	G45	14			29%	29%	71%
Juncus biflorus	2	G45	13		31%	15%	46%	54%
Juncus debilis	2	G45	13		15%	15%	31%	69%
Juncus stygius ssp. americanus	2	G45	6	17%		33%	50%	50%
Juncus subtilis	2	G4	8			25%	25%	75%
Juncus torreyi	2	G45	11			9%	9%	91%
Juncus vaseyi	2	G5	7	14%	14%	29%	57%	43%
Lathyrus ochroleucus	2	G4	10			20%	20%	80%
Leptochloa fusca ssp. fascicularis	2	G45	21	5%	5%	5%	14%	86%
Lespedeza repens	2	G45	3		33%		33%	67%
Linum sulcatum var. sulcatum	2	G45	1				0%	100%
Liparis liliifolia	2	G45	78	12%		46%	58%	42%
Liquidambar styraciflua	2	G45	9	11%	11%	33%	56%	44%
Lomatogonium rotatum	2	G5	12	42%			42%	58%
Lonicera hirsuta	2	G4	28	7%		18%	25%	75%
Ludwigia polycarpa	2	G4	20	20%	10%	15%	45%	55%
Ludwigia sphaerocarpa	2	G45	10		30%	30%	60%	40%
Luzula confusa	2	GU	5	80%	20%		100%	
Luzula spicata	2	G45	21	67%	24%	10%	100%	
Lycopodiella alopecuroides	2	G45	12		33%		33%	67%
Lycopus rubellus	2	G45	9		33%	22%	56%	44%
Minuartia rubella	2	G5	2	50%	50%		100%	
Moehringia macrophylla	2	G45	27	11%		4%	15%	85%
Montia fontana	2	G5	19	11%	11%		21%	79%
Morus rubra	2	G45	21	24%	5%	19%	48%	52%
Muhlenbergia capillaris	2	G45	7		14%	43%	57%	43%
Myriophyllum pinnatum	2	G45	17			18%	18%	82%
Nabalus serpentarius	2	G45	7	29%	43%	29%	100%	
Nuphar advena	2	G45	2	50%			50%	50%
Nymphaea leibergii	2	G5	20		5%	10%	15%	85%
Oligoneuron album	2	G45	20	5%		5%	10%	90%
Oligoneuron rigidum var. rigidum	2	G45	1				0%	100%
Oxalis violacea	2	G45	40	15%	13%	13%	40%	60%
Oxyria digyna	2	GU	6	67%	33%		100%	
Oxytropis campestris var. johannensis	2	T4	2				0%	100%

SCIENTIFIC NAME	DIVISION	G RANK	TOTAL EOs IN GAP STUDY	GAP 1	GAP 2	GAP 3	% SECURED	% UNSECURED
Panicum flexile	2	G45	2	50%			50%	50%
Paronychia fastigiata var. fastigiata	2	G5T5	5			20%	20%	80%
Paspalum laeve	2	G4	8	13%	25%		38%	63%
Paspalum setaceum var. psammophilum	2	G45	15		13%		13%	87%
Pedicularis lanceolata	2	G45	26			38%	38%	62%
Persicaria setacea	2	G45	6		17%	17%	33%	67%
Phleum alpinum	2	GU	18	28%	28%		56%	44%
Phyllodoce caerulea	2	GU	12	100%			100%	
Piptatherum canadense	2	G45	7		29%	29%	57%	43%
Plantago virginica	2	G45	8		13%	25%	38%	63%
Platanthera ciliaris	2	G45	21		5%	10%	14%	86%
Platanthera cristata	2	G45	3			67%	67%	33%
Poa pratensis ssp. alpigena	2	GU	5	60%	40%		100%	
Podophyllum peltatum	2	G45	9		33%	11%	44%	56%
Polymnia canadensis	2	G45	4		25%		25%	75%
Populus heterophylla	2	G45	14		14%	29%	43%	57%
Primula laurentiana	2	G5	11		9%		9%	91%
Pterospora andromedea	2	G45	5				0%	100%
Ranunculus ambigens	2	G4	13		23%		23%	77%
Ranunculus gmelinii	2	GU	4				0%	100%
Ranunculus micranthus	2	G45	11			64%	64%	36%
Rhynchospora capillacea	2	G4	14	29%		14%	43%	57%
Rhynchospora inundata	2	G3	14	7%	7%	7%	21%	79%
Rhynchospora nitens	2	G4	16	25%		31%	56%	44%
Rhynchospora torreyana	2	G4	14	21%	7%	21%	50%	50%
Ribes rotundifolium	2	G45	6	17%		33%	50%	50%
Rosa acicularis ssp. sayi	2	G45	5			100%	100%	
Rotala ramosior	2	G45	49		2%	55%	57%	43%
Rubus cuneifolius	2	G45	11		9%		9%	91%
Sabatia campanulata	2	G45	9	11%	22%	22%	56%	44%
Sabatia stellaris	2	G45	11		9%	36%	45%	55%
Sagittaria subulata	2	G4	17	6%	6%		12%	88%
Salix arctophila	2	G5	1	100%			100%	
Salix argyrocarpa	2	GU	5	80%	20%		100%	
Salix herbacea	2	G45	6	100%			100%	
Salix myricoides	2	G4	18				0%	100%
Salix uva-ursi	2	G45	21	86%	10%		95%	5%
Saururus cernuus	2	G45	7		14%		14%	86%
Saxifraga aizoides	2	G45	2			100%	100%	
Saxifraga cernua	2	GU	1		100%		100%	
Schoenoplectus heterochaetus	2	G45	4			50%	50%	50%
Scleria pauciflora var. caroliniana	2	G45	3			33%	33%	67%
Scleria triglomerata	2	G45	25	4%	32%	8%	44%	56%
Sclerolepis uniflora	2	G4	15	20%		13%	33%	67%

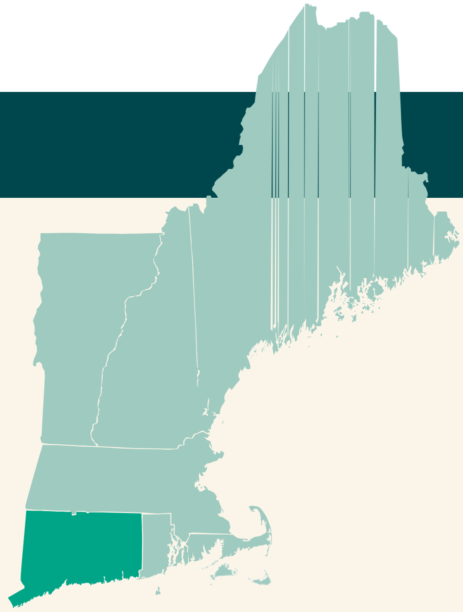
SCIENTIFIC NAME	DIVISION	G RANK	TOTAL EOs IN GAP STUDY	GAP 1	GAP 2	GAP 3	% SECURED	% UNSECURED
Scutellaria integrifolia	2	G45	8		63%		63%	38%
Selaginella selaginoides	2	GU	3		33%	33%	67%	33%
Senna hebecarpa	2	G45	24	4%	17%		21%	79%
Sibbaldia procumbens	2	GU	1	100%			100%	
Silene stellata	2	G45	21		5%	24%	29%	71%
Sphenopholis obtusata	2	G45	3	33%	33%	33%	100%	
Sphenopholis pensylvanica	2	G4	17		6%	29%	35%	65%
Sporobolus clandestinus	2	G45	2				0%	100%
Sporobolus heterolepis	2	G45	8		25%	25%	50%	50%
Sporobolus neglectus	2	G45	16	13%	6%	13%	31%	69%
Strophostyles umbellata	2	G45	1				0%	100%
Suaeda calceoliformis	2	G45	28		18%	14%	32%	68%
Symphyotrichum prenanthoides	2	G45	88	7%		28%	35%	65%
Taenidia integerrima	2	G45	18	6%			6%	94%
Tanacetum bipinnatum ssp. huronense	2	T4	12			8%	8%	92%
Tipularia discolor	2	G4	10			60%	60%	40%
Trichophorum clintonii	2	G4	14	14%		7%	21%	79%
Trichostema brachiatum	2	G45	8			13%	13%	88%
Triosteum angustifolium	2	G45	2				0%	100%
Triosteum perfoliatum	2	G45	19	5%	5%	37%	47%	53%
Utricularia subulata	2	G45	27	4%	22%	19%	44%	56%
Vahlodea atropurpurea	2	G45	1	100%			100%	
Valeriana uliginosa	2	G4	21	19%	5%	10%	33%	67%
Verbena simplex	2	G45	15	7%	7%		13%	87%
Veronica catenata	2	G45	4	25%			25%	75%
Viburnum prunifolium	2	G45	12	8%	25%	8%	42%	58%
Viola brittoniana	2	G45	29		3%	45%	48%	52%
Viola novae-angliae	2	G4	19	11%	11%		21%	79%
Woodsia alpina	2	G4	14	21%	36%	21%	79%	21%
Zizia aptera	2	G45	4				0%	100%

CONSERVING PLANT DIVERSITY IN NEW ENGLAND

STATE SUMMARIES



CONNECTICUT



Connecticut has 24 mapped habitats covering 2 million acres. On average, each habitat is 4% protected for nature(0-15%) and 23% secured against conversion to a differentland use (5-55%), but open to multiple uses, including logging, mineral extraction, and recreation. The conservedlands are 47% resilient. Three habitats cover less than 100 acres and are excluded here.

The metrics below refer to Global Strategy for Plant Conservation (GSPC) targets calling for protecting 15% of each habitat for nature and New England targets (NET) to achieve 30% of each habitat secured against conversion on climate-resilient land, with 5-15% protected for nature. The Important Plant Area numbers are total in the state, followed by how many meetthe GSPC thresholds of 75% protected for nature or secured on resilient land.

- **Important Plant Areas** (IPAs): **32**, 3 Protected, 0 Secured
- **Acres to meet GSPC for all habitats**: 245,979
- **Acres to meet NET for all habitats**: 224,691
- **Habitats meeting targets**: 1 GSPC, 1 NET
  - Acidic Cliff & Talus (GSPC)
  - North-Central Interior & Appalachian Acidic Peatland (NET)
- **Habitats partially meeting NET**: 4
  - Laurentian-Acadian Northern Hardwood Forest
  - Circumneutral Cliff & Talus
  - Acidic Cliff & Talus
  - North Atlantic Coastal Plain Tidal Salt Marsh
- **Opportunity**
  - North Atlantic Coastal Plain Tidal Salt Marsh: Migration Space

Elizabeth Farnsworth© Native Plant Trust

CONNECTICUT

CONTINUED

Unprotected Habitats Threatened by Conversion

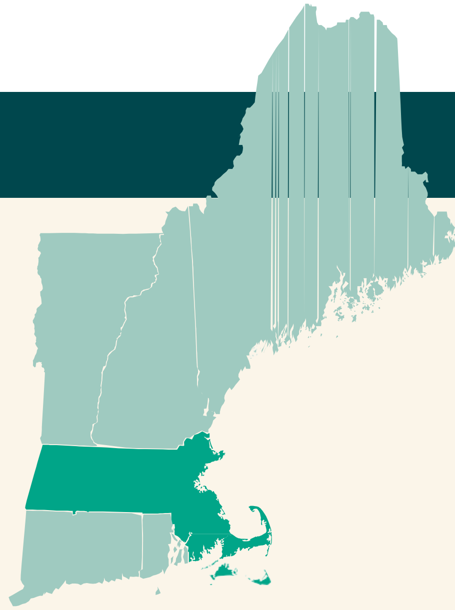
Bold indicates a high responsibility to conserve, as > 33% of the regional habitat is in this state.

HABITAT	TOC	%PR	%S	GSPC	NET	R ac
North-Central Interior Wet Flatwoods	11%	1%	16%	1 K	1 K	1 K
Atlantic Coastal Plain Beach & Dune	6%	1%	27%	327	80	44
Northeastern Coastal and Interior Pine-Oak Forest	9%	1%	23%	5 K	3 K	6 K
North Atlantic Coastal Plain Heathland & Grassland	18%	1%	28%	186	29	158
Northeastern Interior Dry-Mesic Oak Forest	8%	2%	18%	126 K	121 K	197 K
North Atlantic Coastal Plain Hardwood Forest	18%	3%	14%	24 K	32 K	49 K
North-Central Appalachian Acidic Swamp	7%	3%	22%	14 K	9 K	29 K
Appalachian (Hemlock)-Northern Hardwood Forest	5%	3%	20%	68 K	56 K	160 K
North Atlantic Coastal Plain Maritime Forest	16%	7%	26%	461	220	628

P = Protected, **S** = Secured, **R** = Resilient
Unprotected = less than 10% protected & resilient
TOC = threat of conversion by 2050
%PR = % protected & resilient
%S = % secured
GSPC = Global Strategy for Plant Conservation target
NET = New England Target
R ac = resilient acres available

Elizabeth Farnsworth© Native Plant Trust

MASSACHUSETTS



Massachusetts has 35 mapped habitats covering 3.7 millionacres. On average, each habitat is 9% protected for nature (0-59%) and 38% secured against conversion to a different land use (3-100%), but open to multiple uses, including logging, mineral extraction, and recreation. The conserved lands are 52% resilient. Two habitats cover less than 100 acres and are excluded here.

The metrics below refer to Global Strategy for Plant Conservation (GSPC) targets calling for protecting 15% of each habitat for nature and New England targets (NET) to achieve 30% of each habitat secured against conversion on climate-resilient land, with 5-15% protected for nature. The Important Plant Area numbers are total in the state, followed by how many meetthe GSPC thresholds of 75% protected for nature or secured on resilient land.

- **Important Plant Areas** (IPAs): **88**, 2 Protected, 17 Secured
- **Acres to meet GSPC for all habitats**: 382,153
- **Acres to meet NET for all habitats**: 75,577
- **Habitats meeting targets**: 7 GSPC, 4 NET
  - Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest (GSPC, NET)
  - Laurentian-Acadian Red Oak-Northern Hardwood Forest (GSPC, NET)
  - Acidic Cliff & Talus (GSPC)
  - Calcareous Cliff & Talus (GSPC)
  - Atlantic Coastal Plain Beach & Dune (GSPC)
  - Acidic Rocky Outcrop (GSPC)
  - Laurentian-Acadian Alkaline Fen (GSPC, NET)
  - Laurentian-Acadian Northern Hardwood Forest (NET)
- **Habitats meeting NET for Protection & Securement but not Resilience**
  - North Atlantic Coastal Plain Maritime Forest
  - North Atlantic Coastal Plain Pitch Pine Barrens
  - Atlantic Coastal Plain Beach & Dune
  - North Atlantic Coastal Plain Heathland & Grassland
  - Atlantic Coastal Plain Northern Bog
  - North Atlantic Coastal Plain Basin Peat Swamp
  - Laurentian-Acadian Alkaline Conifer-Hardwood Swamp
  - North Atlantic Coastal Plain Tidal Salt Marsh

Elizabeth Farnsworth© Native Plant Trust

MASSACHUSETTS

CONTINUED

Unprotected Habitats Threatened by Conversion

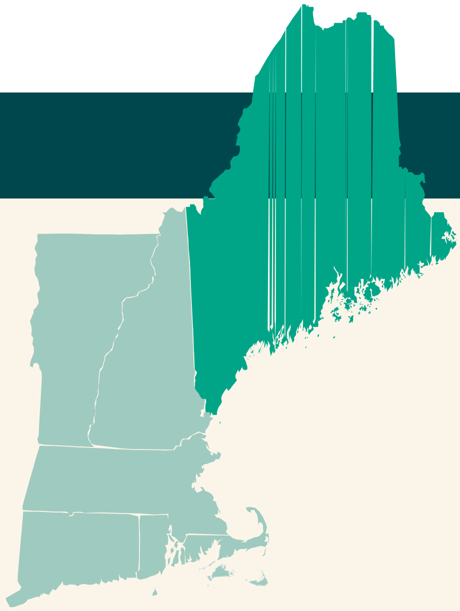
Bold indicates a high responsibility to conserve, as > 33% of the regional habitat is in this state.

HABITAT	TOC	%PR	%S	GSPC	NET	R ac
Northeastern Coastal & Interior Pine-Oak Forest	**9%**	1%	24%	57 K	25 K	34 K
North-Central Interior Wet Flatwoods	**11%**	1%	20%	1 K	<1 K	1.3 K
North Atlantic Coastal Plain Hardwood Forest	**18%**	1%	26%	36 K	12 K	47 K
North-Central Appalachian Acidic Swamp	**7%**	2%	29%	35 K	2 K	58 K
Appalachian (Hemlock)-Northern Hardwood Forest	**5%**	2%	30%	145 K	2 K	367 K
Northeastern Interior Dry-Mesic Oak Forest	**8%**	3%	17%	30 K	31 K	44 K
North-Central Interior & Appalachian Rich Swamp	**5%**	3%	27%	12 K	3 K	25 K
North-Central Interior & Appalachian Acidic Peatland	**5%**	3%	39%	447	268	987
North Atlantic Coastal Plain Pitch Pine Barrens	**15%**	5%	46%	11 K	11 K	7K
North Atlantic Coastal Plain Heathland & Grassland	**18%**	6%	36%	2 K	2 K	3 K
North Atlantic Coastal Plain Maritime Forest	**16%**	9%	30%	2 K	–	6 K

P = Protected, **S** = Secured, **R** = Resilient
Unprotected = less than 10% protected & resilient
TOC = threat of conversion by 2050
%PR = % protected & resilient
%S = % secured
GSPC = Global Strategy for Plant Conservation target
NET = New England Target
R ac = resilient acres available


Elizabeth Farnsworth© Native Plant Trust

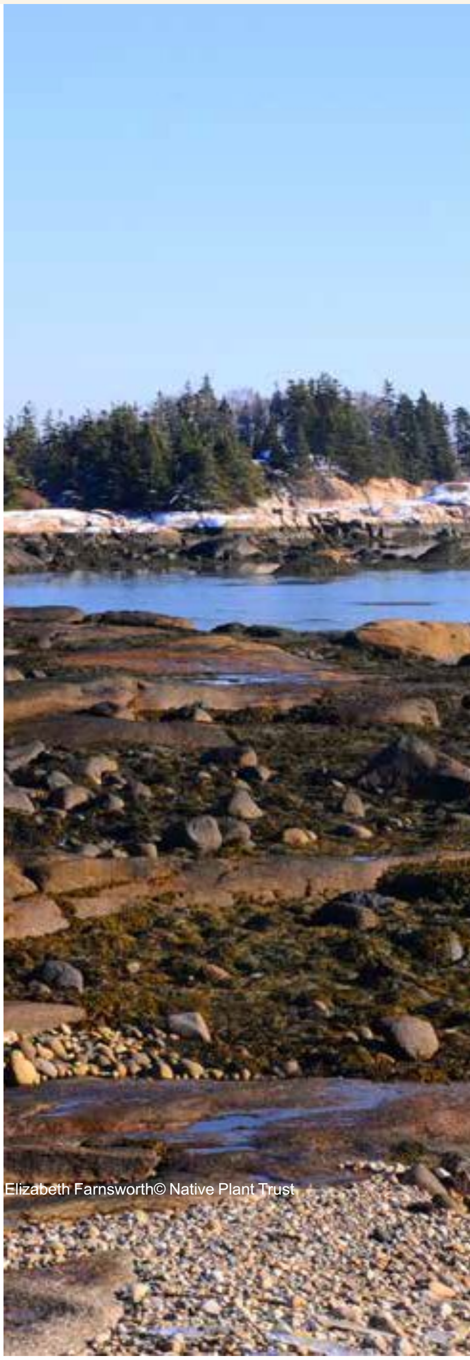
MAINE



Maine has 37 mapped habitats covering 18.8 million acres. On average, each habitat is 9% protected for nature (1-69%) and 27% secured against conversion (1-99%) to a different land use, but open to multiple uses, including logging, mineral extraction, and recreation. The conserved lands are and 78% resilient. Two habitats cover less than 100 acres and are excluded here.

The metrics below refer to Global Strategy for Plant Conservation (GSPC) targets calling for protecting 15% of each habitat for nature and New England targets (NET) to achieve 30% of each habitat secured against conversion on climate-resilient land, with 5-15% protected for nature. The Important Plant Area numbers are total in the state, followed by how many meetthe GSPC thresholds of 75% protected for nature or secured on resilient land.

- **Important Plant Areas** (IPAs): **52**, 4 Protected, 6 Secured
- **Acres to meet GSPC for all habitats**: 1,948,619
- **Acres to meet NET for all habitats**: 1,169,825
- **Habitats meeting GSPC target**: 8
- **Habitats meeting NE target**: 6
  - Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest (GSPC, NET)
  - Acidic Cliff & Talus (GSPC, NET)
  - Calcareous Cliff & Talus (GSPC, NET)
  - Circumneutral Cliff & Talus (GSPC, NET)
  - Acadian-Appalachian Alpine Tundra (GSPC, NET)
  - Acidic Rocky Outcrop (GSPC, NET)
  - Acadian Maritime Bog (GSPC)
  - Boreal-Laurentian Bog (GSPC)
- **Habitats meeting NET for Protection & Securement but not Resilience**
  - Northeastern Interior Pine Barrens
  - Boreal-Laurentian Bog
  - Acadian Coastal Salt & Estuary Marsh
  - North Atlantic Coastal Plain Tidal Salt Marsh



Elizabeth Farnsworth© Native Plant Trust

MAINE

CONTINUED

Unprotected Habitats Threatened by Conversion

Bold indicates a high responsibility to conserve, as > 33% of the regional habitat is in this state.

HABITAT	TOC	%PR	%S	GSPC	NET	R ac
Northeastern Coastal & Interior Pine-Oak Forest	**9%**	1%	9%	53 K	81 K	146 K
North-Central Interior & Appalachian Rich Swamp	**5%**	2%	11%	6 K	10 K	27 K
North-Central Interior & Appalachian Acidic Peatland	**5%**	3%	25%	534	225	2 K
North Atlantic Coastal Plain Maritime Forest	**16%**	4%	15%	4 K	5 K	12 K

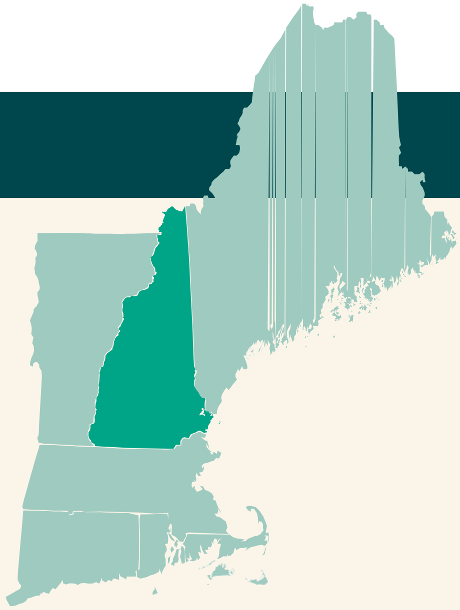
Unprotected Habitats with Low Threat, High Responsibility

Bold indicates a high responsibility to conserve, as > 33% of the regional habitat is in this state.

HABITAT	TOC	%PR	%S	GSPC	NET	R ac
Laurentian-Acadian Pine-Hemlock-Hardwood Forest	**2%**	1%	12%	366 K	492 K	1,013 K
Laurentian-Acadian Alkaline Conifer-Hardwood Swamp	**1%**	2%	16%	66 K	73 K	232 K
Laurentian-Acadian Red Oak-Northern Hardwood Forest	**1%**	3%	12%	72 K	109 K	354 K
Acadian Sub-boreal Spruce Flat	**0%**	4%	28%	143 K	22 K	597 K
Laurentian-Acadian Northern Hardwood Forest	**1%**	4%	25%	499 K	255 K	2,598 K
NA-Acadian Conifer-Hardwood Acidic Swamp	**0%**	4%	23%	68 K	43 K	327 K
Laurentian-Acadian Wet Meadow-Shrub Swamp	**2%**	4%	20%	31 K	30 K	150 K
Acadian Low Elevation Spruce-Fir-Hardwood Forest	**1%**	5%	26%	492 K	180 K	2,086 K
Laurentian-Acadian Large River Floodplain	**1%**	6%	24%	24 K	15 K	133 K
Laurentian-Acadian Freshwater Marsh	**4%**	6%	20%	19 K	22 K	109 K
Boreal-Laurentian-Acadian Acidic Basin Fen	**0%**	8%	28%	23 K	5 K	170 K

P = Protected, **S** = Secured, **R** = Resilient
Unprotected = less than 10% protected & resilient
TOC = threat of conversion by 2050
%PR = % protected & resilient
%S = % secured
GSPC = Global Strategy for Plant Conservation target
NET = New England Target
R ac = resilient acres available

NEW HAMPSHIRE



New Hampshire has 36 mapped habitats covering 5.2 million acres. On average, each habitat is 17% protected for nature (1-99%) and 38% secured against conversion to a different land use (10-99%), but open to multiple uses, including logging, mineral extraction, and recreation. The conserved lands are 84% resilient. Three habitats cover less than 100 acres and are excluded here.

The metrics below refer to Global Strategy for Plant Conservation (GSPC) targets calling for protecting 15% of each habitat for nature and New England targets (NET) to achieve 30% of each habitat secured against conversion on climate-resilient land, with 5-15% protected for nature. The Important Plant Area numbers are total in the state, followed by how many meetthe GSPC thresholds of 75% protected for nature or secured on resilient land.

- **Important Plant Areas** (IPAs): **11**, 0 Protected, 4 Secured
- **Acres to meet GSPC for all habitats**: 409,357
- **Acres to meet NET for all habitats**: 342,172
- **Habitats meeting targets**: 10 GSPC, 8 NET
  - Laurentian-Acadian Northern Hardwood Forest (GSPC, NET)
  - Laurentian-Acadian Red Oak-Northern Hardwood Forest (GSPC, NET)
  - Calcareous Cliff & Talus (GSPC, NET)
  - Laurentian-Acadian Alkaline Conifer-Hardwood Swamp (GSPC)
  - Boreal-Laurentian-Acadian Acidic Basin Fen (GSPC)
  - Calcareous Rocky Outcrop (GSPC, NET)
  - Acidic Cliff & Talus (GSPC, NET)
  - Acidic Rocky Outcrop (GSPC, NET)
  - **Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest** (GSPC, NET)
  - **Acadian-Appalachian Alpine Tundra** (GSPC, NET)
- **Habitats meeting NET for Protection & Securement but not Resilience**
  - North Atlantic Coastal Plain Basin Peat Swamp
  - Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp
  - Acadian Sub-boreal Spruce Flat
  - Acadian Low Elevation Spruce-Fir-Hardwood Forest
  - Laurentian-Acadian Alkaline Conifer-Hardwood Swamp
  - Boreal-Laurentian-Acadian Acidic Basin Fen

© Jenny Wollensak Lussier

NEW HAMPSHIRE

CONTINUED

Unprotected Habitats Threatened by Conversion

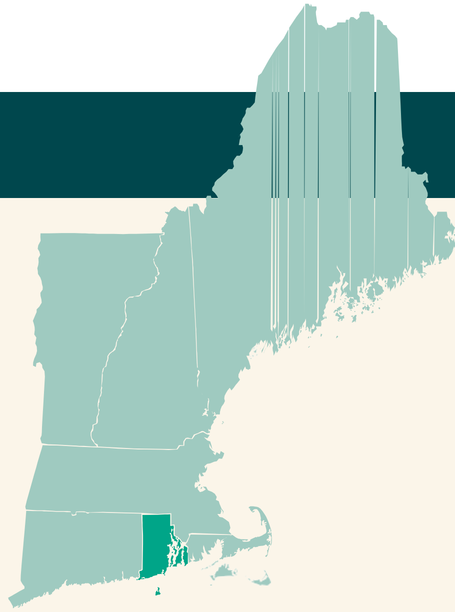
Bold indicates a high responsibility to conserve, as > 33% of the regional habitat is in this state.

HABITAT	TOC	%PR	%S	GSPC	NET	R ac
Northeastern Coastal & Interior Pine-Oak Forest	9%	1%	16%	93 K	89 K	173 K
North-Central Appalachian Acidic Swamp	7%	2%	23%	12 K	6 K	29 K
Appalachian (Hemlock)-Northern Hardwood Forest	5%	2%	16%	158 K	167 K	608 K
N-Central Interior & Appalachian Acidic Peatland	5%	2%	39%	338	–	1 K

P = Protected, **S** = Secured, **R** = Resilient
Unprotected = less than 10% protected & resilient
TOC = threat of conversion by 2050
%PR = % protected & resilient
%S = % secured
GSPC = Global Strategy for Plant Conservation target
NET = New England Target
R ac = resilient acres available

© Jenny Wollensak Lussier

RHODE ISLAND



Rhode Island has 21 mapped habitats covering 462,000 acres. On average, each habitat is 6% protected for nature(0-18%) and 28% secured against conversion to a differentland use (0-73%), but open to multiple uses, including logging, mineral extraction, and recreation. The conserved lands are 37% resilient. Three habitats cover less than 100 acres and are excluded here.

The metrics below refer to Global Strategy for Plant Conservation (GSPC) targets calling for protecting 15% of each habitat for nature and New England targets (NET) to achieve 30% of each habitat secured against conversion on climate-resilient land, with 5-15% protected for nature. The Important Plant Area numbers are total in the state, followed by how many meetthe GSPC thresholds of 75% protected for nature or secured on resilient land.

- **Important Plant Areas** (IPAs): **8**, 0 Protected, 1 Secured
- **Acres to meet GSPC for all habitats**: 50,509
- **Acres to meet NET for all habitats**: 25,329
- **Habitats meeting targets**: 2 GSPC, 0 NET
  - North Atlantic Coastal Plain Tidal Salt Marsh (GSPC)
  - North Atlantic Coastal Plain Pitch Pine Barrens (GSPC)
- **Habitats meeting NET for Protection & Securement but not Resilience**
  - North Atlantic Coastal Plain Tidal Salt Marsh

Elizabeth Farnsworth© Native Plant Trust

RHODE ISLAND

CONTINUED

Unprotected Habitats Threatened by Conversion

Bold indicates a high responsibility to conserve, as > 33% of the regional habitat is in this state.

HABITAT	TOC	%PR	%S	GSPC	NET	R ac
NA Coastal Plain Heathland & Grassland	18%	1%	24%	0.4 K	0.2 K	0.2 K
Northeastern Interior Dry-Mesic Oak Forest	8%	1%	21%	24.5 K	15.6 K	18.1 K
Atlantic Coastal Plain Beach & Dune	6%	3%	17%	0.4 K	0.4 K	0.4 K
North Atlantic Coastal Plain Maritime Forest	16%	3%	26%	1.0 K	0.3 K	0.9 K
North Atlantic Coastal Plain Hardwood Forest	18%	4%	18%	7.1 K	7.8 K	14.4 K
North-Central Appalachian Acidic Swamp	7%	6%	30%	6.1 K	0.1 K	18.4 K

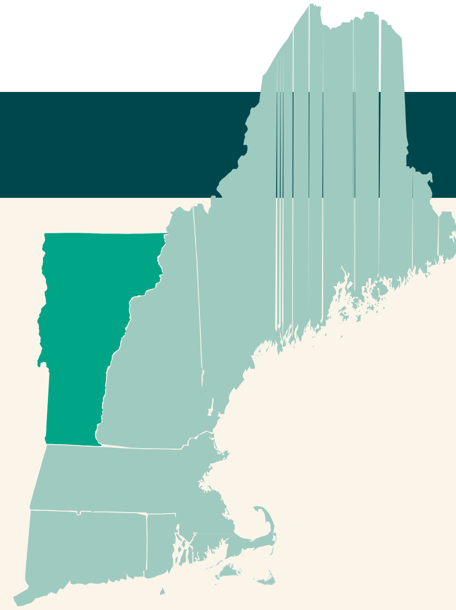
Unprotected Habitats with Low Threat, High Responsibility

Bold indicates a high responsibility to conserve, as > 33% of the regional habitat is in this state.

HABITAT	TOC	%PR	%S	GSPC	NET	R ac
Northeastern Interior Pine Barrens	3%	0%	69%	334	273	80
Laurentian-Acadian Freshwater Marsh	4%	4%	30%	492	20	823
Laurentian-Acadian Wet Meadow-Shrub Swamp	2%	5%	37%	519	378	1.1 K
North Atlantic Coastal Plain Basin Peat Swamp	2%	6%	34%	149	131	464

P = Protected, **S** = Secured, **R** = Resilient
Unprotected = less than 10% protected & resilient
TOC = threat of conversion by 2050
%PR = % protected & resilient
%S = % secured
GSPC = Global Strategy for Plant Conservation target
NET = New England Target
R ac = resilient acres available

VERMONT



Vermont has 30 mapped habitats covering 5.5 million acres. On average, each habitat is 5% protected for nature (0-100%) and 28% secured against conversion to a differentuse (1-100%), but open to multiple uses, including logging,mineral extraction, and recreation. The conserved lands are 90% resilient. One habitat covers less than 100 acres and is excluded here.

The metrics below refer to Global Strategy for Plant Conservation (GSPC) targets calling for protecting 15% of each habitat for nature and New England targets (NET) to achieve 30% of each habitat secured against conversion on climate-resilient land, with 5-15% protected for nature. The Important Plant Area numbers are total in the state, followed by how many meetthe GSPC thresholds of 75% protected for nature or secured on resilient land.

- **Important Plant Areas** (IPAs): **39**, 1 Protected, 4 Secured
- **Acres to meet GSPC for all habitats**: 466,707
- **Acres to meet NET for all habitats**: 484,365
- **Habitats meeting targets**: 7 GSPC, 5 NET
  - Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest (GSPC, NET)
  - Acidic Cliff & Talus (GSPC, NET)
  - Acadian-Appalachian Alpine Tundra (GSPC, NET)
  - Acidic Rocky Outcrop (GSPC, NET)
  - Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp (GSPC, NET)
  - Boreal-Laurentian-Acadian Acidic Basin Fen (GSPC)
  - North-Central Interior & Appalachian Acidic Peatland (GSPC)
- **Habitats meeting NET for Protection & Securement but not Resilience**
  - Boreal-Laurentian-Acadian Acidic Basin Fen
  - North-Central Interior & Appalachian Acidic Peatland

Elizabeth Farnsworth© Native Plant Trust

VERMONT

CONTINUED

Unprotected Habitats Threatened by Conversion

Bold indicates a high responsibility to conserve, as > 33% of the regional habitat is in this state.

HABITAT	TOC	%PR	%S	GSPC	NET	R ac
North-Central Appalachian Acidic Swamp	7%	1%	7%	1.4 K	2.4 K	4.9 K
North-Central Interior & Appalachian Rich Swamp	5%	1%	9%	1.2 K	1.9 K	3.8 K
Appalachian (Hemlock)-Northern Hardwood Forest	5%	2%	8%	81.8 K	137.4K	358.9K
North-Central Interior Wet Flatwoods	11%	2%	6%	0.2 K	0.4 K	0.7 K
Circumneutral Cliff & Talus	7%	4%	15%	0.7 K	1.0 K	5.1 K

Unprotected Habitats with Low Threat, High Responsibility

Bold indicates a high responsibility to conserve, as > 33% of the regional habitat is in this state.

HABITAT	TOC	%PR	%S	GSPC	NET	R ac
Laurentian-Acadian Alkaline Fen	0%	0%	1%	14	27	25
L-A Red Oak-Northern Hardwood Forest	1%	2%	15%	46.6K	52.1K	235.3K
Glacial Marine & Lake Mesic Clayplain Forest	4%	2%	7%	4.1K	7.5K	11.9K
Glacial Marine & Lake Wet Clayplain Forest	3%	2%	12%	1.8K	2.5K	3.7K
Calcareous Rocky Outcrop	0%	7%	23%	1.4K	1.1K	11.4K
Calcareous Cliff & Talus	1%	8%	31%	1.1K	–	10.3K

P = Protected, **S** = Secured, **R** = Resilient
Unprotected = less than 10% protected & resilient
TOC = threat of conversion by 2050
%PR = % protected & resilient
%S = % secured
GSPC = Global Strategy for Plant Conservation target
NET = New England Target
R ac = resilient acres available

Exhibit Five

Charles D. Baker
GOVERNOR

Karyn E. Polito
LIEUTENANT GOVERNOR

Kathleen A. Theoharides
SECRETARY

The Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs100 Cambridge Street, Suite 900

Boston, MA 02114

June 9, 2021

Tel: (617) 626-1000
Fax: (617) 626-1081
http://www.mass.gov/eea

CERTIFICATE OF THE SECRETARY OF ENERGY AND ENVIRONMENTAL AFFAIRSON THE EXPANDED ENVIRONMENTAL NOTIFICATION FORM

PROJECT NAME	: ADM Tihonet Mixed Use Development WarehamPV+ES Projects
PROJECT MUNICIPALITY	: Wareham
PROJECT WATERSHED	: Buzzards Bay
EEA NUMBER	13940
PROJECT PROPONENT	: Borrego Solar Systems,
IncDATE NOTICED IN MONITOR	: March 24, 2021

Pursuant to the Massachusetts Environmental Policy Act (M.G. L. c. 30, ss. 61-62I) andSection 11.06 of the MEPA regulations (301 CMR 11.00), I hereby determine that this project **does not require** the preparation of an Environmental Impact Report (EIR).

This project consists of three proposed solar photovoltaic (PV) generating facilities that are under review pursuant to a Special Review Procedure (SRP). As detailed below, the SRP established MEPA review procedures for an area of over 6,000 acres of land in Carver, Plymouthand Wareham. I received several comments expressing concern that the project will clear over 154 acres of undeveloped forestland possessing significant ecological value, including important pine barrens habitat, to accommodate the proposed solar PV generating facilities. Commenters have also asserted that extensive sand excavation is occurring on land within the SRP area without necessary local approvals and lax enforcement of municipal ordinances, and that these activities were not adequately disclosed or reviewed during MEPA review of both this project and others previously proposed over the 6,000 acre area at issue. Comments also assert that the sand excavation activity threatens a vital drinking water aquifer. I note that the Massachusetts Department of Environmental Protection's (MassDEP) Drinking Water regulations identify prohibited uses within a Zone II at 310 CMR 22.21(2)(a) and (b), which include excavation within the Zone II wellhead protection area to a depth such that there would be less than four feet of soil above the historical high groundwater table elevation unless the material is redepositedwithin 45 days; however, the sites of the solar PV facilities proposed as part of this project arenot located within a Zone II protection area.

As discussed below, I find that there have been sufficient disclosures of impacts associated with the three proposed solar PV facilities, including anticipated sand excavation, to allow this project to proceed to permitting. Pursuant to procedures set forth in the SRP, and consistent with prior reviews conducted for other solar PV projects proposed in this area, I do notfind that further review in the form of an Environmental Impact Report (EIR) is warranted. I notethat the Proponent, at the request of the MEPA Office, submitted an Expanded Environmental Notification Form (EENF) and provided supplemental information with detailed analyses regarding greenhouse gas (GHG) emissions from the project, including potential loss in carbon sequestration associated with forest clearing together with a comparison of offsets in the form of renewable energy generation. As described below, the Proponent has also agreed to consult with the MEPA Office immediately upon completion of review for this project to discuss the need for any future filings, including a potential Notice of Project Change (NPC) or, to the extent development activity in Phase C is nearing completion, a final "close out" filing as contemplatedin the SRP, to disclose the nature and extent of past sand excavation activities to the extent they can be deemed related to previously reviewed projects or otherwise subject to the SRP procedures. I am aware that one commenter has filed a third-party NPC under 301 CMR 11.10 ofthe MEPA regulations. It is my expectation that the Proponent will meet with the MEPA Office to determine next steps as to a potential future filing prior to undertaking any additional sand excavation activities in areas that are subject to the SRP.

It bears repetition that MEPA review is not a permitting process, nor does it serve as an appeal for local decisions. It does not pass judgment on whether a project is or is not beneficial, or whether a project can or should receive a particular permit. Rather, the MEPA process requires public disclosure of a project's environmental impacts as well as the measures that the proponent will undertake to avoid, minimize and mitigate these impacts. MEPA review occurs before public agencies act to issue permits and approvals for a proposed project to ensure that those agencies are fully cognizant of the environmental consequences of their actions. As discussed below, multiple Agency Actions are required to facilitate the overall development planfor this area. Those permitting procedures will further analyze impacts associated with the individual projects associated with the development plan. As noted in prior MEPA documents, the owner of the 6,000 acre area at issue also developed an overall conservation strategy with thestate that will mitigate impacts to rare species by protecting habitat on contiguous parcels adjacent to the Myles Standish State Forest. Thus far, conservation restrictions (CRs) have been placed on 410 acres of land; based on agency comments, it is anticipated that mitigation for this project will add to that protected area. I anticipate that a full accounting of these and other mitigation measures will be forthcoming in future filings and analyzed as part of a final certificate on the entire development plan as contemplated in the SRP.

Project Description

The EENF described three ground-mounted solar PV facilities with battery energy storage (ES) to be constructed in Wareham as part of Phase C of a larger master plan development proposed by A.D. Makepeace (ADM), referenced herein as the Tihonet Mixed Use

Development (or “TMUD”) Project. As described below, one of the sites may also be excavatedto extract sand. The three projects are described below.

27 Charge Pond Road (Phase C10)

The project includes the construction of a 5-megawatt (MW) AC/11.6-MW DC PV generating facility with battery ES within a 37.4-acre area enclosed by a 7-ft high chain link fence. A 20-foot (ft) wide gravel road will provide access to the site from Charge Pond Road andwill continue around the perimeter of the PV array within the fenced area. Two electrical equipment areas with switchgear, transformers, inverters and battery storage equipment will be constructed within PV facility and interconnection equipment will be mounted on a concrete padnear the entrance to the site. Topography on the site ranges from 20 ft to 45 ft NAVD 88; final elevations will not change significantly, but the northeastern part of the site will be regraded slightly to facilitate drainage. Vegetated swales and 14 infiltration basins will be constructed around the perimeter of the site to collect stormwater runoff. The project will clear 42.1 acres of trees and add 0.07 acres of impervious area. The project also includes the removal of debris froman approximately 6,500-sf area of BVW.

The site is bordered by Charge Pond Road to the east, baseball playing fields to the northeast, Route 25 to the north, Parker Mills Pond and associated Bordering Vegetated Wetlands (BVW) to the north and west, and undeveloped land and an industrial use to the south.The site is largely undeveloped and covered by woods, except for a previously-disturbed area inthe northeastern part of the site. Isolated Vegetated Wetlands (IVW) are located in the northwestand southern portions of the site. Approximately 145,000 sf (3.3 acres) of the site is located within the Buffer Zone of BVW. Biomap 2 Core Habitat is located along the western part of the site.

140 Tihonet Road (Phase C11)

The project includes the construction of a 5-MW AC/19.3-MW DC PV generating facility with ES within a 61.1-acre area enclosed by a 7-ft high chain link fence. Existing unpaved roads on the east, south and western edges of the site will be improved and additional 20-ft wide gravel roads will be constructed to provide access around the perimeter and to the interior of the array. Access to the facility will be provided by a connection to Tihonet Pond Road at the northwest corner of the site. Five electrical equipment areas with switchgear, transformers, inverters and battery storage equipment will be constructed within PV facility. Thefacility will be connected to the transmission line that borders the site’s northern property line.

Existing topography on the site ranges from approximately 110 ft NAVD 88 at the north side ofthe site to a low point of approximately 35 ft NAVD 88 at the southwest corner of the site.

Excavation to extract sand and establish finished grades prior to installation of the PV facility will create a steep slope at the north side of the site where the elevation will drop by 25 ft to 85 ftNAVD 88. Most of the site will be lowered by 20 to 30 ft except for the southern part of the site where existing grades will generally be maintained. Vegetated swales and seven infiltration basins will be constructed around the perimeter of the site to collect stormwater runoff. The project will clear trees and excavate up to 1.2 million cubic yards (cy) of sand on a 63.5-acre portion of the site and add 0.16 acres of impervious area.

The site is bordered by cranberry bogs and undeveloped land to the east and south, Tihonet Pond Road to the west and an electric transmission line and the Phase C12 site (described below) to the north. The site is undeveloped and covered by woods. An IVW with a vernal pool is located between the proposed facility and Tihonet Pond Road. Approximately 21,000 sf (0.5 acres) of the southwestern portion of the site is within the 100-ft Buffer Zone of anoff-site drainage canal. The site is located within Biomap 2 Natural Landscape.

150 Tihonet Road (Phase C12)

The project includes the construction of a 5-MW AC/15.5-MW DC PV generating facility with ES within a 48.7-acre area enclosed by a 7-ft high chain link fence. A 20-ft wide gravel road will provide access to the site from Tihonet Pond Road and will continue around the southern and eastern perimeter of the PV array within the fenced area and through the center of the site from north to south. Four electrical equipment areas with transformers, inverters and battery storage equipment will be constructed within PV facility. The facility will be connected to the transmission line borders the site's southern property line. Topography on the site ranges from approximately 90 ft NAVD 88 at the southern end of the site to approximately 63ft NAVD 88 at the northern end of the site. The existing grades will be maintained except for limited excavation necessary to construct infiltration basins. Five drainage basins will be constructed around the perimeter of the site to collect stormwater runoff. The project will clear 49.16 acres oftrees and add 0.15 acres of impervious area.

The site is bordered by cranberry bogs and the Phase C5 solar PV generating facility to the north, undeveloped land and cranberry bogs to the east, an electric transmission line and the Phase C11 site to the south and Tihonet pond Road to the west. The site is undeveloped and covered by woods. Three areas of IVW and two vernal pools are located along the west side of the site and a BVW is located on the west side of the site. Approximately 97,000 sf of the site islocated within the 100-ft Buffer Zones of the BVW on the west side of the site and of the cranberry bog to the north. The site does not include mapped Priority Habitat for rare species; however, approximately 31.18 acres of the site is located within the actual, identified habitat of state-listed pine barrens moth species. The site is located within Biomap 2 Core Habitat and Natural Landscape.

TMUD Project Background

As described in previous MEPA filings, the TMUD Project proposed the phased development of 6,107 acres in the towns of Carver, Plymouth and Wareham over a 25-year period.[1] The phased development program described in an EENF submitted in July 2008 consisted of a mixed-use village community incorporating principles of smart growth, open space preservation, low impact development, traditional village design, and pedestrian orientation. The plan included the use of Transfer of Development Rights (TDR) to concentratedevelopment in certain areas and ensure conservation of ecologically significant lands.
Agriculture operations were proposed to continue to be a major component of the overall project.

The TMUD Project has been proposed in three major phases (Phases A-C) which havechanged in scope and location since the project was originally described. Phases A and B are

[1] According to the EENF, the total TMUD Project area has been reduced from 5,666.91 acres.

located in Wareham. Phase A1 (Tihonet Technology Park) was proposed to include 80,000 sf ofoffice and light industrial uses on a 16-acre portion of the site; the light industrial development has been replaced by the 5.5-MW Tihonet West Solar Project (now known as the 77 Farm-to- Market Road PV + ES Project). Phase A2 included construction of a 65,840-sf a medical office building within the Rosebrook Business Park, and Phase A3 included a 5-acre cranberry bog near the northwest quadrant of Route 195/Route 25 interchange. The Phase B projects include the 0.5-MW Rosebrook Solar PV facility, the 3.6-MW PV facility at 71 Charlotte Furnace Roadthat will be expanded to 7.1 MW and a mixed-use development known as Rosebrook Place. ThePhase B solar facilities have been constructed and are generating power. Rosebrook Solar provides power to ADM properties and facilities. Charlotte Furnace Solar provides power to theelectrical grid. The projects proposed in Phases A and B have completed MEPA review.

Phase C consists of all other elements of the TMUD Project and encompasses 5,287.2 acres. It includes agricultural, commercial and residential uses, PV generating facilities and preservation of open space. Phase C1 included the construction of the Wankinco Bog, a 16.5- acre bog, 2.5-acre reservoir and tailwater recovery pond, 13 acres of bog roads/graded areas and preservation of 24 acres of open space. Phase C2 consisted of the construction of a 140-acre bog that is being built out as older run-of-river bogs are abandoned, construction of a bypass canal around the Frogfoot Bogs and construction of a soil blending facility. The Phase C2 bog project will include 77 acres of unimproved bog roads and grading areas. Phases C3 and C4 consist of solar projects, including the Tihonet West Solar project and the Federal Road Solar project, respectively. The Tihonet West and Federal Road solar projects have been constructed. Phase C5includes the construction of a 6-MW PV facility known as Tihonet East Solar at 160 Tihonet Road in Wareham, which will be expanded to 9.8 MW within the same footprint with the addition of ES. Phase C6 includes the construction of an 8.4-MW PV facility at 59 Federal Roadin Carver, which will be expanded to a 10-MW facility as a result of adding ES and revising the layout of the array; the project is currently under construction. During the comment period, I received a copy of a Carver Earth Removal Special Permit Application indicating that over four million cubic yards of material is proposed to be removed from the Phase C6 site. Phases C7 and C8 include 7-MW and 12.5 MW solar PV facilities, respectively, in Carver; construction of both of these facilities has commenced. Phase C9 is currently under construction and includes a 3-MW solar PV facility in Wareham.

Procedural History

An SRP was signed on January 29, 2007 and established review requirements for the TMUD Project. The SRP allows phases of the project to be filed as ENFs and includes requirements for a baseline environmental resource assessment and cumulative impact assessment for the entire project site, public outreach, and extended public comment periods. Each filing must include a revised and updated master plan, a cumulative impact assessment anddiscussion of the project’s consistency with the Master Plan. The public participation process consists of quarterly public update meetings and/or public meetings prior to the filing of each review document. In addition, the SRP established an extended 45-day review period for projectreview documents filed with MEPA.

Consistent with the SRP, the Proponent filed an EENF in 2008 that included a baseline environmental resource assessment and infrastructure assessment for the entire project site, andinformation and analysis pertaining to the proposed Phase A and Phase B developments. In addition, the Proponent requested a Phase One Waiver to allow Phase One (Phase A) of the project to be permitted prior to completion of the EIR. A Certificate on the EENF and a Draft Record of Decision (DROD) proposing to grant the Phase One Waiver were issued on September12, 2008. The Certificate included a Scope for the EIR for Phase B and for certain aspects and impacts of Phase C. A Final Record of Decision (FROD), granting the Phase One Waiver, was issued on October 15, 2008.

In 2009, the Proponent submitted an NPC for Phase A and requested an amendment to the SRP and to the Phase One Waiver. The NPC identified changes to the project including a reduction in size of Phase A1, relocation and increase in size of Phase A2 and addition of Phase A3 (a 5-acre cranberry bog). A Certificate on the NPC was issued on October 2, 2009 and a FinalAmended Record of Decision (FROD) was issued on October 28, 2009. The Certificate and FROD indicated that an amendment to the SRP was not required. An NPC/Phase B DEIR and Phase C1 ENF (Wankinco Bog) were filed in September 2010. The NPC/DEIR indicated that theBusines Development Overlay District (BDOD) would be deferred to Phase C and described the 344,700-sf development proposal. A Certificate on the NPC/Phase B DEIR was issued on November 12, 2010. It indicated that the DEIR adequately and properly complied with MEPA and directed the Proponent to file an FEIR consisting of Responses to Comments and Proposed Draft Section 61 Findings. A Certificate on the Wankinco Cranberry Bog ENF was also issued on November 12, 2010. It indicated that the Wankinco Cranbery Bog project did not require an EIR. The FEIR for Phase B was filed in January 2011 and a Certificate was issued on March 18, 2011. The Certificate indicated that the FEIR for Phase B properly and adequately complied withMEPA and that the project could proceed to permitting.

An EENF with a request for a Waiver of the requirement to prepare an EIR for the Proposed Cranberry Bogs/Infrastructure ADM Tihonet Mixed Use Development (Phase C2) waspublished in the November 7, 2012 Environmental Monitor. A Certificate and a DROD were issued on December 28, 2012 indicating that the Phase C2 project could be conditioned to meet the standards for a Waiver. A FROD was issued on February 13, 2013 that granted a Waiver of the requirement to prepare an EIR for Phase C2. An Advisory Opinion regarding the Tihonet West Solar Project (Phase C3) and the Federal Road Solar Project (Phase C4) was issued on September 20, 2013 indicating that an ENF filing was not required for those projects because there was no Agency Action associated with either project. An ENF was filed in March 2014 describing Phase C5, the Tihonet East Solar Project. The Phase C5 project involved the construction of a 6-MW solar array on a 49.5-acre site in Wareham. The ENF also provided an update on the Master Plan, a cumulative impact assessment, and described efforts to develop a Master Conservation and Management Permit (CMP) for Eastern Box Turtle. A Certificate was issued on April 11, 2014 indicating that no further MEPA review was required. An ENF was filed describing Phase C6 (Federal West Solar Project, also known as 59 Federal Road Carver PV and ES Project) and the Master Eastern Box Turtle CMP. A Certificate was issued on January 27, 2017 with a finding that no further MEPA review was required for Phase C6. Most recently, an ENF describing Phase C7 (276 Federal Road Carver PV + ES Project), Phase C8 (0 Hammond Street Carver PV + ES Project) and Phase C9 (64 Farm-to-Market Road PV + ES Project) was reviewed by MEPA in 2019. The projects consisted of three solar PV facilities in Wareham and Carver ranging in generating capacity from 3 MW to 12.5 MW. A Certificate wasissued on May 2, 2019 with a finding that no further MEPA review was required for Phases C7- C9.

Project Site

The TMUD Project area is comprised of 5,403.55 acres of land within Carver, Plymouth and Wareham. It includes the ADM corporate headquarters, commercial development and active cranberry bogs. Large areas of undeveloped lands in the TMUD Project area are considered ecologically significant due to the presence of Priority Habitat for rare and endangered species, and the underlying sole source aquifer for Plymouth and Carver. Pine barrens habitat located in the eastern part of the TMUD Project area is part of a larger contiguous barrens system located inand around Myles Standish State Forest that is of regional and global conservation significance. The Phase C10 site is located in Central Wareham south of Route 25, and Phases C11 and C12 are located on sites north and south of an electric transmission line in north-central Wareham.

According to correspondence from the Massachusetts Historical Commission (MHC) included in the EENF, intensive (locational) archaeological surveys at the Phase C10 and C12 sites did not identify significant archaeological resources. An intensive (locational) archaeological survey at the Phase C11 site provided information on ancient Native American land use and occupation in Wareham but did not identify areas of substantial research value. According to MHC, the proposed projects are unlikely to affect significant historical or archaeological resources. Comments from the Herring Pond Wampanoag Tribe and a member ofthe Mashpee Wampanoag Tribe express opposition to the projects and note that the Proponent has not consulted with them. The Proponent should consider sharing the results of the archaeological surveys with these commenters.

Environmental Impacts and Mitigation

Potential environmental impacts associated with the Phases C10, C11 and C12 include the alteration of approximately 154.6 acres of land, which includes excavation of approximately
1.2 million cy of material at the Phase C11 site; addition of approximately 0.38 acres of impervious area; and impacts to 6,500 sf of BVW associated with removal of debris at the PhaseC10 site. According to the EENF, each site will generate up to 50 trips per day during the construction and excavation periods, after which trip generation associated with each PV facilitywill be minimal. Measures to avoid, minimize and mitigate impacts associated with these phasesinclude the construction of stormwater management systems at each site with infiltration basins that will reduce pollutants in runoff and maintain pre-development peak discharge rates and volumes, protection of rare species habitat through a conservation restriction, and funding for pine barrens conservation, research, habitat management and restoration to benefit state-listed pine barrens species, and generation of 60,315 megawatt-hours (MWh) of electricity per year from renewable sources that will offset up to 613,742 metric tons (MT) of carbon dioxide (CO_2)that would otherwise be emitted from fossil fuel generating facilities over a 20 year period.

In accordance with the SRP, the EENF included an updated analysis of cumulative environmental impacts associated with components of Phases A, B, and C that have completed MEPA review. The area of land alteration planned or completed for Phases A, B, and C1-C12 is
823.94 acres and total impervious area planned or completed is 35.97 acres. Phases A, B,

and Cwill alter 25,194 sf of Bordering Vegetated Wetlands (BVW). Phases A, B, and C will generateapproximately 11,078 average daily trips (adt). The TMUD Project will require up to 88,473.3 gallons per day (gpd) of water, withdraw 34,620.7 gpd of water and generate up to 107,713.5 gpd of wastewater. The TMUD Project involves construction of 0.96 miles of water mains and

0.4 miles of sewer mains. As noted above, a final cumulative impact assessment will be providedupon completion of projects subject to the SRP.

Jurisdiction and Permitting

The TMUD Project is undergoing environmental review pursuant to an established SRPbecause it requires State Agency Actions and exceeds MEPA review thresholds, including several thresholds for a mandatory EIR. The project is undergoing review pursuant to the following sections of the MEPA regulations: Section 11.03(1)(a)(1) and (2) because it will involve alteration of 50 or more acres of land and creation of 10 or more acres of new impervious area; Section 11.03(2)(b)(2) because it will result in a take of a state-listed species; Section 11.03 (3)(b)(d) and (f) because it involves alteration of 5,000 or more sf of Bordering Vegetated Wetlands (BVW) and alteration of one-half or more acres of other wetlands; Section11.03(4)(b)(3) because it involves construction of one or more new water mains five or more miles in length; Section 11.03(5)(b)(3)(c) because it will result in construction of five or more miles of new sewer main; and Section 11.03(6)(a)(6) and (7) because it will result in generationof 3,000 or more new vehicle trips and 1,000 or more new parking spaces.

The TMUD Project has received or may require multiple State Agency Actions includingCMPs from the Natural Heritage and Endangered Species Program (NHESP); a Vehicular Access Permit from the Massachusetts Department of Transportation (MassDOT); and a Groundwater Discharge Permit, New Source Approval, 401 Water Quality Certification, Water Supply System Distribution Modification, and Sewer Extension/Connection permits from the Department of Environmental Protection (MassDEP). Components of the project are subject to review MHC and may be subject to federal consistency review by the Massachusetts Office of Coastal Zone Management (CZM). The TMUD Project is subject to the GHG Policy.

Some phases of the TMUD Project require Orders of Conditions (OOC) from the Carver,Plymouth and/or Wareham conservation commissions, or, on appeal only, Superseding Orders ofConditions from MassDEP. The TMUD Project is subject to the U.S. Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) permit requirements for construction activities.

Phases C10, C11 and C12, which are subject of this review, each involve direct alterationof 25 or more acres of land. Phase C11 exceeds the mandatory EIR threshold at 301 CMR 11.03(1)(a), direct alteration of 50 or more acres of land. Phase C12 requires a new or amended CMP and Phase C11 requires a Superseding Order of Conditions from MassDEP. The WarehamConservation Commission issued OOCs for Phase C10 (DEP File # SE-76-2612) and for Phase C12 (DEP File # SE-76-2613) that were not appealed.

Previous MEPA Certificates indicated that the Proponent of the TMUD Project has applied for Financial Assistance from the Commonwealth, including grants from the Massachusetts Technology Collaborative (MTC), and is likely to apply for additional funding such as financial assistance from the Massachusetts Opportunity Relocation and Expansion (MORE) Program. However, according to the Proponent, none of the previously reviewed projects has received State Financial Assistance nor is any anticipated for Phases

C10, C,11, C12or any future phases. Therefore, MEPA jurisdiction is limited to those aspects of the project that are within the subject matter of any required or potentially required Agency Actions and that may cause Damage to the Environment, as defined in the MEPA regulations. As noted, multipleAgency Actions are required to facilitate development of Phase C of the TMUD Project.

Review of the EENF

In accordance with the SRP established for the TMUD Project, the EENF included descriptions of the Phase C10, C11 and C12 projects, an update of the Master Plan for the full TMUD Project, including a discussion of its consistency with the conceptual plan as most recently presented to MEPA, a cumulative impact assessment, and an update on public outreach activities. During the review period, the Proponent submitted a revised GHG analysis (dated May 11, 2021) and a supplemental description (dated May 25, 2021) of the Phase C11 project identifying the excavation and removal of up to 1.2 million cy of material from the site. This additional information was distributed and the comment period extended by 23 days (a commentperiod of 68 days total) to provide additional time for review and comment.

According to the Proponent, the project is eligible for the Solar Massachusetts RenewableTarget (SMART) program, through which utility companies provide financial incentives to eligible solar PV generating facilities. In accordance with recently amended Land Use and SitingCriteria at 225 CMR 20.05(5)(e)7., effective April 15, 2020, new projects are generally not eligible for SMART Program incentives if they are located within BioMap 2 Core Habitat and/orNatural Landscape; as noted above, the three sites are located within these BioMap2 areas.
According to the Proponent, however, the project is grandfathered under 225 CMR 20.05(5)(e)1.c., and must meet a different set of siting criteria listed at 225 CMR 20.05(5)(e)2.-6.that do not exclude projects from BioMap 2 areas.

Alternatives Analysis

The EENF reviewed the siting criteria that led to the selection of the sites and evaluated alternative uses of the sites. As described in the EENF, the sites were selected because they meetsiting criteria for PV facilities, including proximity to grid interconnections, potential to minimize impacts to wetlands and rare species habitat and sufficient parcel size to accommodatethe facilities.

Potential alternative uses of the sites include construction of cranberry bogs, agriculturalreservoirs or single-family homes. According to the EENF, additional cranberry bogs are not needed because of the on-going development of cranberry bogs in Phase C2, nor are the sites located in areas where agricultural reservoirs are needed for cranberry farming. As described inthe EENF, residential development would have greater impacts to land alteration, traffic generation, water demand, sewer use, and GHG emissions than the Preferred Alternative.
Furthermore, the Proponent indicated that there is not adequate market demand for a residential development to justify the residential alternative; according to the EENF, the residential uses thatwere previously envisioned to be constructed in Phase C are no longer under consideration and have been eliminated from the TMUD Project. Alternative facility

layouts would require more land disturbance and alteration within wetland buffer zones.

The EENF also reviewed alternative structural support methods for the PV arrays. The solar panels could be supported by posts with concrete footings, which would require relativelyshallow but wider foundations that would result in more land disturbance to install and greater impervious area. Another alternative includes the use of concrete ballast trays that extend the entire length of each row of panels and do not penetrate the ground. The EENF indicated that theballast would significantly increase impervious area and require larger stormwater management facilities to address runoff.

The Preferred Alternative includes installation of the PV panels on pile-supported racksthat will be augered into the soil to minimize construction impacts and new impervious area.

According to the EENF, the size of each of the PV arrays has been minimized to avoid direct impacts to wetland resource areas and maintain a minimum setback of 150 ft from Tihonet Pond.As described in the EENF, the Preferred Alternative will generate renewable energy, is consistent with local zoning and will minimize new impervious area and impacts to rare species habitat and avoid direct alteration of wetlands.

Rare Species

None of the three sites is located within mapped Priority Habitat for rare species. However, approximately 31.18 acres of the Phase C12 site (150 Tihonet Road) is located within the actual, identified habitat of state-listed pine barrens moth species.[2] According to NHESP, theproject will likely result in a Take of state-listed species due to the loss of suitable habitat and interference with their feeding, breeding, migratory, sheltering and over-wintering activities and a new or amended CMP will be required. In order to qualify for a CMP, the Proponent must demonstrate that the projects will avoid, minimize and mitigate impacts to rare species. The analysis must include: (1) an assessment of alternatives to temporary and permanent impacts to the species; (2) a demonstration that an insignificant portion of the local population will be impacted; and, (3) the development and implementation of a conservation and management planthat provides a long-term net benefit to the conservation of the local population of the impacted species.

According to NHESP, it is anticipated that the projects will meet the CMP performance standards by providing a long-term net benefit to the impacted species by permanently protectingappropriate habitat in the vicinity of previously designated conservation areas near Myles Standish State Forest and providing funding for pine barrens conservation, research, habitat management and restoration to benefit state-listed pine barrens species. As described in the EENF, the owner of land within the SRP area has developed an overall conservation strategy with NHESP that will mitigate impacts to rare species by protecting habitat on contiguous parcels adjacent to the Myles Standish State Forest. Thus far, conservation restrictions have beenplaced on 410 acres of land; based on comments from NHESP, it is anticipated that mitigation for the Phase C12 project will add to that protected area if a CMP is issued.

I received comments that indicated that a Bald Eagle nest may be located within proximity of the Phase C11 and C12 sites and that pointed out inconsistencies among lists of rarespecies present in Wareham. Determinations regarding the status and presence of rare species aremade by NHESP pursuant to the Massachusetts Endangered Species Act (MESA; M.G.L. c.
131A) and its regulations at 321 CMR 10.00. I encourage commenters to report observations of

[2] According to the Proponent, the TMUD Project proponent and NHESP have agreed that NHESP permitting will be required for projects affecting certain areas of pine barrens habitat that are not mappedas Priority Habitat.

rare species to NHESP through its Heritage Hub[3] online reporting system and to contact NHESPwith questions about state-listed rare species. Documentation included in comment letters will beavailable to NHESP as attachments to this certificate.

Wetlands

The projects have been designed to avoid direct impacts to wetland resource areas. As noted above, portions of each site are within the 100-ft Buffer Zone of wetlands regulated underthe Wetlands Protection Act. Approximately 145,000,000 sf (3.3 acres) of the Phase C10 site is within the Buffer Zone of BVW. According to the EENF, ten of the approximately 28,260 solar modules, as well as portions of the perimeter fence and roadway and seven infiltration basins, will be located within the Buffer Zone. At the Phase C11 site, approximately 21,000 sf (0.5 acres) at the southeast corner of the site is within the Buffer Zone of an off-site drainage canal. Proposed structures within this area include small sections of a gravel vehicular access drive, a gate and fencing. Approximately 97,000 sf (2.2 acres) of the Phase C12 is located within the Buffer Zone of BVW and an off-site cranberry bog. According to the EENF, 13 of the approximately 38,394 solar modules, as well as portions of the perimeter fence and gravel vehicular drive and gate will be located within the Buffer Zone. In addition, the Proponent will remove debris from an approximately 6,500-sf area of BVW at the Phase C10 site. Final Ordersof Conditions addressing wetlands mitigation measures and stormwater management have been issued by the Wareham Conservation Commission for the Phase C10 and C12 projects. The OOC for the Phase C11 project has been appealed. The area subject to the appeal does not include any portion of the proposed PV array or excavation and is limited to a small area of gravel roadway and fencing. To the extent applicable, MassDEP will review the potential wetlands impacts, proposed mitigation measures and adequacy of stormwater management system of the Phase C11 project during the Superseding Order of Conditions review process.

Climate Change

Governor Baker's Executive Order 569: Establishing an Integrated Climate Change Strategy for the Commonwealth (EO 569; the Order) was issued on September 16, 2016. TheOrder recognizes the serious threat presented by climate change and directs Executive
Branch agencies to develop and implement an integrated strategy that leverages state resources to combat climate change and prepare for its impacts. The Order seeks to ensure that Massachusetts will meet GHG emissions reduction limits established under the Global WarmingSolution Act of 2008 (GWSA) and will work to prepare state government and cities and towns for the impacts of climate change. I note that the MEPA statute directs all State Agencies to consider reasonably foreseeable climate change impacts, including additional greenhouse gas emissions, and effects, such as predicted sea level rise, when issuing permits, licenses and other administrative approvals and decisions. M.G.L. c. 30, § 61.

Greenhouse Gas Emissions

The three projects will alter approximately 154.6 acres of land. In accordance with the GHG Policy, projects that alter over 50 acres of land are generally required to analyze the carbonassociated with removal of trees and soil disturbance during the construction period and loss of

---

[3] https://eeaonline.eea.state.ma.us/dfg/nhesp/#/home

carbon sequestration. The purpose of this analysis is to develop an *estimate,* not an exact accounting of GHG emissions associated with land alteration, including removal of trees and release of sequestered carbon in soil, and to identify measures to avoid, minimize and mitigate impacts. The EENF included an analysis that estimated existing carbon stocks and annual rates of carbon sequestration in the vegetation and soil at the sites, and quantified the project's impactsresulting in emissions of carbon and lost sequestration potential. It compared the project's GHG impacts to emissions savings from the displacement of energy generated by fossil fuels by the renewable energy produced by the proposed solar PV facilities over a 20-year period corresponding to the anticipated useful life of the PV facilities.

Carbon Stored in Trees

Existing biomass estimates were prepared based on forestry surveys of the age/size distribution of tree species present at each site.[4] Eastern White Pine and Pitch Pine are the predominant tree species at the sites. Carbon content of the biomass at each site was estimated byfirst applying a biomass dry weight ratio of 72.5 percent to above- and below-ground biomass; then calculating the carbon content of dry biomass for hardwood and softwood species using carbon factors of 0.521 and 0.498 respectively; and finally by converting carbon stock to carbon dioxide-equivalent (CO_2) values based on the molar mass ratio of 44 units of CO_2 to 12 units of carbon). Based on the acreage, species composition and age/size distribution of trees at each site,the EENF estimated current carbon stocks of 19,059 metric tons (MT) of CO_2 in the vegetation at the three sites (an average of 123.28 MT CO_2 per acre); this value represents the project's potential GHG impact from tree clearing. However, according to the EENF, only 35 percent of the wood from cleared trees will be burned, resulting in emissions of 3,812 MT CO_2; the remaining 65 percent of the cut trees will be chipped on-site. The EENF did not attribute any CO_2 emissions to the chipped wood; however, chipped wood would be expected to release carbon over time.

The EENF determined values of 126.03 MT CO_2 per acre at the Phase C10 site, 140 MT CO_2 per acre at the C11 site, and 98.33 MT CO_2 per acre at the C12 site. The differences in thesevalues appear to be largely due to the proportion of biomass contributed by Eastern White Pine and Pitch Pine. Eastern White Pine is the most prevalent species at all of the sites except the Phase C12 site (150 Tihonet Pond Road), where Pitch Pine is the dominant species. According toestimates developed by the U.S. Department of Agriculture's Forestry Inventory and Analysis (FIA) Program, above- and below ground biomass of Eastern White Pine averages 182.32 MT CO_2 per acre in Massachusetts compared to 79.66 MT CO_2 per acre for Pitch Pine.[5]

The EENF did not use the FIA data and calculated carbon content based on the biomass estimates in the forestry reports. The average of the three sites, 123.28 MT CO_2 per acre, is lessthan the average of 133.11 MT CO_2 per acre for all forests derived from the findings of the *Massachusetts 2050 Decarbonization Roadmap Land Sector Report* (Land Sector Report).[6]

[4] The forestry surveys were prepared by Jeffrey D. Golay, a Massachusetts Licensed Forester and provided to the MEPA office on May 10, 2021.

[5] The data is available at https://apps.fs.usda.gov/fia/datamart/datamart_excel.html.

[6] https://www.mass.gov/doc/land-sector-technical-report/download

For purposes of comparison only, a more conservative estimate of the project's GHG impacts from tree clearing would use the FIA estimate of 182.32 MT CO_2 per acre for Eastern White Pine to estimate biomass from all sites, even the site with a predominance of Pitch Pine. Inaddition, a more conservative estimate of the project's GHG impacts would assume that all existing biomass will be released into the atmosphere as CO_2 rather than remain sequestered, as modeled by the Proponent. This would result in emissions of 28,186.67 MT CO_2 compared to theestimate of 3,812 MT CO_2 included in the EENF.

Carbon Stored in Soil

Estimates of existing soil organic carbon (SOC) stocks were based on the statewide average of 414.56 MT CO_2 per acre for forest soils provided in the Land Sector Report. According to the EENF, total SOC at the three sites was estimated as 64,044 MT CO_2, including 16,616 MT CO_2 at the Phase C10 site, 27,058 MT CO_2 at the Phase C11 site and 20,370 MT CO_2 at the Phase C12 site; therefore, 64,044 MT CO_2 represents the project's potential GHG emissions from SOC and assumes that soil across nearly the entire land area of the three sites will be disturbed by removal of tree stumps, regrading for drainage purposes or excavated for sand. However, the EENF assumed that not all of the SOC present at the sites would be lost because most of the forest will be converted to grassland under and around the solar PV arrays, which will continue to store carbon in the soil over time. As a result, the EENF estimated that netGHG emissions from direct impacts to soil would be 38,021 MT CO_2. The EENF did not indicate how soon the areas would be converted to grassland. Therefore, a more conservative estimate of the project's GHG impact would assume that all of the existing soil carbon (64,044 MT CO_2) is emitted due to construction activities.[7]

Annual Carbon Sequestration

The EENF included an estimate of future biomass carbon stocks at the sites by applying agrowth rate derived from the age and size (diameter at breast height or DBH) of trees present at the sites and estimating the associated increase in biomass for each species. Using this method, the EENF estimated that over a 20-year period, carbon in biomass at the three sites would increase by 21,303 MT CO_2 from 19,059 MT CO_2 under existing conditions to 40,361 MT CO_2 in 2040, an average of 6.74 MT CO_2 per acre per year. This value represents the ongoing GHG impact of the project due to the lost sequestration potential of the trees to be cleared. As noted inthe EENF, the sequestration is considerably larger than nationwide average rate of 0.24 MT CO_2 per acre per year developed by the EPA.[8] It is also considerably higher than the estimate of 1.5 MT CO_2 per acre per year cited in a 2019 forest carbon report by Catanzaro and D'Amato.[9]

[7] The Land Sector Report estimate of soil carbon in forests includes forested wetlands, which are likely to sequester more carbon than upland forests. Therefore, average soil carbon in Massachusetts upland forests may be less than the estimate of 414.56 MT CO_2 per acre identified in the Land Sector Report and used in the EENF analysis.

[8] https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-annexes.pdf

[9] https://masswoods.org/sites/masswoods.org/files/Forest-Carbon-web_1.pdf

Therefore, the estimate of the loss of future sequestration in biomass provided in the EENF appears to represent a conservative estimate of the project's GHG impact from this source.[10]

In total, the EENF estimated that carbon loss expected from the project from both tree clearing and soil disturbance over the 20-year period from 2021 to 2040 amounts to 63,170 MT CO_2, or 408.6 MT CO_2 per acre. For purposes of comparison only, the project's GHG impacts using the more conservative estimates identified above would amount to emissions of 113,533.67MT CO_2, or 734.37 MT CO_2 per acre.

GHG Emissions Savings

According to the EENF, the three PV facilities will generate 60,315 MWh of electricity per year, or over 1.2 million MWh over a 20-year period. The EENF estimated that the project will result in grid GHG emissions savings of 550,572 MT CO_2 over 20 years because electricitygenerated by the project will displace fossil-fuel generated energy and the associated GHG emissions. Thus, the EENF indicates that grid emissions savings from energy generated by the proposed solar PV facilities will far exceed the project's estimated total GHG emissions of 63,170 MT CO_2 for the 20-year period 2021-2040. As a comparison, this would continue to be the case using a more conservative estimate of 113,533.67 MT CO_2 over 20 years, which includes the higher biomass values for Eastern White Pine forests provided by the FIA dataset and loss of all biomass and soil carbon due to construction activities.[11] The projected emissionssavings will only be realized if the PV facilities are constructed in the near term and generate electricity that offsets grid emissions that currently include significant fossil fuel-generation. I encourage the Proponent to minimize the project's GHG impacts installing the generating facilities as soon as possible, reusing harvested wood so that carbon continues to be sequestered within it and leaving tree stumps and roots in place.

Construction Period

The Proponent should implement measures to prevent and minimize nuisance conditionssuch as dust, noise, and odors during construction. Many commenters noted impacts of truck traffic associated with sand extraction activities. The Proponent should employ mitigation measures to minimize these impacts, including covering trucks before they leave the site, implementing measures to minimize off-site tracking of soil, wetting exposed spoil to minimize

---

[10] The EENF did not include an estimate of lost carbon sequestration potential from impacts to soil. The Executive Office of Energy and Environmental Affairs (EEA) has commissioned a *Healthy Soils Action Plan* (HSAP) that is currently in draft form. The draft HSAP estimates that the average annual carbon sequestration by soils in forests is 0.79 MT CO_2 per acre per year. Applying that rate to the project's land area, the project would have an additional GHG impact of 122.13 MT CO_2 per year or a total of 2,442.68 MT CO_2 if the project resulted in no carbon sequestration in soil over the next

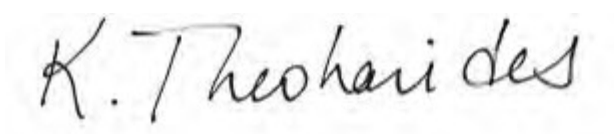
20 years. However, I note that the project may not result in impacts to soil across the entire project land area, such as a 1.7-acre areaat the Phase C10 site where tree cutting only is proposed; in addition, soil remaining at the site may beginto sequester carbon within the 20-year period.

[11] The EENF estimated emissions savings using grid marginal emission rates from the National Renewable Energy Laboratory's (NREL) Cambium model. The MEPA GHG Policy requires the use of marginal average emissions as calculated by the Independent System Operator-New England (ISO-NE), which are considerably lower than those used in the Cambium model and would result in a lower level ofemissions savings for the project.

dust and using designated truck routes. To minimize noise and emissions of air pollutants from construction equipment, all work should conform to the anti-idling measures of the Air Quality regulations (310 CMR 7.11), which limit vehicle idling to five minutes. I encourage the Proponent to require that its contractors use construction equipment with engines manufactured to Tier 4 federal emission standards, or select project contractors that have installed retrofit emissions control devices or vehicles that use alternative fuels to reduce emissions of volatile organic compounds (VOCs), carbon monoxide (CO) and particulate matter (PM) from diesel- powered equipment. Off-road vehicles are required to use ultra-low sulfur diesel fuel (ULSD). The Proponent must prepare a Stormwater Pollution Prevention Plan (SWPP) in compliance withthe NPDES CGP to address construction-period stormwater management. All construction activities should be undertaken in compliance with the conditions of all State and local permits.

Conclusion

Based on a review of the SRP, previous MEPA filings, the EENF, and consultation with State Agencies and review of comment letters, I find that additional MEPA review of the projectis not warranted.



June 9, 2021
Date

Kathleen A. Theoharides

Comments received:

03/25/2021 Joe Tripp
03/26/2021 Meg Sheehan
04/04/2021 Barry Cosgrove
04/19/2021 Marie Oliva
04/27/2021 James Bisson
04/29/2021 Scott Sullivan
04/30/2021 Meg Sheehan
05/04/2021 Meg Sheehan
05/04/2021 Natural Heritage and Endangered Species Program (NHESP)
05/05/2021 Annie Hayes
05/07/2021 Meg Sheehan
05/21/2021 Herring Pond Wampanoag Tribe
05/21/2021 A.D. Makepeace Companies
05/21/2021 Mason A. Hendricks
05/23/2021 Kathleen Pappalardo

05/24/2021	Mary Booth
05/24/2021	Massachusetts Department of Environmental Protection (MassDEP)/Southeast

Regional Office (SERO)
05/24/2021 Meg Sheehan
05/24/2021 Petition with 377 signees opposed to the project05/25/2021 Annie Hayes
05/25/2021 Meg Sheehan
05/29/2021 Meg Sheehan
05/31/2021 Kathleen Pappalardo
06/01/2021 Southeastern Massachusetts Pine Barrens Alliance
06/02/2021 Community Land & Water Coalition/Save the Pine Barrens,

Inc.KAT/AJS/ajs

Exhibit Six

The Trustees of Reservations
200 High Street | Boston, MA 02110

June 7, 2021

Via Email selectmen@wareham.ma.us
Judith Whiteside, Chair
Wareham Board of Selectmen
Memorial Town Hall
54 Marion Road
Wareham, MA 02571

Re: Opposition to industrial-scale solar development and mining in Wareham

Dear Chair Whiteside and Members of the Wareham Selectboard,

The Trustees of Reservations is concerned over the proliferation of industrial-scale solar in Wareham, and the mining of earth, sand, soil, and gravel to prepare sites for solar installations. So far, millions of cubic yards of topsoil and sand have been removed to develop 300 acres of ground mounted solar, and solar is being planned for an additional 1,500 acres in globally rare pine forest.

While The Trustees supports renewable energy development to mitigate climate impacts, we encourage solar on rooftops, highways, parking lots, brownfields, industrial complexes, and other developed lands; and oppose large scale solar that requires the removal of forested land and that impacts rivers, streams, wetlands and other critical natural resources especially resources that are drawing and storing carbon pollution out of the atmosphere, creating climate resiliency, and protecting fish and wildlife habitat and drinking water supplies.

We are particularly concerned about the large-scale solar developments in Wareham because of their impacts on the local aquifer -- the only source of fresh-water for the region. The pine barrens are delicate landscapes; the sandy soils and trees are vital to naturally filter the groundwater that supplies Wareham residents and businesses with drinking water.

Strip mining and industrial solar developments in the pine barrens are exacerbating habitat fragmentation, removing and displacing plant and animal species from the area, and threatening nearby rivers, streams, and natural areas, including the Red Brook Wildlife Management Area and The Trustees' Lyman Reserve. The reserve sits at the mouth of Red Brook, a 4.5-mile spring-fed, coldwater stream that flows from White Island Pond to Buttermilk Bay -- a critical estuary and shellfish production area. Red Brook is one of the few coastal streams in the state that supports anadromous fish and is home to one of the last remaining native sea-run Brook Trout fisheries in the Eastern US. The historic and live herring runs in Red Brook also contribute to the region's recreational fishing economy as they are a primary food source for stripe bass and other coastal fish.

The impacts of industrial scale solar development on these already impacted and sensitive resources will likely result in an irreversible collapse of the region's unique ecosystems and will detrimentally impact quality of life for Wareham residents. We urge the Town of Wareham to pause these industrial projects, and to identify and pursue already-developed areas for solar developments, for the benefit of nature and future generations.

If you have questions, please contact me at toshea@thetrustees.org. Thank you for your consideration.

Sincerely,

____

Thomas K. O'Shea
Managing Director of Resources and Planning

Founded in 1891 by Charles Eliot, The Trustees preserves, for public use and enjoyment, properties of exceptional scenic, historic, and ecological value in Massachusetts. Today, 130 years after our founding, we are Massachusetts' largest conservation and preservation organization and with the support of our 150,000 members we care for 120 properties nearly 27,000 irreplaceable acres. The Trustees works with a variety of volunteer, nonprofit, and community-based partners in communities across the state to preserve remarkable, scenic landscapes and historic and cultural resources. [*thetrustees.org*]

Exhibit Seven

TROUT UNLIMITED
Southeastern Massachusetts Chapter

June 3, 2021

Peter Teitelbaum, Esq., Chair
Wareham Board of Selectmen
Memorial Town Hall
54 Marion Road
Wareham, MA 02571

Dear Chairman Teitelbaum:

The Southeastern Massachusetts Chapter of Trout Unlimited, the local affiliate of Trout Unlimited a national nonprofit organization with more than 300,000 members devoted to protecting coldwater fisheries and their habitat in North America, wishes to express with this letter our support for the proposed Article 17 of the Wareham bylaws limiting the size of ground-mounted solar installations.

The Southeast Chapter, with members from around the region including Wareham, remains committed to the continued progress of healthy, self-sustaining populations of wild Sea Run Brook Trout for all coastal regions of the Commonwealth. As I'm sure you are aware, TU along with partners, such as the Trustees of Reservations, Mass Fish and Wildlife, U.S. Fish and Wildlife, the Sea Run Brook Trout Coalition, the National Oceanographic and Atmospheric Administration, has for the past 30 years has worked to restore and sustain Red Brook as a stronghold for these special fish.

Article 17 allows for a pause and policy reset for the sake of common sense. Existing state and local laws have created a situation whereby mature forestlands that are well suited for reducing carbon concentrations in the atmosphere over the long term are being clear-cut and replaced with ground-mounted solar panels. In Wareham in particular, the loss to citizens and the important (and in some places rare) habitats is then exacerbated by the practice of strip-mining sands and gravel as part of the process. Please refer to the Appendix. The resulting alterations of the landscape upset the natural flows of surface water and reduce the ability of exposed and overburden soils to filter contaminants before they enter and flow with the aquifer.

Reasonable alternatives exist. The practice of strip-mining square miles of forest followed by solar panel installation is detrimental to fish and wildlife, an eyesore to residents and visitors to Wareham and creates an unhealthy strain on the sole source aquifer that sustains your citizenry and coldwater fisheries. Just as Wareham is blessed with an abundance of undeveloped forested pine barren uplands, wetland lowlands and vernal pools, it is also home to a substantial array of commercially or industrially developed and otherwise disturbed lands where solar installations can be added on to existing uses.

The citizens of Wareham expect more. As the recent vote on the zoning change proposed by the NOTOS Group indicates, your voters expect the town's leaders to take any and all steps to plan carefully and thoughtfully so as to balance economic stability with thoughtful stewardship of the varied natural habitat within the community.

We ask that you support Article 17 and the path for Wareham that your voters have laid for you where green truly means green.

Please feel free to contact me or any member of Trout Unlimited in Massachusetts if you think we can be of further assistance.

Respectfully Submitted,

[signed]

Matthew R. Hoagland, President
Southeastern Chapter, Trout Unlimited

cc. Wareham Planning Board

<u>Appendix</u>

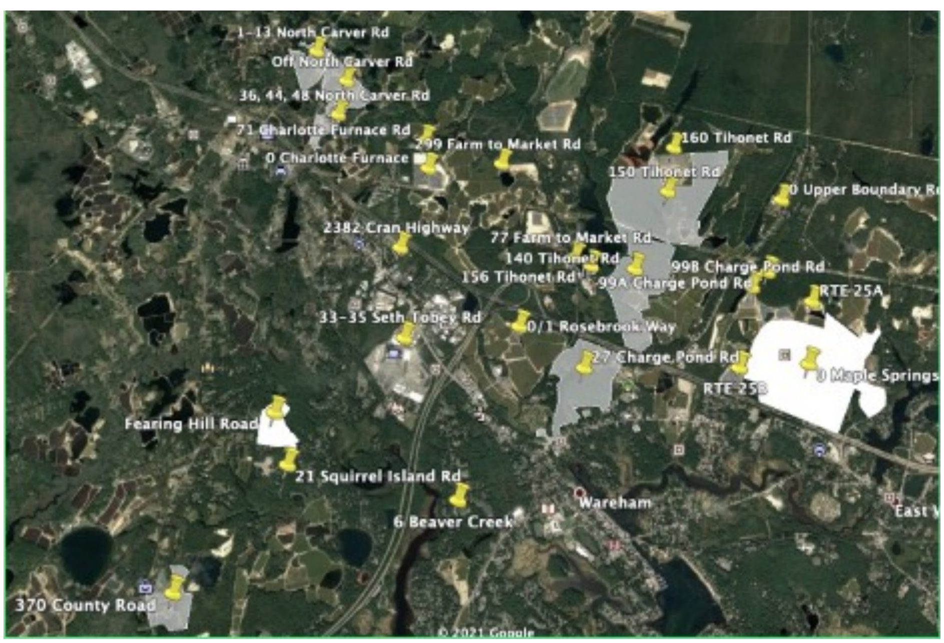


Exhibit Eight

COMMUNITY LAND —and— WATER COALITION

West Wareham Fearing Hill forest targeted by bankrupt solar company & land speculators

44 acres of industrial solar; toxic batteries risk fire, explosions in residential neighborhood

SOLAR SCHEME Bankrupt Colorado corporation "Clean Energy Collective" has teamed up with land speculators Joe Crespi and Robert Ahearn to propose an industrial solar and energy storage facility on 44 acres of West Wareham forest. The land speculators owe Wareham $217,370.00 from a tax fight with the Town & bankrupt solar developer CEC has sales that plummeted 97% in 2020. These speculators threaten our community! Site Plan Review Application, Option & Lease Agreement showing "Site Control" PDF page 80: https://www.wareham.ma.us/sites/g/files/vyhlif5146/f/pages/final_site_plan_review_application_binder_5-14-21.pdf

THUMBING THEIR NOSE AT WAREHAM VOTERS On June 12, 2021, Wareham Town Meeting voted unanimously to outlaw this type of industrial solar project -- 44 acres that cuts down trees --- but these developers want an exemption.

REAL ESTATE VALUES, RECREATION HARMED The project abuts 44 homes in West Wareham residential neighborhood and 114 acre Fearing Hill conservation land owned by the people of Wareham. Industrial solar reduces our property values & will be an eyesore to users of the conservation land trails. University of Rhode Island Study: https://web.uri.edu/coopext/files/PropertyValueImpactsOfSolar.pdf

DESTROYS FORESTS The project will destroy wild, woodland habitat and forest in a globally rare Atlantic Coastal Pine Barrens ecosystem with many rare and protected species.

POLLUTES WATER The important Weweantic River watershed will be harmed by the loss of forest cover that filters water and by stormwater runoff. This project will scrape vegetation and soil that protects and filters the Plymouth Carver Sole Source Aquifer - our drinking water.

NOT CLEAN & GREEN, WE PAY Massachusetts energy czars force ratepayers and taxpayers to give lavish subsidies to these developers claiming this is clean energy. The solar scheme can't succeed without our subsidies! Do we want our money spent on this?

SAFETY THREAT: EXPLOSIONS, FIRE, TOXIC CHEMICALS & WASTE

The project has 7,333 solar panels and massive 4.4 MW AC batteries that will be trash in 20 years and very expensive to get rid of. The batteries are unsafe and pose a risk of fire and explosion and can leak toxic chemicals into the ground overlying our aquifer. A fire could engulf the nearby forest, threatening residences. There is only one main access road that could cause a delayed fire department response. Harvard Business Review: https://hbr.org/2021/06/the-dark-side-of-solar-power
Explosion in Arizona: https://www.azcentral.com/story/ money/business/energy/2020/07/27/aps-battery-explosion-surprise-new-report-findings/5523361002/

INJUSTICE! Solar developers are preying on Wareham which has significant environmental justice and working-class population dangling cash payments. Solar panel manufacturing often exploits workers - many are made in China by Uyghur minorities under questionable labor practices. Lithium and cadmium mining for panels and batteries is destructive and often exploits workers and Indigenous communities.

TAKE ACTION!

All Town boards and committees must take a stand and reject this project!

What: Wareham Planning Board public hearing JUNE 28 at 6 p.m.to decide whether to grant "Special Permit Site Plan Review" under the Town's Zoning Bylaws

Where: Multi-Service Center 48 Marion Road, Wareham

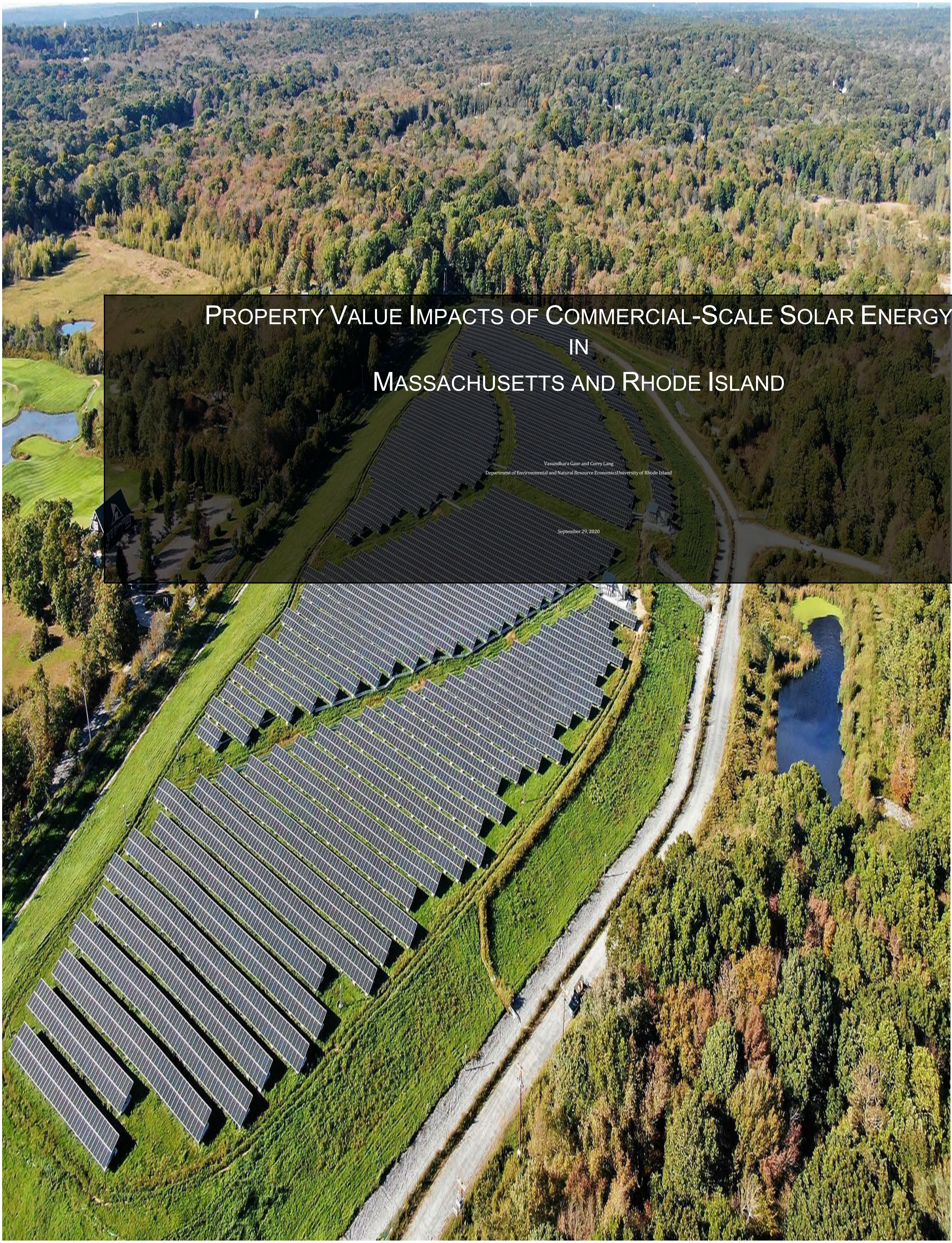
Email, write and call: 508-291-3100

George Barrett, Chair, Wareham Planning Board
Judith Whiteside, Chair Board of Selectmen: jwhiteside@wareham.ma.us
Sandy Slavin, Chair Conservation Commission

Proposed 44-acre solar site on Fearing Hill's "The Grove"

www.savethepinebarrens.org
Facebook @LandWaterPlymouthArea
Twitter @SavePines
Instagram @savepinebarrens

Exhibit Nine



Property Value Impacts of Commercial-Scale Solar Energy in Massachusetts and Rhode Island

Vasundhara Gaur and Corey Lang
Department of Environmental and Natural Resource EconomicsUniversity of Rhode Island

September 29, 2020

ABSTRACT

While utility-scale solar energy is important for reducing dependence on fossil fuels, solar arraysuse significant amounts of land (about 5 acres per MW of capacity), and may create local land use disamenities. This paper seeks to quantify the externalities from nearby solar arrays using thehedonic method. We study the states of Massachusetts and Rhode Island, which have high population densities and ambitious renewable energy goals. We observe over 400,000 transactions within three miles of a solar site. Using a difference-in-differences, repeat sales identification strategy, results suggest that houses within one mile depreciate 1.7% following construction of a solar array, which translates into an annual willingness to pay of $279.

Additional results indicate that the negative externalities are primarily driven by solar developments on farm and forest lands in non-rural areas. For these states, our findings indicatethat the global benefits of solar energy in terms of abated carbon emissions are outweighed by the local disamenities.

ACKNOWLEDGEMENTS

We thank Ben Hoen, Salma Elmallah, and conference participants at AERE and NAREA for useful feedback. This work was supported by the USDA National Institute of Food and Agriculture, Agricultural and Food Research Initiative Competitive Program, Critical Agricultural Research and Extension, grant number 2019-68008-29826.

CONTACT

Please direct questions to Corey Lang at 401-874-4569 or clang@uri.edu.

CITATION

Please cite this report as:

Gaur, V. and C. Lang. (2020). Property Value Impacts of Commercial-Scale Solar Energy inMassachusetts and Rhode Island. Submitted to University of Rhode Island Cooperative Extension on September 29, 2020. Accessed at https://web.uri.edu/coopext/valuing-siting- options-for-commercial-scale-solar-energy-in-rhode-island/.

1 INTRODUCTION

Solar energy in the United States has grown at an average rate of 49% per year since 2009, making the US the second largest producer of solar energy in the world (EIA InternationalEnergy Outlook 2019). In 2019, solar energy accounted for 40% of all new capacity additions inthe country, the largest ever in its history, and exceeding all other energy sources (Perea et al., 2020). By June 2020, the cumulative installed capacity of solar in the United States reached 81.4gigawatts (GW), which is enough to power 15.7 million homes (Perea et al., 2020). Solar is predicted to overtake wind to become the largest source of renewable energy in the US by 2050,accounting for 46% of all energy produced from renewable sources (EIA Annual Energy Outlook 2018).

While there is a broad support for renewable energy in the United States (Bates & Firestone, 2015; Farhar, 1994; Firestone et al., 2018; Hoen et al., 2019; Krohn & Damborg, 1999), and for solar energy in particular (Carlisle et al., 2014, 2015; Farhar, 1994; Greenberg, 2009; Jacobe, 2013; Pew Research Center, 2019), the development of large-scale solar installations has not been obstacle free. One major hurdle to overcome before construction begins is the siting process. Solar installations require over ten times more land area than non- renewable sources to generate the same amount of energy, and the requirement of large tracts ofland for their construction has become the largest cause of land use change in the United States (Trainor et al. 2016; Ong et al. 2013). Recently, the siting of large solar projects has become contentious in some parts of the country due to concerns about visual disamenities, impacts on ecosystems, siting of transmission lines, loss of a town's rural character, water pollution, fire risk, water use, and reduction in property values (Farhar et al., 2010; Gross, 2020; Lovich & Ennen, 2011). The debate is especially heated when solar development is proposed on existing farm and forest lands, which is common because these are the cheapest locations for development (Kuffner, 2018; Naylor, 2019).

The purpose of this paper is to quantify the externalities associated with proximity to utility-scale solar installations using hedonic valuation. Theory indicates that property values willreflect people's willingness to pay to avoid the cumulative disamenities of solar development (Bishop et al., 2019; Rosen, 1974). Our study focuses on the states of Massachusetts (MA) and Rhode Island (RI), which are ideal for two reasons. First, both states have recently experienced a sudden boom in the development of large-scale solar installations. This trend has been driven by the Renewable Portfolio Standards (RPS), regulations that require increased energy productionfrom renewable energy sources, which have been adopted by both states. MA's RPS calls for 25% of electricity generated by renewable sources by 2030 and RI's RPS calls for 38.5% by 2035. Second, both states have high population density, ranked 2nd and 3rd among U.S. states. This level of development means that most solar sites are proximate to residential areas, whichyields many observed transactions for precise estimates.

We analyze the impact of utility-scale solar installations sized 1 MW and above on nearby property prices in MA and RI.[1] We use a difference-in-differences (DID) identification strategy, which compares changes in housing prices after construction for nearby properties withthose further away. We empirically estimate the spatial extent of treatment to be one mile from the solar installation and choose a cutoff for control properties of three miles. Our primary sample consists of 208 solar installations, 71,337 housing transactions occurring within one mile(treated group), and 347,921 transactions between one to three miles (control croup).

Across a variety of specifications, our results suggest that solar installations negatively affect nearby property values. Our preferred specification, which includes property fixed effects (i.e., repeat sales), month-year fixed effects, and county-year fixed effects, indicates that propertyvalues in the treatment group decline 1.7% (or $5,751) relative to the control group, and this estimate is statistically different from zero at the 1% level. These findings suggest that solar arrays create local, negative externalities, and the average household annual willingness to pay toavoid these externalities is $279. This helps explain local concerns and opposition and gives pause to current practices of not including proximate residents in siting decisions or compensating them after siting has occurred. While we cannot estimate producer and consumer surplus, we can compare external benefits and costs. Our estimates imply that the global positive external benefits of carbon mitigation are outweighed by local externalities costs at a ratio of 0.46. However, renewable energy in New England usually displaces natural gas use by power plants. Solar in more rural places (thus affecting fewer households) and solar that displaces coalwould have a more favorable benefit-cost ratio.

We also examine heterogeneity in treatment effects in several ways. First, with respect toproximity, we find substantially larger negative impacts on homes located within

0.1 mile of

---

[1] Following the U.S. Energy Information Administration (EIA), we define large-scale solar installations as those with an installed capacity of 1 MW or larger.

solar installations (-7.0%). Second, we estimate a series of models exploring heterogeneity basedon prior land use (farm or forest vs. landfills or industrial areas) and rural character of a municipality (defined based on population density). The results suggest that the overall negative effects of solar arrays on nearby property values are driven by farm and forest sites in non-rural areas (non-rural is most akin to suburban, as there are very few solar sites in urban areas). Solar developments on landfills and industrial areas or in rural areas have smaller and statistically insignificant effects on prices. We posit that solar arrays on farm and forest lands cause greater externalities, given the dual loss of open space amenities and gain of industrial disamenities, andthat this effect hinges on the scarcity of open space typical in non-rural areas.

2 CONCEPTUAL FRAMEWORK

Environmental goods and services are often 'non-market goods', meaning they are nottraded in any market. However, that does not mean that they have no value. Using economic theory, we can estimate environmental values by examining people's decisions and how they make choices and tradeoffs regarding such goods.

One way of valuing environmental goods and services is through the revealed preferencemethod where the preferences of individuals are inferred through their actual buying and selling decisions in a related market. For example, air quality is not transacted in any market, but people'reveal' their value for it when they buy homes away from urban and industrial areas with high traffic volumes and poor air quality. In this example, air quality is the non-market good, the 'actual buying and selling decision' is the choice of purchasing a house with specific characteristics, and the 'related market' is the housing market.

A common application of the revealed preference method is the hedonic housing price technique. First theorized by Rosen (1974), the hedonic price model (HPM) measures the implicit price of each attribute of a bundled good. Applied to the housing market, the idea is that the price of a property can be broken down into the price of its various attributes. These attributes can be structural (e.g. lot size, living area, number of bedrooms and bathrooms, presence of air conditioning or pool, etc.), neighborhood (e.g. school quality, proximity to shopping, etc.), and environmental (e.g. air and groundwater quality, tree cover, proximity to brownfield, etc.). More formally, let us consider a house ii, and let PP_{ii}

denote its price, SS_{ii} the set ofstructural characteristics, NN_{ii} the neighborhood characteristics, and EE_{ii} the environmental characteristics of that house. Then the hedonic price function of the house can be representedmathematically as a function of its characteristics:

$$P_i = f(S_i, N_i, E_i) \quad (1)$$

When purchasing a house, the consumers make tradeoffs between their desired quantities of eachof these attributes and price. Further, in equilibrium, prices adjust to reflect willingness to pay forthe bundled attributes. By examining transacted properties with sales price and attributes, the implicit value of each attribute can be estimated. In the context of solar development, the value that people place on solar arrays can be estimated by examining transactions in close proximity to solar arrays compared to those further away.

The HPM is a well-established and frequently used tool for measuring nonmarket values. It has been used extensively in the literature for estimating the willingness to pay for environmental amenities like air quality (Bajari et al., 2012; Bayer et al., 2009; Bento et al., 2014; Chay and Greenstone, 2005; Grainger, 2012; Lang, 2015; Ridker and Henning, 1967) and open space (Anderson and West, 2006; Black, 2018; Geoghegan et al., 1997; Irwin, 2002; Lang, 2018), and also environmental disamenities like brownfields (Haninger et al., 2017; Lang and Cavanagh, 2018; L. Ma, 2019) and electrical transmission lines (Hamilton and Schwann, 1995). Several hedonic studies also estimate the public's valuation of non-renewable energy sources andinfrastructure, particularly coal plants (Davis, 2011), nuclear energy (Gawande and Jenkins- Smith, 2001; Tanaka and Zabel, 2018), petroleum storage (Zabel and Guignet, 2012), and hydraulic fracturing (Boslett et al., 2016, 2019; Gopalakrishnan and Klaiber, 2014; Muehlenbachs et al., 2015).

The HPM produces intuitive and policy relevant results. For example, Haninger et al. (2017) analyze federal brownfield remediation and find that properties in close proximity to EPA-funded remediated brownfields appreciate 5-11% following cleanup, and that in aggregatethis valuation exceeds the costs of remediation and hence the federal program passes a benefit- cost test. Lang (2018) examines municipal land conservation spending in the United States, andestimates that properties on average appreciate 0.68–1.12% for every $1000 per household of open space spending authorized. The positive appreciation implies that the valuation of open space amenities exceeds the costs of additional taxes, and further that land conservation is underprovided. Muehlenbachs et al. 2015 analyze hydraulic fracturing ("fracking") in Pennsylvania and find that properties within 1km of a well pad decline in value 16.5%, but only when the properties use well water, public water supply houses are unaffected. These resultssuggest that perception of risk is focused on contaminated drinking water.

The HPM has become increasingly popular for the valuation of renewable energy in recent years, with the most frequent applications focusing on wind energy. Within the United States, studies that use data with large numbers of observations close to turbines find no significant impact on property prices. Hedonic studies that find no negative externalities from onshore wind energy development include Hoen et al. (2011) for 24 wind facilities across the United States; Lang et al. (2014) for 10 wind turbine sites in Rhode Island; Hoen et al. (2015) for67 wind facilities (with over 45,000 turbines) installed all over the United States through 2011, and Hoen and Atkinson-Palombo (2016) for 41 turbines in densely populated areas of Massachusetts. In contrast, studies in European countries find that wind turbines have a significantly negative impact on nearby properties, though the magnitude of the effect differs by region (Dröes & Koster, 2016; Gibbons, 2015; Sunak & Madlener, 2016). Vyn (2018) finds the Canadian experience to be heterogeneous and dependent on community acceptance. More recently, hedonic methods have focused on estimating externalities from offshore wind turbines. While this literature is still in its infancy, early studies indicate no negative impacts to property values in the vicinity of offshore wind turbines (Jensen et al., 2018) and positive impacts to tourism (Carr-Harris & Lang, 2019).

Hedonic valuation has also been applied to residential rooftop solar. General consensus isthat houses installed with rooftop photovoltaic (PV) panels sell for a premium, though there is regional variation in the size of the effect: 3.5% in California (Dastrup et al., 2012; Hoen et al., 2012), 5.4% in Hawaii (Wee, 2016), 17% in Arizona (Qiu et al. 2017), and 3.2% in Western Australia (Ma et al. 2016). However, this literature is only tangentially related as it is about quantifying internalities (valuation of personal financial benefits), not externalities, and has nothing to do with land use.

In sum, there exists little information on the externalities associated with large-scale solarinstallations within the United States. It is therefore necessary to understand the value people place on solar structures in order to help state and municipal policy makers implement policies and decisions that reflect public preferences.

3 DATA

To implement the hedonic analysis, we build a composite dataset that integrates: 1) thedata on the location and attributes of all solar developments in MA and RI, and 2) the data on attributes and locations of residential properties in MA and RI.

3.1 *Solar data*

The dataset on solar installations is obtained from the Energy Information Administration's (EIA's) report EIA-860M, or the Monthly Update to the Annual Electric Generator Report. The EIA-860M contains data on the total capacity of electric generation facilities in the United States that have a capacity of 1 MW and above, their point location (latitude and longitude), and the month and year that generation begins. Figure 1 represents a map of 284 solar installations constructed prior to August 2019, which is when we set the cutofffor being in our sample. The installations are well dispersed across all regions in both states, which increases confidence that estimates will not be affected by unobserved regional differences. We exclude 76 solar installations (27% of all installations) that are built within 1 mile of each other, since property value impacts may be hard to measure for observations in theproximity of multiple installations.[2] This is similar to a sample cut made by Haninger et al. (2017).

Figure 2 graphs new and cumulative solar capacity by year. The first installation came online in December 2010. New capacity displays a continuous upward trend through 2014. Thereis a sharp fall in 2015, after which the trend rises again and peaks in 2017, before falling again in2018. As of August 2019, the cumulative solar capacity in RI and MA is 817 MW. Capacity factors for this region are about 16.5% (EIA 2019), which means these solar installations are collectively producing 1180 GWh of electricity per year, which is enough to power 157,681 homes.

One limitation of our data is that we do not have shapefiles representing the exact footprint of the solar installations, thus we must approximate that using Geographic Information Systems (GIS) software. Solar installations require approximately 5 acres of land per MW of capacity (Denholm & Margolis, 2008; Ong et al., 2013). We assume that the point location is the

[2] Figure A1 in the online appendix represents a map of the resultant 208 solar installations.

centroid of the installation and then create a circle around it with an area equal to 5 times thecapacity (in MW) of each array.[3]

We hypothesize that prior land use may affect property value impacts. Specifically, houses in proximity to farms and forests that are developed into solar may depreciate more than houses in proximity to a brownfield or capped landfill that is developed into solar.[4] Since farms, forests, and other open space are amenities and boost home values (Irwin, 2002; Lang, 2018), conversion of these types of lands may lead to larger price decreases because it is the combination of a loss of amenities and the gain of disamenities. To infer prior land use, we overlay the estimated circular footprints on 2005 land use data obtained from Massachusetts Bureau of Geographic Information and 2011 land use data obtained from Rhode Island Geographic Information System for the respective states. We then assign each installation a priorland use: 'greenfield' if it was formerly either a farm or forest land, and 'non-greenfield' if it waseither a commercial site or a landfill.[5] 63% of installations and 70% of capacity is classified as greenfield (see Figure A2 in the online appendix).

3.2 Property data

We use ZTRAX housing transaction data from Zillow (http://www.zillow.com/data), which include information on property location (latitude and longitude), sales price, date of transaction, and many property characteristics (lot size, square feet of living area, number of bedrooms, number of bathrooms, year built, number of fireplaces, central air-conditioning, and

---

[3] We manually crosscheck the EIA data with Google Maps, and correct the latitude and longitude when they do notcorrespond to the centroid of the array. We recognize that this approach could lead some properties to be misclassified as treatment or control, inducing a small amount of measurement error in treatment status. As a result, our DID estimates may be slightly attenuated.

[4] Solar developers prefer farm and forest lands because they have substantially lower construction costs compared to alternative sites like brownfields, landfills, superfunds and industrial lands.

[5] Several solar installations cover an area with multiple land uses. We obtain exactly one land use type per solar site in five additional steps. First, we classify the land use

as ‘landfill’ if the installations have the term ‘landfill’ in their name, or if they are listed in the EPA’s dataset of contaminated land. Second, we use a stratifying logic to group all land-use types under seven major categories: commercial, farm, forest, landfill, recreational, residential, and wetland. Third, we place *‘transportation’, ‘urban public/institutional’, ‘industrial’, ‘powerline/utility’*, and *‘junkyard’* under commercial; *‘orchard’, ‘cropland’, ‘pasture’, ‘nursery’,* and *‘cranberry bog’* under farm; *‘spectator recreation’,* and *‘participation recreation’* under recreation, *‘multi-family residential’, ‘low density residential’, ‘medium density residential’, ‘very low density residential’*, and *‘high density residential’* under residential; and *‘forested wetland’, ‘water’,* and *‘non-forested wetland’* under wetland. Fourth, we rank all land use categories under each installation by area, such that the land use with the greatest area gets the highest rank. We drop all land use categories but the ones with the highest rank to obtain exactly one land use per installation in the following four major categories: commercial, farm, forest, and landfill.

swimming pool). The data include 2,095,835 property transactions from January 2005 to June 2019 in the states of RI and MA. Houses with missing observations for sales price, bedrooms, full bathrooms, and half bathrooms are dropped. We also drop groups of single-family residentialproperties with the same latitudes and longitudes, but different addresses. Sales prices are adjusted to 2019 levels using the Northeast regional housing Consumer Price Index from Bureau of Labor Statistics. After dropping transactions with prices of $100 or less, since these are clearlynot arms-length transactions, we drop transactions in the bottom and top 5% of the sales price distribution to get rid of outliers. Further, we drop observations that have more than four stories, six bedrooms, five full bathrooms, or three half bathrooms. Houses that underwent major reconstruction are dropped since they may have different attributes in previous transactions. We exclude homes that sell before they were built, as there is evidence these are lot sales without improved property. We also drop single-family residential properties with lot sizes larger than 10acres, since large plots could be potential sites for solar development and price impacts of nearbysolar could be completely different. Condominiums are assigned a lot size value of zero acres and are identified with an indicator variable. The subjective condition of properties is defined by a dummy variable equal to 1 indicating above average condition.

Similar to prior land use, we hypothesize that existing development in areas surrounding solar arrays may impact property prices. Many rural areas pride themselves on their rural character and residents seek out that type of bucolic setting. Hence, construction of solar installations could be seen as an industrialization of the landscape and may cause larger negative impacts on property values. We proxy for rural character with municipality-level population density, which comes from the 2010 Census. We define an indicator variable $RRRRRRRRRR$, which equals one if the town has a population density of 850 people per square mile or fewer. We chosethis cutoff because 850 is the average population density of MA, which forms the bulk of the observations in our dataset, and, at this cutoff, almost a third of the properties and 60% of the solar installations are classified as rural, which we believe are reasonable proportions. However, we examine different cutoffs in the appendix. It is important to note non-rural properties should not be thought of as urban, but more suburban. Very few utility-scale solar developments are built in urban areas as there is just not space.

To build our main dataset, we spatially merge the solar data with the property dataset. Wematch every property to the nearest eventual site of solar development to infer proximity. We only include transactions occurring within three miles of any eventual solar installation to increase similarities in observable and unobservable characteristics for sample properties. For properties lying within three miles of two installations, we keep only those that transacted beforeboth installations were built and those that transacted after both were constructed. This ensures cleaner identification of the pre-construction and post-construction periods in our model.

The final, composite dataset includes 419,258 property transactions representing 284,364 unique properties around 208 solar installations. Figure 3 shows the number of transactions by distance to nearest solar installation. We have roughly 18,000 transactions within half a mile, and71,337 transactions within one mile of a solar installation. This is far more compared to many prior studies measuring externalities of wind energy, and it enables precise estimation of any effect that may be present. Further, 27.43% of transactions occur post-construction and 17.27% of the post-construction observations are within one mile.[6]

4 METHODS

We use the difference-in-differences (DID) method in the hedonic framework to analyzethe causal impact of solar installations on housing prices. We compare treated properties locatednear large-scale solar installations to similar control properties that are further away from such installations. The treated properties are defined as those that lie within some distance *d* of a solarsite, and control properties are greater than distance *d* (and less than three miles). Our basic empirical specification is:

$$P_{it} = \beta_1 Treated_i + \beta_2 Post_{it} + \beta_3 (Treated_i \times Post_{it}) + \gamma X_{it} + \epsilon_{it} \quad (2)$$

Where P_{it} is the log sales price of house i at time t. $Treated_i$ is a dummy variable equal to 1 if a house is in the treatment group and 0 otherwise, $Post_{it}$ is an indicator for post-treatment, which equals 1 if a house sells after the construction of the nearest solar installation, X_{it} is a vector of housing variables (bedrooms, bathrooms, etc.), as well as census block fixed effects and month- year fixed effects. Month-year fixed effects capture macroeconomic trends that affect the entire region that could be correlated with solar development trends. Block fixed effects account for location-specific unobservable heterogeneity that could be correlated with solar development.

Lastly, ϵ_{it} is the error term. β_1 is the pre-treatment price difference between treated and control

[6] Figure A3 in the online appendix presents the number of post-construction transactions by distance bin.

houses, and β_2 is the price difference between control properties, before and after treatment. The coefficient of interest is β_3, which is the differential price change from before to after solar development for treated properties relative to control properties.

In addition, we also estimate repeat sales models that include property fixed effects:

$$P_{it} = \beta_2 Post_{it} + \beta_3 (Treated_i \times Post_{it}) + \gamma X_{it} + \alpha_i + \epsilon_{it} \quad (3)$$

This model uses only within-property variation to identify β_3, and thus controls for time-invariant unobservables at the property level. In this specification, X_{it} only includes temporal fixed effects, as other housing variables are time-invariant. In addition to this specification, we also estimate a model that adds county-year fixed effects, which allows for different county- specific trends in the housing market. Across all specifications, our preferred model includes property, month-year, and county-year fixed effects, as it best controls for unobservable determinants of price and most flexibly controls for regional price trends, both of which could becorrelated with solar development. In all models, we cluster standard errors at the census tract level to allow for correlated errors within a larger area.

Since the extent of treatment is unknown, we first seek to empirically identify *d,* the distance up to which the effects of constructing a solar installation persist, and this will define the boundary for our treatment group. Following similar strategies as Davis (2011), Muehlenbachs et al. (2015), and Boslett et al. (2019), we estimate a series of DID models similarto our preferred specification, except with treatment defined by successive tenth-mile incrementsand control always being 2-3 miles. Figure 4 plots the estimates for each tenth-mile increment ranging from zero to two miles; each point and confidence interval represents a separate regression. Results indicate large, negative impacts for houses within 0.1 mile, but with large standard errors. Point estimates bounce around some, but more or less show effects diminishing with distance as expected. Beyond one mile, all estimates are statistically insignificant. Given this evidence, in all future specifications, we define the treatment group to be within one mile and the control group to be 1-3 miles.

We extend the analysis to investigate heterogeneity in treatment effect in multiple ways. First, we estimate a model that allows for heterogeneity in the impact based on distance. We identified treatment extending to one mile with Figure 4, but Figure 4 also suggests that treatment effects could be substantially larger within 0.1 mile. To explore this possibility moreformally, we develop a model that defines multiple distance bands. The first (outermost) band

represents control properties located two to three miles away from the nearest solar installation (per usual). The second (outer-middle) band includes treated properties located 1 – 2 miles from the nearest solar installation. The third (middle) band includes treated properties located 0.5 – 1 mile from the nearest solar installation. The fourth (inner-middle) band includes treated properties located 0.1 – 0.5 miles from the nearest solar installation. Finally, the fifth (innermost)band consists of treated properties within a distance of 0.1 mile from the closest installation. Ourspecification is:

$$PP_{iiii} = \beta\beta_2 PPPPPPTT_{iiii} + \sum_{kk=2}^{5} \beta\beta^{kk}_{3} \left(ddiiPPTT^{kk}_{ii} \times PPPPPPTT_{iiii} \right) + \gamma\gamma XX_{iiii} + \alpha\alpha_{ii} + \epsilon\epsilon_{iiii} \quad (4)$$

where $ddiiPPTT^{kk}_{ii}$ is a dummy variable equal to 1 if a property ii lies within the kk^{iih} distance band. PP_{iiii}, $PPPPPPTT_{iiii}$, XX_{iiii}, and $\alpha\alpha_{ii}$ are as defined in Equation 3. Our coefficients of interest are $\beta\beta^{kk}$, which are the differential changes in property prices from before to after the construction of solar installations, for homes in distance band kk, compared to changes in property values of control houses (lying indistance band 1).

Second, we investigate heterogeneity in treatment effect by two more characteristics: priorland use and rural character. This is done by a triple difference analysis in which we interact the treatment effect term in Equation 3 with a variable for our characteristic of interest. The specifications are as follow:

$$PP_{iiii} = \beta\beta_2 PPPPPPTT_{iiii} + \beta\beta_3 (TTRRTTRRTTTTdd_{ii} \times PPPPPPTT_{iiii}) + \beta\beta_4 (PPPPPPTT_{iiii} \times GGRRTTTTGGffiiTTRRdd_{ii})$$
$$+ \beta\beta_5 (TTRRTTRRTTTTdd_{ii} \times PPPPPPTT_{iiii} \times GGRRTTTTGGffiiTTRRdd_{ii}) + \gamma\gamma XX_{iiii} + \alpha\alpha_{ii} + \epsilon\epsilon_{iiii} \quad (5)$$

$$PP_{iiii} = \beta\beta_2 PPPPPPTT_{iiii} + \beta\beta_3 (TTRRTTRRTTTTdd_{ii} \times PPPPPPTT_{iiii}) + \beta\beta_4 (PPPPPPTT_{iiii} \times RRRRRRRRRR_{ii})$$
$$+ \beta\beta_5 (TTRRTTRRTTTTdd_{ii} \times PPPPPPTT_{iiii} \times RRRRRRRRRR_{ii}) + \gamma\gamma XX_{iiii} + \alpha\alpha_{ii} + \epsilon\epsilon_{iiii} \quad (6)$$

where $GGRRTTTTGGffiiTTRRdd_{ii}$ is an indicator variable equal to 1 if a property is located within the vicinityof a solar installation that was built on land that was formerly a farm or forest, and $RRRRRRRRRR_{ii}$ is an indicator variable equal to 1 if property ii lies in a town with a population density of 850 people per square mile or fewer.

Our coefficients of interest in Equations 5 and 6 are $\beta\beta_3$ and $\beta\beta_5$. $\beta\beta_5$ is interpreted as the difference in price impacts for greenfields relative to non-greenfield sites (Eq. 5) and the difference in price impacts for homes in rural areas relative to non-rural ones (Eq. 6). In Equation5, we expect $\beta\beta_5$ to be negative. We hypothesize that developments on farm and forest lands will lead to larger negative impacts on housing prices due to the more dramatic change in landscape compared to a commercial site or landfill and the loss of open space amenities. We also expect anegative sign on $\beta\beta_5$ in Equation 6, reflecting a loss in the rural character of a town due to the construction of solar installations.

Intuition would suggest a positive correlation between *GGRRTTTTGGffiiTTRRdd* and *RRRRRRRRRR*, which indeed plays out in the data. To try to separate the effects and test for multiplicative effects, we estimate a quadruple difference model that includes both *GGRRTTTTGGffiiTTRRdd* and *RRRRRRRRRR* fully interactedwith *TTRRTTRRTTTTdd* and *PPPPPPTT*.

4.1 Summary statistics and assumptions

Having defined treatment and control, we now evaluate the comparability of those groups. The summary statistics for key variables are given in Table 1. The first column represents the mean values of our full sample. The mean sales price is $338,320. The average property in our data has a lot size of half an acre, has living area of just under 3000 square feet,approximately 3 bedrooms, and is about 49 years old. About 21% of the properties are condominiums, 45% are located within 3 miles of a greenfield development, and 34% are rural.

The second and third columns in Table 1 compare pre-treatment housing attribute meansbetween the 0 – 1 miles (treated) and 1 – 3 miles (control) observations to examine similarity between the treatment and control groups. In the last column, we report the normalized differences in means, which is the difference in means between the treatment and control groupsdivided by the square root of the sum of their variances. None of the covariates have a normalized difference exceeding 0.25, which is the limit beyond which the difference in means becomes substantial.

The critical assumption for the DID design to yield causal estimates is the parallel trends assumption, which requires that the treatment and control properties have the same trend in outcomes if treatment did not occur. A common way of assessing the plausibility of this assumption is to examine pre-treatment trends in sales prices for the treatment and control groups. In Figure 5 we plot pre-treatment average sales prices of treatment and control groups upto 2010, which is the year in which the first solar installations were constructed. The price trendsare similar for both groups, thus boosting our confidence that the assumption holds, and the control group serves as a good counterfactual.

5 RESULTS

5.1 Main results

We present our main results in Table 2. Column 1 results are obtained from estimating Equation 2, which includes housing covariates (described in detail in the notes of the table), census block fixed effects, and month-year fixed effects. Columns 2 and 3 are results obtained from estimating repeat sales models described by Equation 3. Both columns include month-yearfixed effects, and Column 3 additionally includes county-year fixed effects. The coefficient on *Treated* is insignificant in Column 1 suggesting that, controlling for housing characteristics and spatial and temporal fixed effects, treated properties are not statistically significantly different from control properties pre-construction. The DID coefficient of interest ranges between -0.016to -0.026 and is statistically significantly different from zero across all models. Our preferred specification is Column 3 which includes property, month-year, and county-year fixed effects. This model indicates that on average, houses lying within one mile of solar installations sell for 1.7% less post construction relative to properties further away, all else equal. This finding confirms our hypothesis that nearby solar installations are a disamenity.

We convert the percentage reduction to dollars by multiplying the coefficient and theaverage property price for treated properties prior to construction ($327,700), which equals
$5,571. Assuming capitalization can be converted to a welfare measure in this context (see Kuminoff & Pope, 2014), we can then translate this price discount into an annual willingness topay for avoiding proximity to solar. Assuming a 5% interest rate, average annual willingness topay is $279 per household.

There are no other property value studies of solar arrays for us to compare our estimates to. To date, Botelho et al. (2017) is the only study to examine the negative externalities from large-scale solar facilities. Using a contingent valuation framework, they find that local residentsin Portugal are willing to accept $12.93 – $56.64 per month on average as compensation for being in the vicinity of solar installations. While their methods are different and vicinity is defined differently, their results are consistent with ours ($25.17/month). In addition, Botelho et al. conduct a discrete choice experiment to delve into aspects of siting that drive the disamenity and estimate that respondents are willing to pay $8.65, $7.57, and $5.15 per month to avoid negative impacts on flora and fauna, landscape, and glare effects, respectively. Second, we extend the hedonic valuation literature on renewable energy to include large-scale solar.

First, we provide the first estimates of the non-market valuation of large-scale solar installation externalities in the United States.

5.2 Robustness checks

In Table 3 we present results from a series of robustness checks to ensure that the resultsfrom our preferred model are consistent to alternative data samples. In Column 1 we drop all observations with sales prices in the top and bottom 1% of the distribution (as opposed to 5% inthe main sample) to assess whether the results are robust to including more high and low value properties. In Column 2 we restrict the sample to include only properties with a lot size of 5 acres or lesser, decreasing the maximum from 10 acres in our main sample. While it is unlikely that a solar array would be sited on a parcel of 5 – 10 acres, it is possible and so these propertiesmay appreciate based on expectations of possible lease payments. Column 3 excludes all condominiums from the sample. Column 4 includes all 284 solar installations from our full sample, which means properties could be exposed to multiple treatments. Columns 5 and 6 explore different amounts of land required per MW of installed capacity, 4 acres in Column 5, and 6 acres in Column 6. By contracting and expanding the assumed size of installations, the setof properties that are designated as treatment control is altered. Across all columns, our coefficient of interest is statistically significant and the magnitude ranges between -0.014 to -0.017. In sum, we find that our results are robust across all specifications.

5.3 Heterogeneity in treatment effect

In Table 4, we examine the heterogeneity in treatment effect by three characteristics: proximity to solar installations, prior land use, and rural character of towns. Each panel represents a different regression and all panels include property fixed effects, month-year fixedeffects, and county-year fixed effects.

In Panel A, we estimate the model described by Equation 4 that allows for heterogeneity in the impact on prices based on distance. The coefficient on the 1 – 2 miles band is statistically insignificant, which is congruent with our assumption that treatment effects do not persist beyond 1 mile. The coefficients on the 0.1 – 0.5 miles and 0.5 – 1 mile bands are significant and similar magnitude to the main results. The coefficient on the 0 – 0.1 mile band is -0.070, which is4 times larger in magnitude than the 0.1 – 0.5 miles and 0.5

– 1 mile bands, though only

significant at the 10% level. This suggests that property prices for homes lying within 0.1 mile from a solar installation fall by 7.0% ($23,682) post-construction, compared to houses further away. These results suggest extremely large disamenities for properties in very close proximity.

In Panel B, we provide estimates from the model described by Equation 5 where we explore heterogeneity by prior land use. The triple-interaction coefficient of interest is negativeas expected, and implies that farm and forest lands that are developed into solar arrays decreaseproperty values 0.8% more than brownfields and industrial areas. However, this coefficient is statistically insignificant, meaning the differential impact is imprecise and could even be zero.

In Panel C, we examine heterogeneity by rural character of towns and report the coefficients from the specification defined in Equation 6. The coefficient on $TTRRTTRRTTTTdd \times PPPPPPTT$ is larger in magnitude (-0.024) than the main results. The coefficient on $TTRRTTRRTTTTdd \times PPPPPPTT \times RRRRRRRRRR$ is essentially the same magnitude as the coefficient on $TTRRTTRRTTTTdd \times PPPPPPTT$, but the opposite sign. Taken together, these results suggest that the treatment effect in rural areas is effectively zero (a statistically insignificant 0.1%), and that the negative externalities of solar arrays are only occurring in non-rural areas. These findings go against our intuition. One possibility is that land is abundant in rural areas, so the development of some land into solar does little to impact scarcity, whereas in non-rural areas it makes a noticeable impact. A second possibility is that there are unobserved visibility differences across sites. If visibility is a key driver of negative impacts and installations in rural locations are less visible on average (due to land abundance for vegetative buffers), then this could produce the results observed.

In Panel D we further explore heterogeneity by land use and rural character. This is doneby estimating a quadruple difference model that interacts the treatment effect term in Equation 2with both the $GGRRTTTTGGffiiTTRRdd$ and $RRRRRRRRRR$ indicator variables.[7] The coefficient on $TTRRTTRRTTTTdd \times PPPPPPTT$, which represents the effect of non-greenfield solar arrays in non-rural areas is -0.014, which is slightly smaller than the overall average effect observed in Table 2, but is also imprecisely estimated. The coefficient on $TTRRTTRRTTTTdd \times PPPPPPTT \times GGRRTTTTGGffiiTTRRdd$, which applies to greenfield sites in non-rural areas, is -0.036 and is statistically significant. This suggests a large additional effectof greenfield sites in non-rural areas relative to non-greenfield sites, and a total effect of -5.0%.

[7] Tables A2-A4 in the online appendix examine the robustness of the results presented in Table 4, including differentregression specifications and different population density cutoff values that define *RRRRRRRRRR*. The results are broadly consistent with the findings presented.

The coefficient on $TTRRTTRRTTTTdd \times PPPPPPTT \times RRRRRRRRRR$, which applies to non-greenfield sites in rural areas, is 0.002 and is statistically insignificant. This suggests no statistical difference between theproperty value effect of non-greenfield sites in rural versus non-rural areas. Lastly, the coefficient on $TTRRTTRRTTTTdd \times PPPPPPTT \times GGRRTTTTGGffiiTTRRdd \times RRRRRRRRRR$, which applies to greenfield sites in rural areas, is 0.056 and is statistically significant. This indicates a counter-effect to the negativesseen for $TTRRTTRRTTTTdd \times PPPPPPTT$ and $TTRRTTRRTTTTdd \times PPPPPPTT \times GGRRTTTTGGffiiTTRRdd$, and the total effect for greenfield sites in rural areas is a positive 0.008. The total effect is statistically indistinguishable from zero. Taken together, the results of Panel D suggest that the overall negative effects of solar arrays on nearby property values are driven by greenfield sites in non-rural areas. Similar developments onfarm and forest lands in rural areas have no impact on nearby properties. These findings are consistent with the ideas that greenfield developments cause greater externalities, given the dual loss of open space amenities and gain of industrial disamenities, but that effect hinges on the scarcity of open space.

In the online appendix, we also present results that test for heterogeneity by size ofinstallation and time since construction (see Tables A5 and A6). In both cases we find no evidence of differential property value impacts by size and by time.

6 CONCLUSION

This paper estimates the valuation of externalities associated with nearby utility-scale solar installations using revealed preferences from the property market. Using the DID empiricaltechnique, we estimate regression models with treatment and control groups defined by distanceto the nearest solar installation. We observe 71,337 housing transactions occurring within one mile (treated group), and 347,921 transactions between one to three miles (control croup) of 208solar installations in MA and RI.

Our preferred model suggests that property values in the treatment group decline by 1.7%($5,751) on average compared to those in the control group after the construction of a nearby solar installation, all else equal. This translates to an annual willingness to pay of $279 per household to avoid disamenities associated with proximity to the installations. However, this average effect obscures heterogeneity. We find substantially larger negative effects for propertieswithin 0.1 miles and properties surrounding solar sites built on farm and forest lands in non-ruralareas.

While a full cost-benefit analysis of solar arrays is beyond the scope of this paper, because we do not know anything about consumer and producer surplus, we can still compare the negative local externalities to the global benefits of carbon mitigation to gain a more holisticunderstanding of local opposition.[8] We therefore conduct the following back-of-the-envelope calculations. On the cost side, we first consider the point estimate from our preferred specification which translates to a loss of $5,751 per household for treated homes close to solar installations. Our complete sample (prior to any data cuts) consists of 289,254 unique propertieslocated within 1 mile of all solar installations in the dataset. Put together, we estimate a net loss of $1.66 billion in aggregate housing value due to proximate solar installations in MA and RI.

To quantify the benefits from solar installations, we first calculate net generation from solar installations. Assuming a capacity factor of 16.5%, the 817 MW of installed solar capacity in MA and RI generates is 1,180,892 MWh (megawatt hours) of electricity per year.[9] Current non-renewable generation in MA and RI comes almost entirely from natural gas. According to the EIA, 0.42 mt (metric tons) of CO_2 are emitted from each MWh of electricity that is generatedfrom natural gas, implying that a total of 495,975 mt of CO_2 are abated annually from solar energy generation. Assuming that an average solar installation lasts 30 years, we estimate 14.88 million mt of CO_2 are abated in their entire life-span. The EPA (Environmental Protection Agency) estimates a social cost of $51.80 per metric ton of CO_2, which translates to $771 millionin lifetime benefits from the production of energy from solar installations (US EPA). We find that, considering only externalities, the benefit-cost ratio is 0.46, with a net loss of $893 million.

However, we caution against generalizing the benefit-cost findings to other regions in theUnited States for two main reasons. First, over 90% of the energy generated in MA and RI comes from natural gas, which emits only half as much CO_2 as coal. It is possible for benefits tooutweigh the costs in states where coal dominates the fuel mix for electricity generation. Second,MA and RI are the 3rd and the 2nd most densely populates states in the country, respectively, which makes the siting of solar installations away from residential areas a herculean task.

Careful siting of installations in states that have large tracts of open land available and aroundsparsely populated regions may allow for more favorable cost-benefit ratios.

[8] To be sure, significant amounts of money are part of the market transactions. A developer quoted us that they offerlandowners $15-20,000 per MW per year of installed capacity. It is unknown how much is profit and whether some portion of that could be used to compensate proximate households.

[9] $NNTTTT\ ggTTGGTTRRRRTTiiPPGG\ (MMMMh) = \%\ CCRRCCRRCCiiTTCCffRRCCTTPPRR \times 365\ ddRRCCPP \times 24\ hPPRRRRPP \times IIGGPPTTRRRRRRTTdd\ CCRRCCRRCCiiTTCC\ (MMMM)$

The demographic and geographical differences across states have implications for their respective RPS goals. For densely populated New England states with ambitious RPS targets, wind energy may be the better choice. Onshore wind turbines require a fraction of the land areaper MW of installed capacity compared to solar, while offshore turbines require none.

Furthermore, unlike solar installations, wind turbines in the United States (both onshore and offshore), have been found to have no disamenities associated with their proximity (Carr-Harris& Lang, 2019; Hoen et al., 2011, 2015; Hoen & Atkinson-Palombo, 2016; Lang et al., 2014).

Moving forward, states should customize plans to meet renewable energy targets that work bestwith their respective geographies.

REFERENCES

Anderson, S. T., & West, S. E. (2006). Open space, residential property values, and spatialcontext. *Regional Science and Urban Economics*, *36*(6), 773–789. https://doi.org/10.1016/j.regsciurbeco.2006.03.007

Bajari, P., Fruehwirth, J. C., Kim, K. il, & Timmins, C. (2012). A Rational Expectations Approach to Hedonic Price Regressions with Time-Varying Unobserved Product Attributes: The Price of Pollution. *American Economic Review*, *102*(5), 1898–1926.https://doi.org/10.1257/aer.102.5.1898

Bates, A., & Firestone, J. (2015). A comparative assessment of proposed offshore wind power demonstration projects in the United States. *Energy Research & Social Science*, *10*, 192–205. https://doi.org/10.1016/j.erss.2015.07.007

Bayer, P., Keohane, N., & Timmins, C. (2009). Migration and hedonic valuation: The case of airquality. *Journal of Environmental Economics and Management*, *58*(1), 1–14. https://doi.org/10.1016/j.jeem.2008.08.004

Bento, A., Freedman, M., & Lang, C. (2014). Who Benefits from Environmental Regulation? Evidence from the Clean Air Act Amendments. *The Review of Economics and Statistics*,*97*(3), 610–622. https://doi.org/10.1162/REST_a_00493

Bishop, K. C., Kuminoff, N. V., Banzhaf, H. S., & Boyle, K. J. (2019). Best Practices in UsingHedonic Property Value Models for Welfare Measurement. *Review of Environmental Economics and Policy*, 43.

Black, K. J. (2018). Wide open spaces: Estimating the willingness to pay for adjacent preservedopen space. *Regional Science and Urban Economics*, *71*, 110–121. https://doi.org/10.1016/j.regsciurbeco.2018.06.001

Boslett, A., Guilfoos, T., & Lang, C. (2016). Valuation of expectations: A hedonic study of shalegas development and New York's moratorium. *Journal of Environmental Economics and Management*, *77*, 14–30. https://doi.org/10.1016/j.jeem.2015.12.003

Boslett, A., Guilfoos, T., & Lang, C. (2019). Valuation of the External Costs of Unconventional Oil and Gas Development: The Critical Importance of Mineral Rights Ownership. *Journal of the Association of Environmental and Resource Economists*, *6*(3), 531–561.https://doi.org/10.1086/702540

Botelho, A., Lourenço-Gomes, L., Pinto, L., Sousa, S., & Valente, M. (2017). Accounting for local impacts of photovoltaic farms: The application of two stated preferences approachesto a case-study in Portugal. *Energy Policy*, *109*, 191–198. https://doi.org/10.1016/j.enpol.2017.06.065

Carlisle, J. E., Kane, S. L., Solan, D., Bowman, M., & Joe, J. C. (2015). Public attitudes regarding large-scale solar energy development in the U.S. *Renewable and SustainableEnergy Reviews*, *48*, 835–847. https://doi.org/10.1016/j.rser.2015.04.047

Carlisle, J. E., Kane, S. L., Solan, D., & Joe, J. C. (2014). Support for solar energy: Examining sense of place and utility-scale development in California. *Energy Research & Social Science*, *3*, 124–130. https://doi.org/10.1016/j.erss.2014.07.006

Carr-Harris, A., & Lang, C. (2019). Sustainability and tourism: The effect of the United States' first offshore wind farm on the vacation rental market. *Resource and Energy Economics*,*57*, 51–67. https://doi.org/10.1016/j.reseneeco.2019.04.003

Chay, K. Y., & Greenstone, M. (2005). Does Air Quality Matter? Evidence from the Housing Market. *Journal of Political Economy*, *113*(2), 376–424. https://doi.org/10.1086/427462

Dastrup, S. R., Graff Zivin, J., Costa, D. L., & Kahn, M. E. (2012). Understanding the Solar Home price premium: Electricity generation and “Green” social status. *European Economic Review*, *56*(5), 961–973. https://doi.org/10.1016/j.euroecorev.2012.02.006

Davis, L. W. (2011). THE EFFECT OF POWER PLANTS ON LOCAL HOUSING VALUES AND RENTS. *The Review of Economics and Statistics*, *93*(4), 1391–1402.

Denholm, P., & Margolis, R. M. (2008). Land-use requirements and the per-capita solar footprintfor photovoltaic generation in the United States. *Energy Policy*, *36*(9), 3531–3543. https://doi.org/10.1016/j.enpol.2008.05.035

Dröes, M. I., & Koster, H. R. A. (2016). Renewable energy and negative externalities: The effectof wind turbines on house prices. *Journal of Urban Economics*, *96*, 121–141. https://doi.org/10.1016/j.jue.2016.09.001

EIA - Annual Energy Outlook 2018. (2018, July 17). https://www.eia.gov/outlooks/aeo/

EIA International Energy Outlook. (2019). https://www.eia.gov/outlooks/ieo/

Farhar, B. C. (1994). Trends in US Public Perceptions and Preferences on Energy and Environmental Policy. *Annual Review of Energy and the Environment*, *19*(1), 211–239.https://doi.org/10.1146/annurev.eg.19.110194.001235

Farhar, B. C., Hunter, L. M., Kirkland, T. M., & Tierney, K. J. (2010). *Community Response to Concentrating Solar Power in the San Luis Valley: October 9, 2008 - March 31, 2010* (NREL/SR-550-48041). National Renewable Energy Lab. (NREL), Golden, CO (UnitedStates). https://doi.org/10.2172/983406

Firestone, J., Bidwell, D., Gardner, M., & Knapp, L. (2018). Wind in the sails or choppy seas?:People-place relations, aesthetics and public support for the United States' first offshorewind project. *Energy Research & Social Science*, *40*, 232–243. https://doi.org/10.1016/j.erss.2018.02.017

Gawande, K., & Jenkins-Smith, H. (2001). Nuclear Waste Transport and Residential Property Values: Estimating the Effects of Perceived Risks. *Journal of Environmental Economicsand Management*, *42*(2), 207–233. https://doi.org/10.1006/jeem.2000.1155

Geoghegan, J., Wainger, L. A., & Bockstael, N. E. (1997). Spatial landscape indices in a hedonicframework: An ecological economics analysis using GIS. *Ecological Economics*, *23*(3), 251–264. https://doi.org/10.1016/S0921-8009(97)00583-1

Gibbons, S. (2015). Gone with the wind: Valuing the visual impacts of wind turbines throughhouse prices. *Journal of Environmental Economics and Management*, *72*, 177–196. https://doi.org/10.1016/j.jeem.2015.04.006

Gopalakrishnan, S., & Klaiber, H. A. (2014). Is the Shale Energy Boom a Bust for NearbyResidents? Evidence from Housing Values in Pennsylvania. *American Journal of Agricultural Economics*, *96*(1), 43–66. https://doi.org/10.1093/ajae/aat065

Grainger, C. A. (2012). The distributional effects of pollution regulations: Do renters fully payfor cleaner air? *Journal of Public Economics*, *96*(9), 840–852. https://doi.org/10.1016/j.jpubeco.2012.06.006

Greenberg, M. (2009). Energy sources, public policy, and public preferences: Analysis of USnational and site-specific data. *Energy Policy*, *37*(8), 3242–3249. https://doi.org/10.1016/j.enpol.2009.04.020

Gross, S. (2020). *Renewables, land use, and local opposition in the United States* (p. 24). TheBrookings Institution. https://docs.wind-watch.org/FP_20200113_renewables_land_use_local_opposition_gross.pdf

Hamilton, S. W., & Schwann, G. M. (1995). Do High Voltage Electric Transmission LinesAffect Property Value? *Land Economics*, *71*(4), 436–444. JSTOR. https://doi.org/10.2307/3146709

Haninger, K., Ma, L., & Timmins, C. (2017). The Value of Brownfield Remediation. *Journal ofthe Association of Environmental and Resource Economists*, *4*(1), 197–241. https://doi.org/10.1086/689743

Hoen, B., & Atkinson-Palombo, C. (2016). Wind Turbines, Amenities and Disamenitites: Astudyof Home Value Impacts in Densely Populated Massachusetts. *Journal of Real Estate Research*, *38*(4), 473–504. https://doi.org/10.5555/0896-5803-38.4.473

Hoen, B., Brown, J. P., Jackson, T., Thayer, M. A., Wiser, R., & Cappers, P. (2015). Spatial Hedonic Analysis of the Effects of US Wind Energy Facilities on Surrounding PropertyValues. *The Journal of Real Estate Finance and Economics*, *51*(1), 22–51. https://doi.org/10.1007/s11146-014-9477-9

Hoen, B., Firestone, J., Rand, J., Elliott, D., Hübner, G., Pohl, J., Wiser, R., Lantz, E., Haac, R.,& Kaliski, K. (2019). Attitudes of U.S. Wind Turbine Neighbors: Analysis of a Nationwide Survey. *Energy Policy*, *134*. https://doi.org/10.1016/j.enpol.2019.110981

Hoen, B., Wiser, R., Cappers, P., Thayer, M., & Sethi, G. (2011). Wind Energy Facilities andResidential Properties: The Effect of Proximity and View on Sales Prices. *Journal of Real Estate Research*, *33*(3), 279–316. https://doi.org/10.5555/rees.33.3.16133472w8338613

Hoen, B., Wiser, R., Thayer, M., & Cappers, P. (2012). Residential Photovoltaic Energy Systemsin California: The Effect on Home Sales Prices. *Contemporary Economic Policy*, *31*(4), 708–718. https://doi.org/10.1111/j.1465-7287.2012.00340.x

Irwin, E. G. (2002). The Effects of Open Space on Residential Property Values. *LandEconomics*, *78*(4), 465–480. https://doi.org/10.2307/3146847

Jacobe, D. (2013, March 27). *Americans Want More Emphasis on Solar, Wind, Natural Gas*.Gallup.Com. https://news.gallup.com/poll/161519/americans-emphasis-solar-wind- natural-gas.aspx

Jensen, C. U., Panduro, T. E., Lundhede, T. H., Nielsen, A. S. E., Dalsgaard, M., & Thorsen, B. J. (2018). The impact of on-shore and off-shore wind turbine farms on property prices. *Energy Policy*, *116*, 50–59. https://doi.org/10.1016/j.enpol.2018.01.046

Krohn, S., & Damborg, S. (1999). On public attitudes towards wind power. *Renewable Energy*,*16*(1), 954–960. https://doi.org/10.1016/S0960-1481(98)00339-5

Kuffner, A. (2018, March 16). *Worry over solar sprawl spreads across Rhode Island*. Providencejournal.Com. https://www.providencejournal.com/news/20180316/worry-over-solar-sprawl-spreads-across-rhode-island

Kuminoff, N. V., & Pope, J. C. (2014). Do “Capitalization Effects” for Public Goods Reveal the Public’s Willingness to Pay? *International Economic Review*, *55*(4), 1227–1250. https://doi.org/10.1111/iere.12088

Lang, C. (2015). The dynamics of house price responsiveness and locational sorting: Evidencefrom air quality changes. *Regional Science and Urban Economics*, *52*, 71–82. https://doi.org/10.1016/j.regsciurbeco.2015.02.005

Lang, C. (2018). Assessing the efficiency of local open space provision. *Journal of PublicEconomics*, *158*, 12–24. https://doi.org/10.1016/j.jpubeco.2017.12.007

Lang, C., & Cavanagh, P. (2018). Incomplete Information and Adverse Impacts of Environmental Cleanup. *Land Economics*, *94*(3), 386–404. https://doi.org/10.3368/le.94.3.386

Lang, C., Opaluch, J. J., & Sfinarolakis, G. (2014). The windy city: Property value impacts of wind turbines in an urban setting. *Energy Economics*, *44*, 413–421. https://doi.org/10.1016/j.eneco.2014.05.010

Lovich, J. E., & Ennen, J. R. (2011). Wildlife Conservation and Solar Energy Development in the Desert Southwest, United States. *BioScience*, *61*(12), 982–992. https://doi.org/10.1525/bio.2011.61.12.8

Ma, C., Polyakov, M., & Pandit, R. (2016). Capitalisation of residential solar photovoltaicsystems in Western Australia. *Australian Journal of Agricultural and Resource Economics*, *60*(3), 366–385. https://doi.org/10.1111/1467-8489.12126

Ma, L. (2019). Learning in a Hedonic Framework: Valuing Brownfield Remediation. *International Economic Review*, *60*(3), 1355–1387.

https://doi.org/10.1111/iere.12389 Muehlenbachs, L., Spiller, E., & Timmins, C. (2015). The Housing Market Impacts of Shale Gas Development. *American Economic Review*, *105*(12), 3633–3659.https://doi.org/10.1257/aer.20140079

Naylor, D. (2019, October 16). *West Greenwich residents air concerns over proposed solarproject*. Providencejournal.Com. https://www.providencejournal.com/news/20191016/west-greenwich-residents-air- concerns-over-proposed-solar-project

Ong, S., Campbell, C., Denholm, P., Margolis, R., & Heath, G. (2013). *Land-Use Requirementsfor Solar Power Plants in the United States* (NREL/TP-6A20-56290, 1086349). https://doi.org/10.2172/1086349

Perea, A., Smith, C., Davis, M., Sun, X., White, B., Cox, M., Curtin, G., Rumery, S., Holm, A., Goldstein, R., & Baca, J. (2020). *U.S. Solar Market Insight Executive summary*. Wood Mackenzie and Solar Energy Industries Association.

Pew Research Center. (2019, November 25). *U.S. Public Views on Climate and Energy*. https://www.pewresearch.org/science/2019/11/25/u-s-public-views-on-climate-and- energy/

Qiu, Y., Wang, Y. D., & Wang, J. (2017). Soak up the sun: Impact of solar energy systems on residential home values in Arizona. *Energy Economics*, *66*, 328–336. https://doi.org/10.1016/j.eneco.2017.07.001

Ridker, R. G., & Henning, J. A. (1967). The Determinants of Residential Property Values with Special Reference to Air Pollution. *The Review of Economics and Statistics*, *49*(2), 246–257. JSTOR. https://doi.org/10.2307/1928231

Rosen, S. (1974). Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy*, *82*(1), 34–55. https://doi.org/10.1086/260169

Sunak, Y., & Madlener, R. (2016). The impact of wind farm visibility on property values: A spatial difference-in-differences analysis. *Energy Economics*, *55*, 79–91. https://doi.org/10.1016/j.eneco.2015.12.025

Tanaka, S., & Zabel, J. (2018). Valuing nuclear energy risk: Evidence from the impact of theFukushima crisis on U.S. house prices. *Journal of Environmental Economics and Management*, *88*, 411–426. https://doi.org/10.1016/j.jeem.2017.12.005

Trainor, A. M., McDonald, R. I., & Fargione, J. (2016). Energy Sprawl Is the Largest Driver ofLand Use Change in United States. *PLOS ONE*, *11*(9), e0162269. https://doi.org/10.1371/journal.pone.0162269

U.S. Energy Information Administration (EIA). (n.d.). Retrieved June 24, 2020, from https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity- and-sales.php

US EPA. (n.d.). *The Social Cost of Carbon* [Reports and Assessments]. Retrieved July 9, 2020, from /climatechange/social-cost-carbon

Vyn, R. J. (2018). Property Value Impacts of Wind Turbines and the Influence of Attitudestoward Wind Energy. *Land Economics*, *94*(4), 496–516. https://doi.org/10.3368/le.94.4.496

Wee, S. (2016). The effect of residential solar photovoltaic systems on home value: A case studyof Hawai‘i. *Renewable Energy*, *91*, 282–292. https://doi.org/10.1016/j.renene.2016.01.059

Zabel, J. E., & Guignet, D. (2012). A hedonic analysis of the impact of LUST sites on houseprices. *Resource and Energy Economics*, *34*(4), 549–564. https://doi.org/10.1016/j.reseneeco.2012.05.006

Figures and Tables

Figure 1: Map of solar installations across Massachusetts and Rhode Island

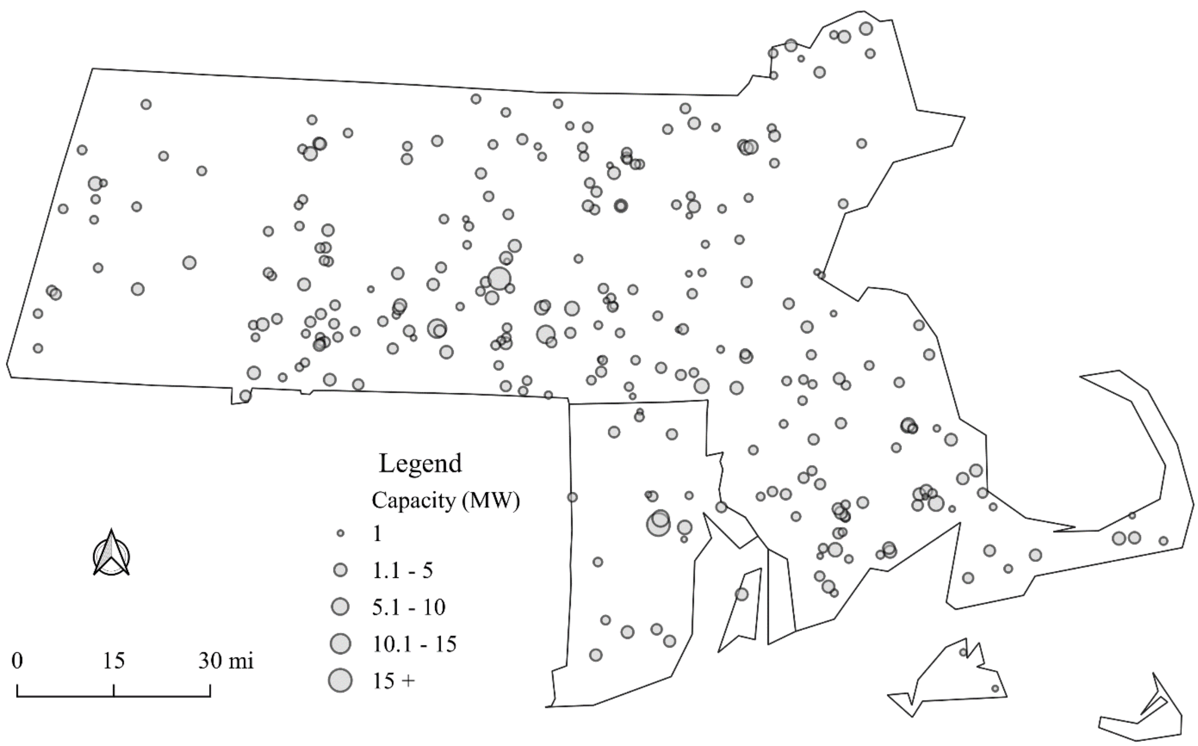


Figure 2: New and cumulative utility-scale solar capacity by year

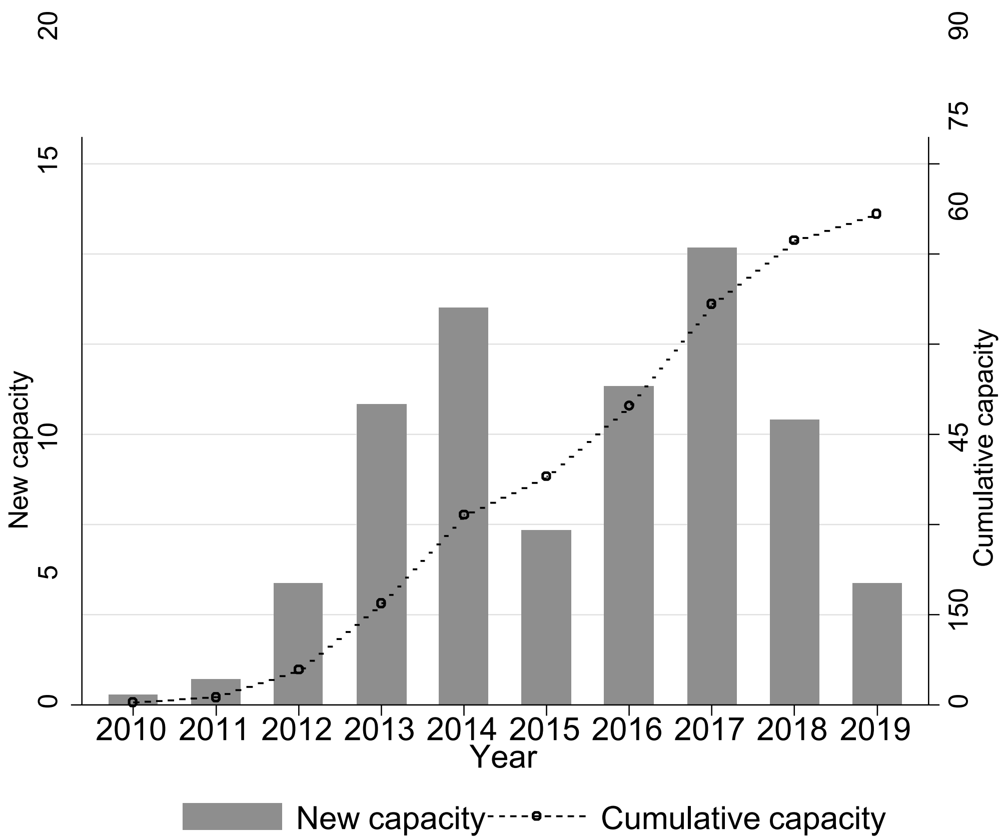
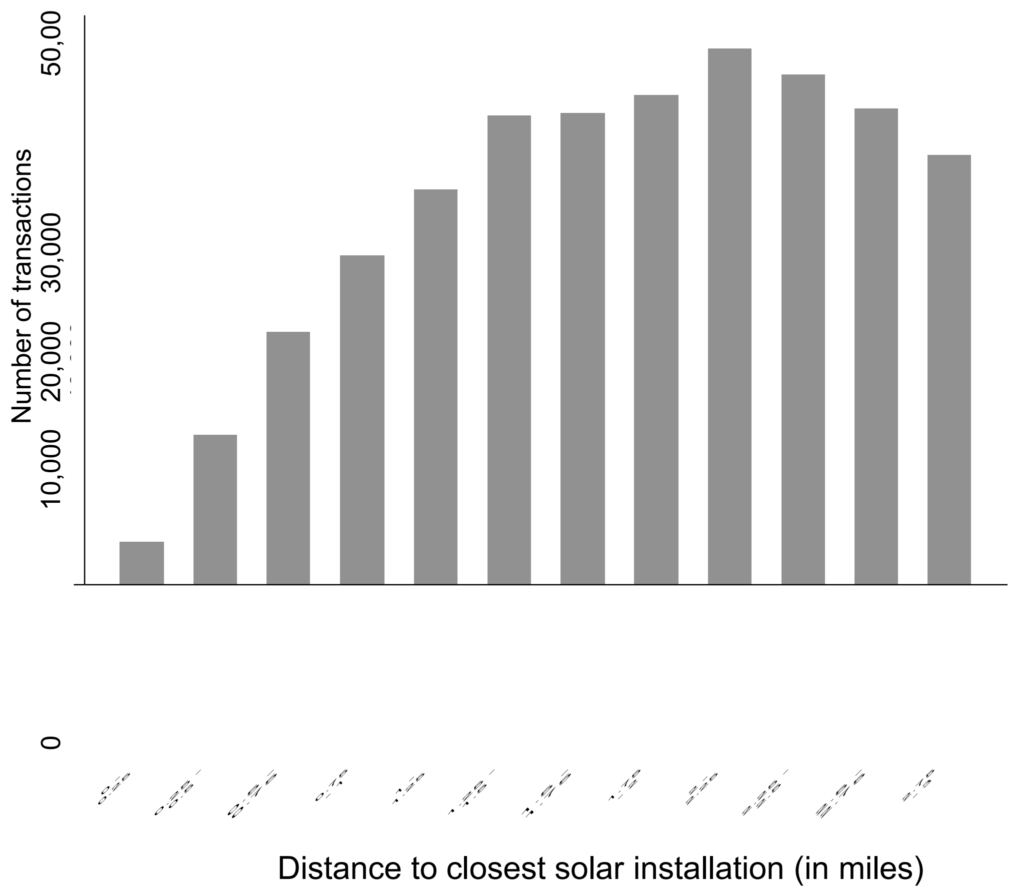
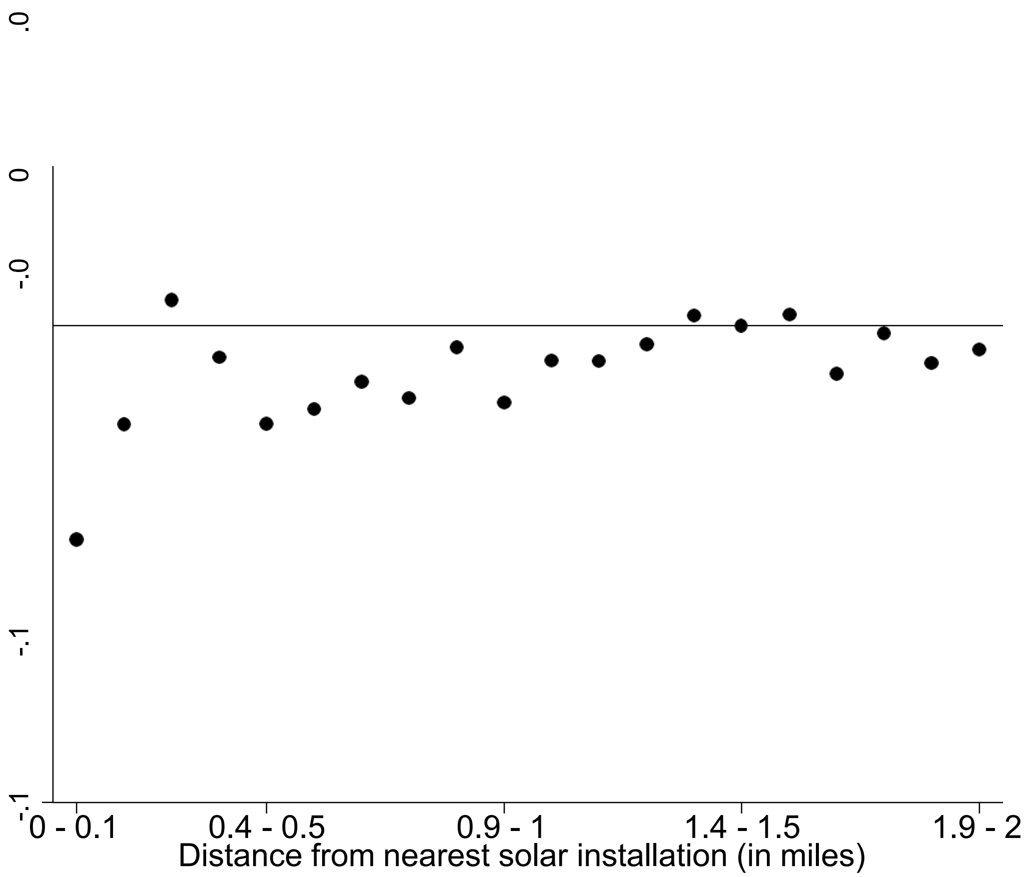


Figure 3: Number of transactions by distance to nearest solar installation



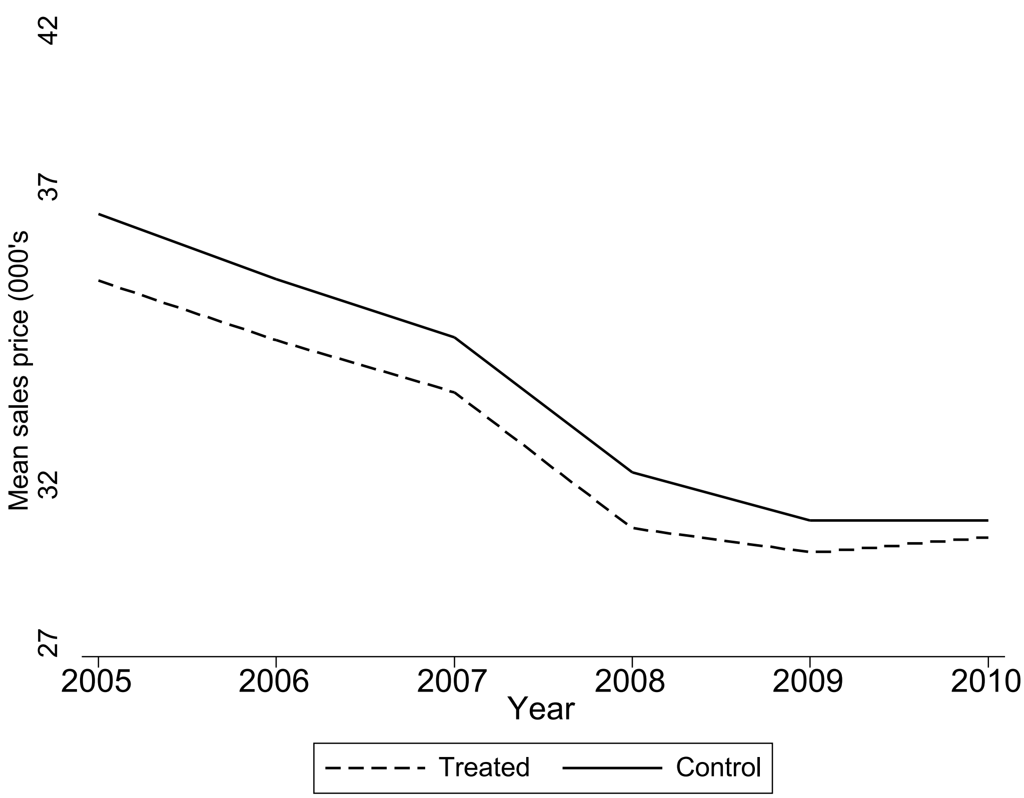
Notes: These transactions occur near eventual solar installations, since the data span across the years 2005 – 2019, and the construction of the installations is staggered throughout that time period.

Figure 4: Distance bin coefficient estimates



Notes: The treatment variable is defined as a bin variable, with treated properties lying within 1/10 mile distance bands up to 2 miles. Control properties are those lying 2 – 3 miles away from the nearest solar installation. The coefficients are obtained by estimating a series of DID models similar to Equation 2 that regresses log sales price on 1/10 mile distance bands up to 2 miles, along with month-year, county-year, and property fixed effects. Resulting coefficients and 95% confidence intervals are graphed.

Figure 5: Pre-treatment trends between treatment and control groups



Notes: The graph represents all transactions occurring pre-construction. Treated are properties within one mile of aneventual solar installation, and Control is between one and three miles. The sample size is 181,190.

Table 1: Housing attribute means by treatment status

Variables	Full sample	Pre-treatment means		Normalized difference in means
		0 - 1 mile	1 - 3 miles	
Sales price (000's)	338.32	327.70	340.74	-3.11e-07
Lot size (acres)	0.49	0.50	0.48	0.017
House area (sq. feet)	2874.92	2849.70	2865.73	-5.83e-06
Bedrooms	2.91	2.88	2.91	-0.027
Full bathrooms	1.56	1.56	1.56	-0.012
Half bathrooms	0.52	0.52	0.52	-0.009
Age of home (years)	49.23	43.06	48.11	-0.003
Condo (1=yes)	0.21	0.22	0.21	0.058
Pool (1 = yes)	0.04	0.04	0.04	-0.027
Air conditioning (1 = yes)	0.43	0.47	0.43	0.121
Fireplace number	0.41	0.38	0.42	-0.076
Condition (1 = above average)	0.26	0.22	0.26	-0.150
Greenfield (1 = yes)	0.45	0.46	0.46	0.021
Rural (1 = yes)	0.34	0.40	0.34	0.199
Observations	419,258	51,471	252,773	

Notes: Sales prices are adjusted to 2019 levels using the CPI. Normalized difference in means calculated according to Imbens and Wooldridge (2009). Normalized differences exceeding 0.25 in absolute value are considered statistically different.

Table 2: Difference-in-differences estimates of the impact of solar installations on property prices

Independent variables	Dependent variable: Sale price (ln)		
	(1)	(2)	(3)
Treated	0.002		
	(0.005)		
Post	0.015***	0.011**	-0.006
	(0.004)	(0.005)	(0.004)
Treated × Post	-0.016***	-0.026***	-0.017***
	(0.005)	(0.007)	(0.006)
Fixed Effects			
Month-year	Y	Y	Y
Block	Y		
Property		Y	Y
County-year			Y
Observations	419,258	231,503	231,503
R^2	0.804	0.889	0.893

Notes: Treat = 1 if a house is within 1 mile of a solar construction and Post = 1 if a house sells post-construction. Column 1 includes the following control variables: lot size, house area, number of bedrooms, full bathrooms, half bathrooms, and fireplaces, indicator variables for condos, the condition of the house, and for the presence of a pool and air conditioning, capacity of installation (in MW) and greenfield. Standard errors are clustered at the tract level and shown in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Table 3: Robustness checks

Independent variables	Dependent variable: Sale price (ln)					
	Price cuts at top and bottom 1%	Lot size nomore than 5 acres	Drop Condos	Keep all installations	1 MW = 4 acres	1 MW = 6 acres
	(1)	(2)	(3)	(4)	(5)	(6)
Treated × Post	-0.015**	-0.016***	-0.014***	-0.017***	-0.016***	-0.017***
	(0.007)	(0.006)	(0.005)	(0.006)	(0.006)	(0.005)
Observations	258,562	230,100	179,387	273,878	233,943	231,977
R^2	0.865	0.894	0.880	0.897	0.894	0.893

Notes: Treated = 1 if a house is within 1 mile of a solar construction, and Post = 1 if a house sells post-construction. All specifications include property, month-year, and county-year fixed effects. Standard errors are clustered at the tract level and shown in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Table 4: Heterogeneity of treatment effects

Independent variables	Dependent variable: Sale price (ln)
Panel A: Heterogeneity by proximity	
(1 – 2 miles) × Post	-0.005
	(0.005)
(0.5 – 1 mile) × Post	-0.019***
	(0.007)
(0.1 – 0.5 miles) × Post	-0.017*
	(0.009)
(0 – 0.1 miles) × Post	-0.070*
	(0.038)
Panel B: Heterogeneity by prior land use	
Treated × Post	-0.013*
	(0.008)
Treated × Post × Greenfield	-0.008
	(0.011)
Panel C: Heterogeneity by population density	
Treated × Post	-0.024***
	(0.008)
Treated × Post × Rural	0.025**
	(0.011)
Panel D: Heterogeneity by population density and land use	
Treated × Post	-0.014
	(0.009)
Treated × Post × Greenfield	-0.036**
	(0.014)
Treated × Post × Rural	0.002
	(0.017)
Treated × Post × Greenfield × Rural	0.056**
	(0.022)
Observations	231,503

Notes: Treated = 1 if a house is within 1 mile of a solar construction and Post =1 if a house sells post-construction. In Panel A, (1 – 2 miles), (0.5 – 1 mile), (0.1 – 0.5 miles) and (0 – 0.1 mile) are dummy variables = 1 if properties lie within the respective distances from the nearest solar installation, and distance bin for 2 – 3 miles is omitted. Greenfield = 1 if the prior land use is farm or forest land, and Rural = 1 if the population density per square mile is ≤850. Panel B includes an interaction term Post*Greenfield and Panel C includes Post*Rural. Additional interactions included in Panel D are: Treated*Rural, Treated*Greenfield, Post*Rural, Post*Greenfield, Rural*Greenfield, Post*Greenfield*Rural, and Treated*Rural*Greenfield. All models include month-year, county-year, and property fixed effects. Standard errors are clustered at the tract level and shown in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

APPENDIX

This appendix provides supplemental figures and tables to our main results.

Figure A1 maps the location and capacities (in MW) of the 208 solar installations that areincluded in our main results.

Figure A2 depicts the increase in new and cumulative solar capacity over time by prior land use.

Figure A3 represents the number of sample post-treatment transactions by distance to nearestsolar installation, in quarter mile intervals.

Figure A4 shows the distribution of solar installations by capacity.

Table A1 provides post-treatment means and the normalized differences in means between thetreated and control groups for key property attributes.

Table A2 assesses robustness of results presented in Table 4 of the main text. We present twoadditional specifications: month-year fixed effects and block fixed effects in Column 1, and month-year and property fixed effects in Column 2. Column 3 is the same as the results presented in Table 4. In Panel A, we find that the large, negative coefficient found for (0 − 0.1 mmmmmmmm) xx PPPPmmPP is only found when property fixed effects are included. In Panels B, C, and D, results are largely similar across columns.

Table A3 explores how different population density cutoff values that define the variable RRRRRRRRmm affect the results presented in Panel C of Table 4 in the main paper. 850 people/square mile is thecutoff used in the main text. The results in the first three columns (500 people/square mile, 850 people/square mile, and 1000 people/square mile) are quite consistent. The results in columns 4 and 5 (1200 people/square mile, 1500 people/square mile) are qualitatively similar to the previous results, but the coefficient on TTRRmmRRPPmmTT xx PPPPmmPP xx RRRRRRRRmm is smaller in magnitude and not statistically significantly different from zero. In the final column (2000 people/square mile), the coefficient on TTRRmmRRPPmmTT xx PPPPmmPP xx RRRRRRRRmm is negative and statistically insignificant, and the coefficient on TTRRmmRRPPmmTT xx PPPPmmPP is statistically insignificant as well. The trend in results is expected as more areas are classified as rural. Given that we find that negative property value impacts of solar are strongest in non-rural (suburban) areas, as these places are increasingly classified as rural, the coefficient on TTRRmmRRPPmmTT xx PPPPmmPP xx RRRRRRRRmm is a mixture of the zero impacts in rural areas and the negative impacts in non-rural areas.

Table A4 explores how different population density cutoff values that define the variable RRRRRRRRmm affect the results presented in Panel D of Table 4 in the main paper, similar to Table A3. We specify different cutoff values of population density per square mile and report results using our main specification. The coefficients are consistent with the results of Panel D in Table 4, for allcutoff values except the highest one (2000 people/square mile).

Table A5 explores heterogeneity in treatment effect by the size of the solar installations. We define *LLRRRRaammaaRRaaRRaammPPaa* as an indicator variable = 1 if the size of the installation (in MW) is greater than the median value in our sample (2 MW). We find no evidence of heterogeneity by installation size, the coefficient is small and statistically insignificant, implying no additional disamenities from solar developments larger than 2 MW. We additionally explore an alternative specification (results not provided) where capacity is treated as a linear variable and is interactedwith *TTRRmmRRPPmmTT* × *PPPPmmPP* . These estimates yield the same conclusion to those in Table A3. This result indicates that the presence of utility-scale solar is a disamenity regardless of size. Given that the smallest installations in our analysis are still quite large at five acres in size (about 3.8 football fields), it could be that there is no additional impact of size because it is difficult or evenimpossible to see beyond five acres from ground level. However, one limitation of this analysis is that the range of observed sizes is narrow. Of the 208 installations in our dataset, almost 50% have a capacity of 2 MW or lesser, and only 13 (6%) are 5 MW or larger.

Table A6 examines heterogeneity in treatment effect by time elapsed. We split our *PPPPmmPP* variableinto two sub-categories: *PPPPmmPP* (*LLmmmmm PPhRRaa* 3 *aammRRRRmm*) and *PPPPmmPP* (3 *PPRR mmPPRRmm aammRRRRmm*), where
PPPPmmPP (*LLmmmmm PPhRRaa* 3 *aammRRRRmm*) is a dummy variable = 1 if a property transacts less than three years post-construction, and *PPPPmmPP* (3 *PPRR mmPPRRmm aammRRRRmm*) is a dummy variable = 1 if a property transacts 3 or more years post-construction. We interact both variables with *TTRRmmRRPPmmTT*, and find that both coefficients are significant and almost equal across the board, implying no change in the effect over time.

Figure A1: Map of solar installations at least 1 mile apart across Massachusetts and Rhode Island

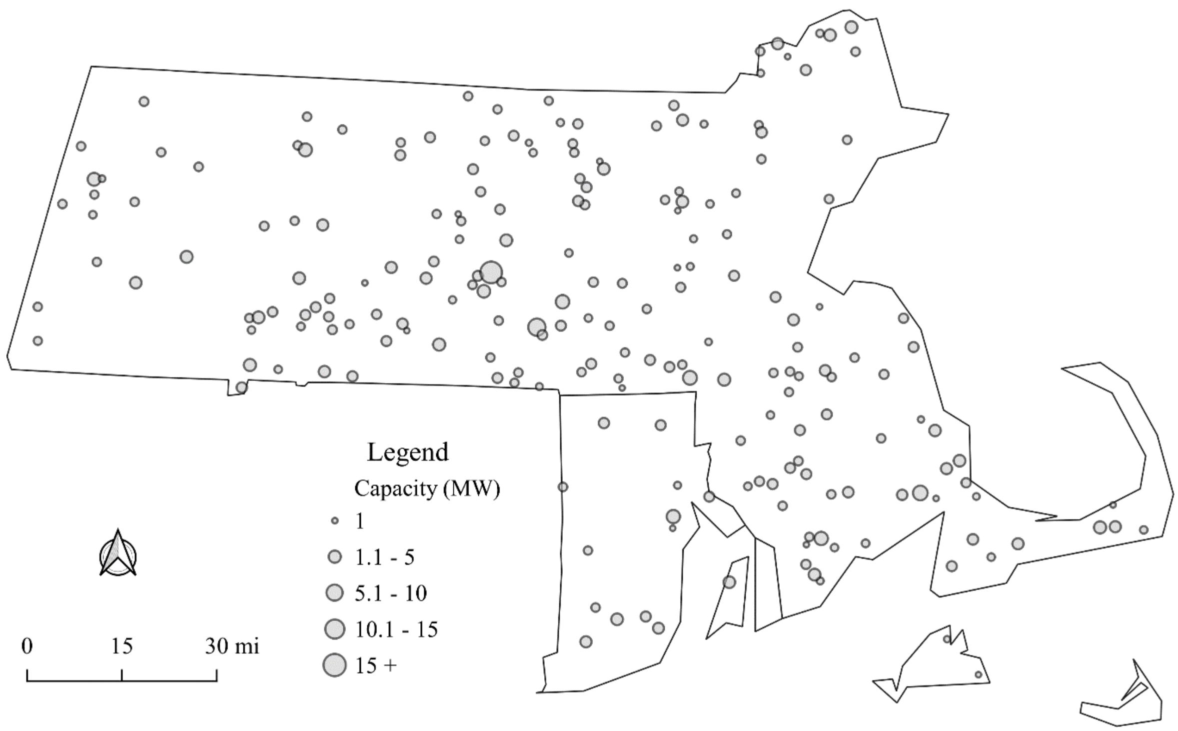


Figure A2: New and cumulative capacity by year and land use

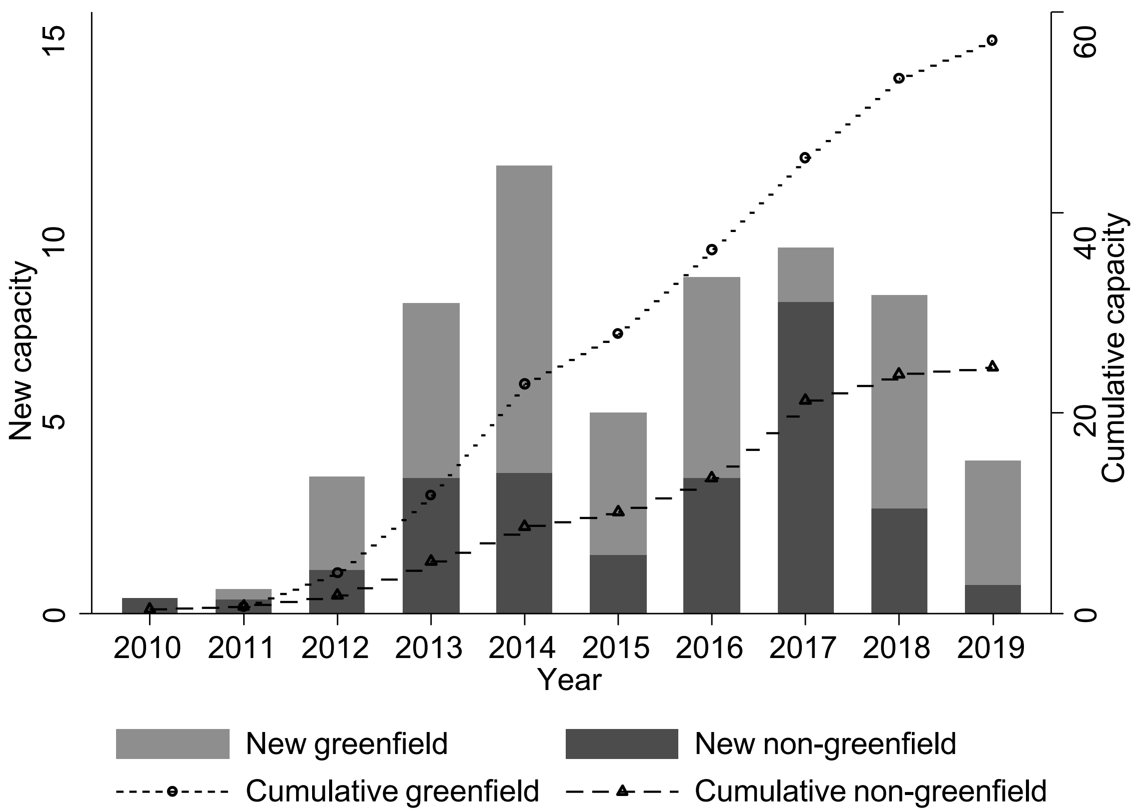
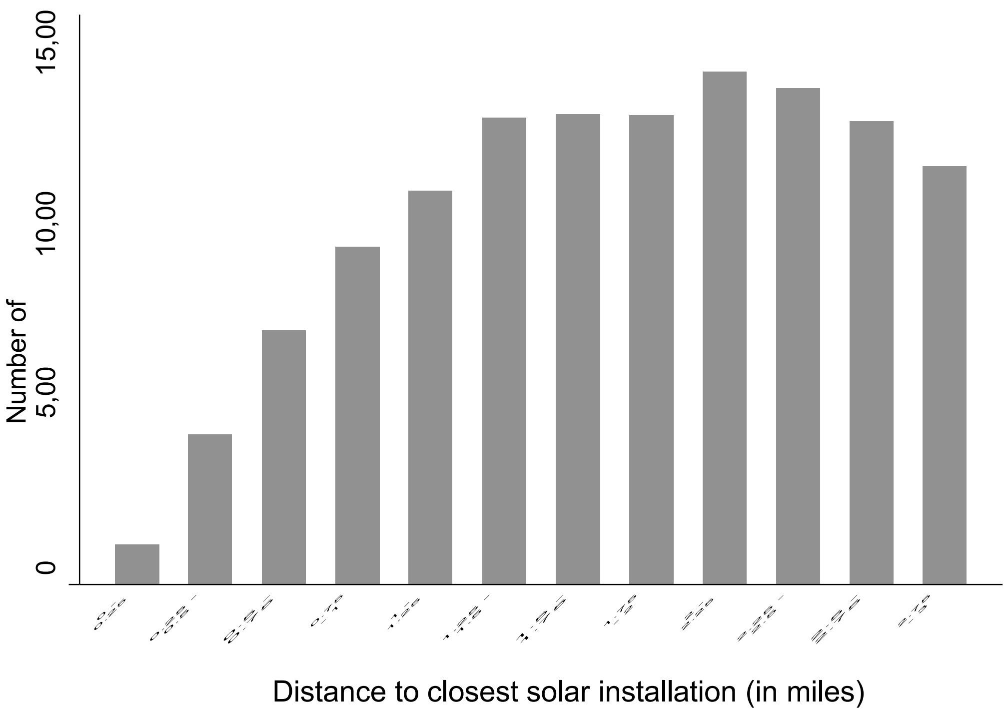


Figure A3: Number of post-construction transactions by distance to nearest solar installation



Notes: These transactions occur near eventual solar installations, since the data span across the years 2005 – 2019,and the construction of the installations is staggered throughout that time period.

Figure A4: Frequency of solar installations by capacity

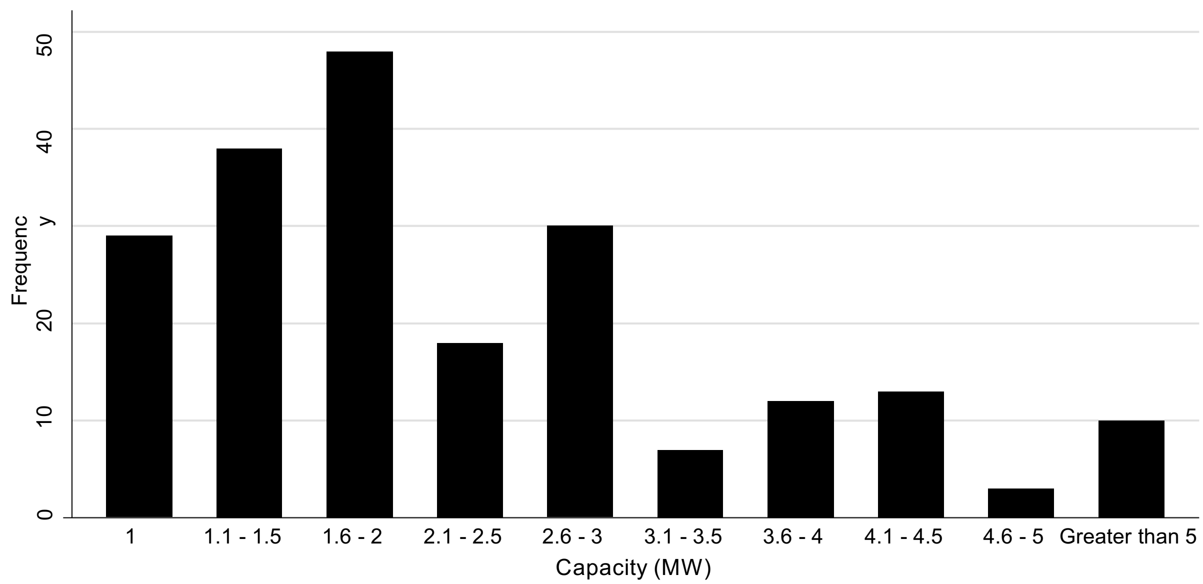


Table A1: Housing attribute means by treatment status, post construction

Variable	Post-treatment means		Normalized difference in means
	0 - 1 mile	1 - 3 miles	
Price (000's)	321.02	341.25	-4.64e-07
Lot size (acres)	0.48	0.50	-0.013
House area (sq. feet)	2872.97	2913.40	-1.47e-05
Bedrooms	2.90	2.93	-0.024
Full bathrooms	1.56	1.57	-0.020
Half bathrooms	0.53	0.53	0.001
Age of home (years)	52.17	54.95	-0.001
Condo (1=yes)	0.21	0.20	0.041
Pool (1 = yes)	0.04	0.04	-0.033
Air conditioning (1 = yes)	0.45	0.43	0.078
Fireplace number	0.35	0.40	-0.117
Condition (1 = above average)	0.25	0.28	-0.013
Greenfield (1 = yes)	0.39	0.42	-0.095
Rural (1 = yes)	0.40	0.32	0.239
Observations	19,866	95,148	

Table A2: Heterogeneity of treatment effects

Independent variables	Dependent variable: Sale price (ln)		
	(1)	(2)	(3)
Panel A: Heterogeneity by proximity			
(1 – 2 miles) × Post	-0.009*	-0.006	-0.005
	(0.005)	(0.006)	(0.005)
(0.5 – 1 mile) × Post	-0.019***	-0.027***	-0.019***
	(0.007)	(0.009)	(0.007)
(0.1 – 0.5 miles) × Post	-0.025***	-0.030***	-0.017*
	(0.008)	(0.011)	(0.009)
(0 – 0.1 miles) × Post	-0.037	-0.092**	-0.070*
	(0.028)	(0.036)	(0.038)
Panel B: Heterogeneity by prior land use			
Treated × Post	-0.013	-0.024**	-0.013*
	(0.008)	(0.010)	(0.008)
Treated × Post × Greenfield	-0.009	-0.005	-0.008
	(0.010)	(0.014)	(0.011)
Panel C: Heterogeneity by population density			
Treated × Post	-0.022***	-0.034***	-0.024***
	(0.008)	(0.010)	(0.008)
Treated × Post × Rural	0.024**	0.034**	0.025**
	(0.010)	(0.014)	(0.011)
Panel D: Heterogeneity by population density and land use			
Treated × Post	-0.013	-0.024*	-0.014
	(0.010)	(0.013)	(0.009)
Treated × Post × Greenfield	-0.029**	-0.030	-0.036**
	(0.014)	(0.019)	(0.014)
Treated × Post × Rural	0.008	0.011	0.002
	(0.014)	(0.019)	(0.017)
Treated × Post × Greenfield × Rural	0.041**	0.051**	0.056**
	(0.019)	(0.026)	(0.022)
Fixed Effects			
Month-year	Y	Y	Y
Block	Y		
Property		Y	Y
County-year			Y
Observations	419,258	231,503	231,503

Notes: Treated = 1 if a house is within 1 mile of a solar construction and Post =1 if a house sells post-construction.
In Panel A, (1 – 2 miles), (0.5 – 1 mile), (0.1 – 0.5 miles) and (0 – 0.1 mile) are dummy variables = 1 if properties lie within the respective distances from the nearest solar installation, and distance bin for 2 – 3 miles is omitted. Greenfield = 1 if the prior land use is farm or forest land, and Rural = 1 if the population density per square mile is
≤ 850. Panel B includes an interaction term Post*Greenfield and Panel C includes Post*Rural. Additional interactions included in Panel D are: Treated*Rural, Treated*Greenfield, Post*Rural, Post*Greenfield, Rural*Greenfield, Post*Greenfield*Rural, and Treated*Rural*Greenfield. All models include month-year, county-year, and property fixed effects. Standard errors are clustered at the tract level and shown in parentheses. *, **, and
*** indicate significance at 10%, 5%, and 1%, respectively.

Table A3: Heterogeneity of treatment effects by population density

Independent variables	Population density per square mile cutoff					
	500	850	1000	1200	1500	2000
Treated × Post	-0.020***	-0.024***	-0.024***	-0.023***	-0.018**	-0.006
	(0.006)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)
Treated × Post × Rural	0.022*	0.025**	0.023**	0.016	0.008	-0.013
	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Observations classified as rural						
Solar installations	40%	61%	69%	76%	82%	87%
Properties	16%	32%	39%	46%	53%	62%
Observations	231,503	231,503	231,503	231,503	231,503	231,503
R^2	0.894	0.894	0.894	0.894	0.894	0.894

Notes: Dependent variable is Sale price (ln) in all specifications. Treated = 1 if a house is within 1 mile of a solar construction, Post =1 if a house sells post-construction, and Rural = 1 if the population density per square mile is ≤column heading value. All models include month-year, county-year, and property fixed effects. Standard errors are
clustered at the tract level and shown in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Table A4: Heterogeneity of treatment effects by population density and land use

Independent variables	Population density per square mile cutoff					
	500	850	1000	1200	1500	2000
Treated × Post	-0.014*	-0.014	-0.016	-0.014	-0.006	0.005
	(0.008)	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)
Treated × Post × Greenfield	-0.018	-0.036**	-0.028*	-0.031**	-0.041***	0.005
	(0.012)	(0.014)	(0.015)	(0.015)	(0.016)	(0.010)
Treated × Post × Rural	0.000	0.002	0.008	0.002	-0.013	-0.055***
	(0.018)	(0.017)	(0.016)	(0.016)	(0.015)	(0.018)
Treated × Post × Greenfield × Rural	0.038*	0.056**	0.039*	0.040*	0.057***	-0.029**
	(0.023)	(0.022)	(0.021)	(0.021)	(0.021)	(0.014)
Observations classified asrural						
Solar installations	40%	61%	69%	76%	82%	87%
Properties	16%	32%	39%	46%	53%	62%
Observations	231,503	231,503	231,503	231,503	231,503	231,503
R^2	0.894	0.894	0.894	0.894	0.894	0.894

Notes: Dependent variable is Sale price (ln) in all specifications. Treated = 1 if a house is within 1 mile of a solar construction, Post =1 if a house sells post-construction, and Rural = 1 if the population density per square mile is ≤column heading value. All models include month-year, county-year, and property fixed effects. Standard errors are clustered at the tract level and shown in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Table A5: Heterogeneity of treatment effects by solar installation size

Independent variables	Dependent variable: Sale price (ln)		
	(1)	(2)	(3)
Treated × Post	-0.012*	-0.024***	-0.019***
	(0.007)	(0.009)	(0.007)
Treated × Post × LargeCapacity	-0.011	-0.005	0.004
	(0.011)	(0.015)	(0.012)
Fixed Effects			
Month-year	Y	Y	Y
Block	Y		
Property		Y	Y
County-year			Y
Observations	419,258	231,503	231,503
R^2	0.801	0.889	0.893

Notes: Treated = 1 if a house is within 1 mile of a solar construction and Post =1 if a house sells post- construction and LargeCapacity = 1 if the capacity of the installation is greater than 2 MW. Column 1 includesthe following housing controls: lot size, house area, number of bedrooms, full bathrooms, half bathrooms, and fireplaces, a set of dummy variables for the age of the house at purchase, indicator variables for condos, the condition of the house, and for the presence of a pool and air conditioning. Standard errors are clustered at the tract level and shown in parentheses. *, **, and *** indicate significance at 10%, 5%, and 1%, respectively.

Table A6: Heterogeneity of treatment effects by years since construction of installation

Independent variables	Dependent variable: Sale price (ln)		
	(1)	(2)	(3)
Treated × Post (Less than 3 years)	-0.016**	-0.026***	-0.016**
	(0.006)	(0.009)	(0.007)
Treated × Post (3 or more years)	-0.016**	-0.024***	-0.016**
	(0.006)	(0.008)	(0.007)
Fixed Effects			
Month-year	Y	Y	Y
Block	Y		
Property		Y	Y
County-year			Y
Observations	419,258	419,258	231,503
R^2	0.491	0.801	0.889

Notes: Post (Less than 3 years) = 1 if a house sells within 3 years post-construction, and Post (3 or more years) = 1 if a house sells 3 or more years post-construction. Columns 1 includes the following controls: lot size, house area, number of bedrooms, full bathrooms, half bathrooms, and fireplaces, a set of dummyvariables for the age of the house at purchase, indicator variables for condos, the condition of the house, and for the presence of a pool and air conditioning, capacity of installation (in MW) and greenfield.
Standard errors, clustered at the tract level, are in parentheses. *, **, and *** indicate significance at10%, 5%, and 1%, respectively.