



MASSWILDLIFE

Climate Change Refugia: Coldwater fisheries and associated forests

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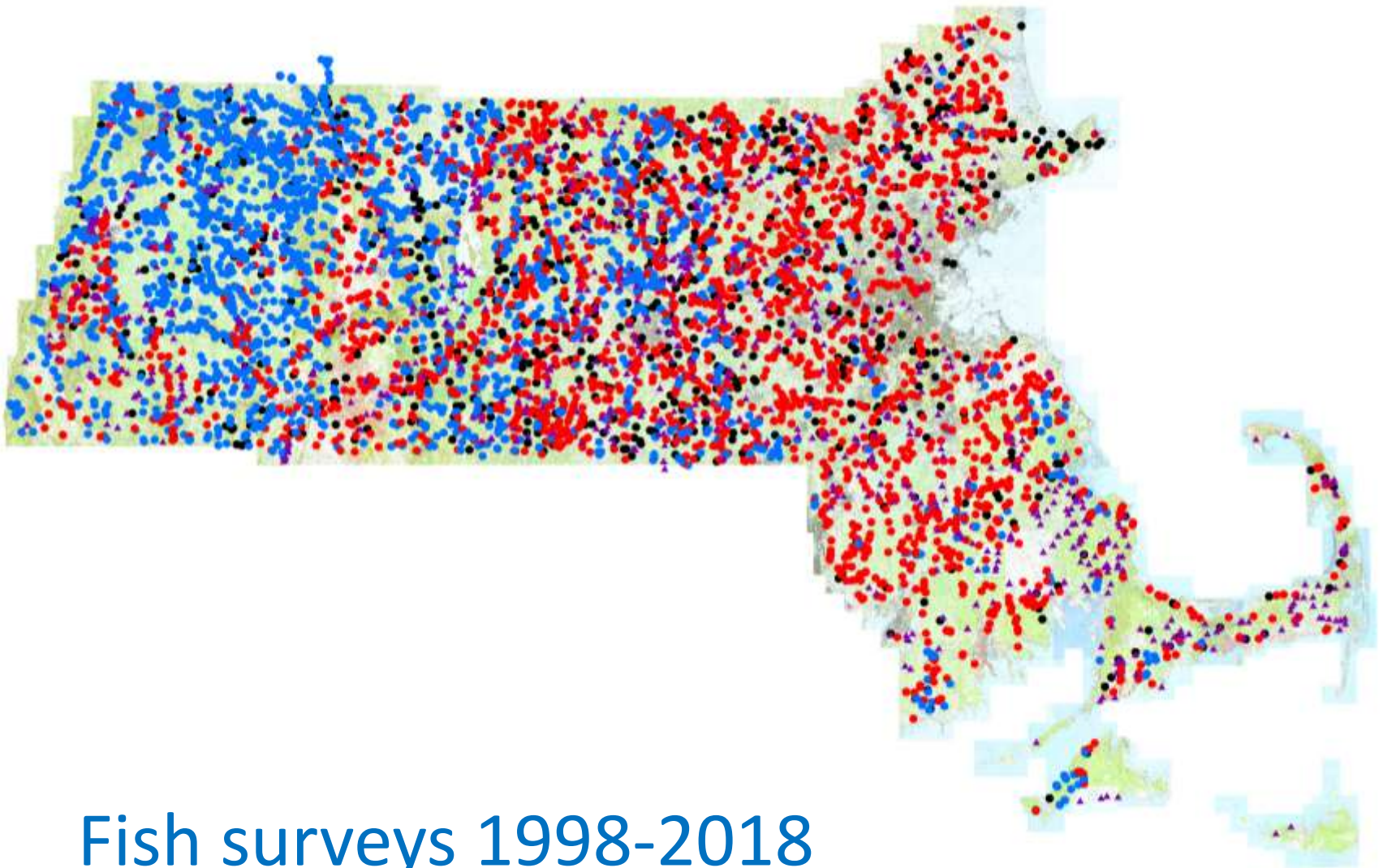
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MassWildlife

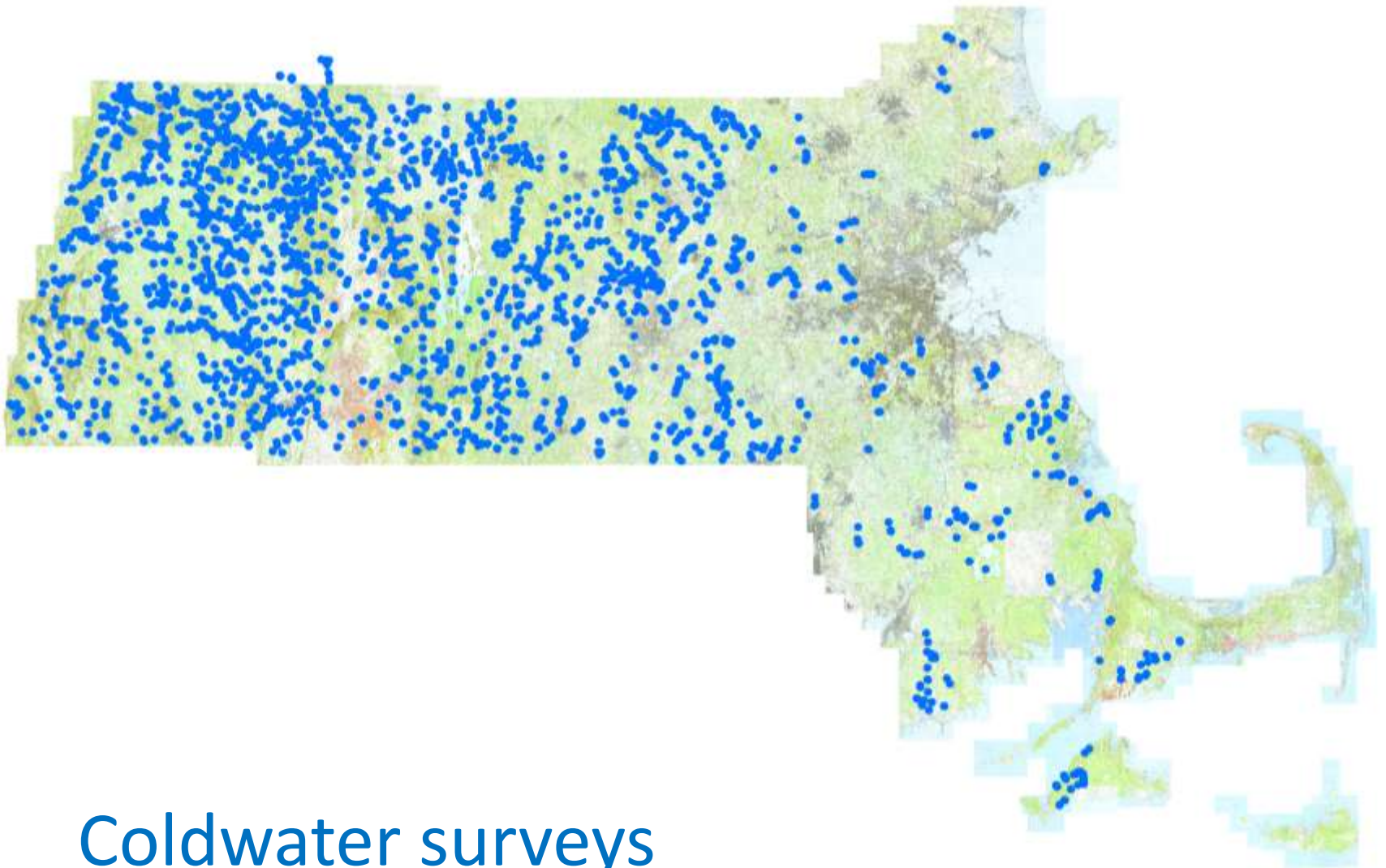
- Mission:

The conservation—including restoration, protection, and management—of freshwater fish and wildlife resources for the benefit and enjoyment of the public

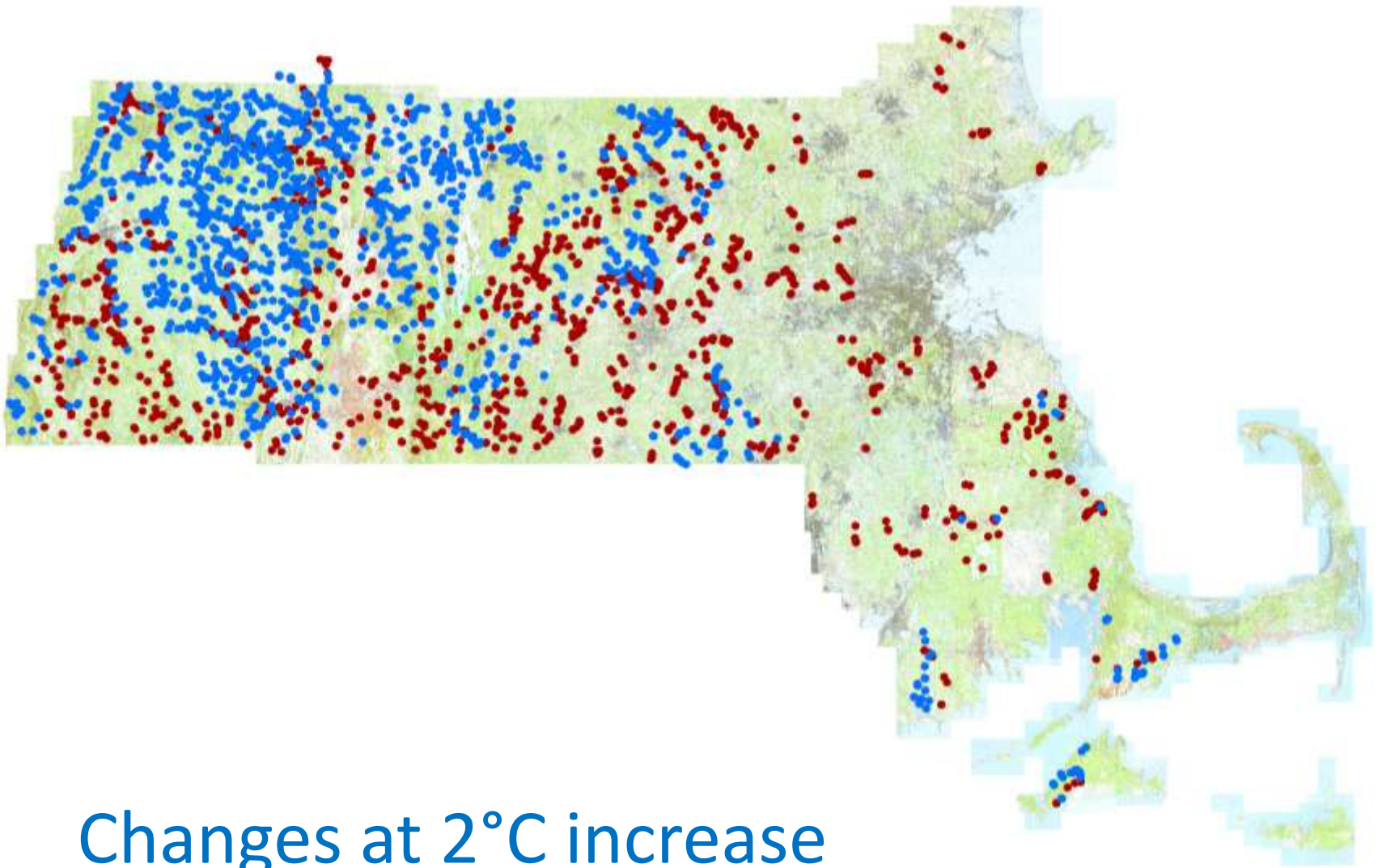




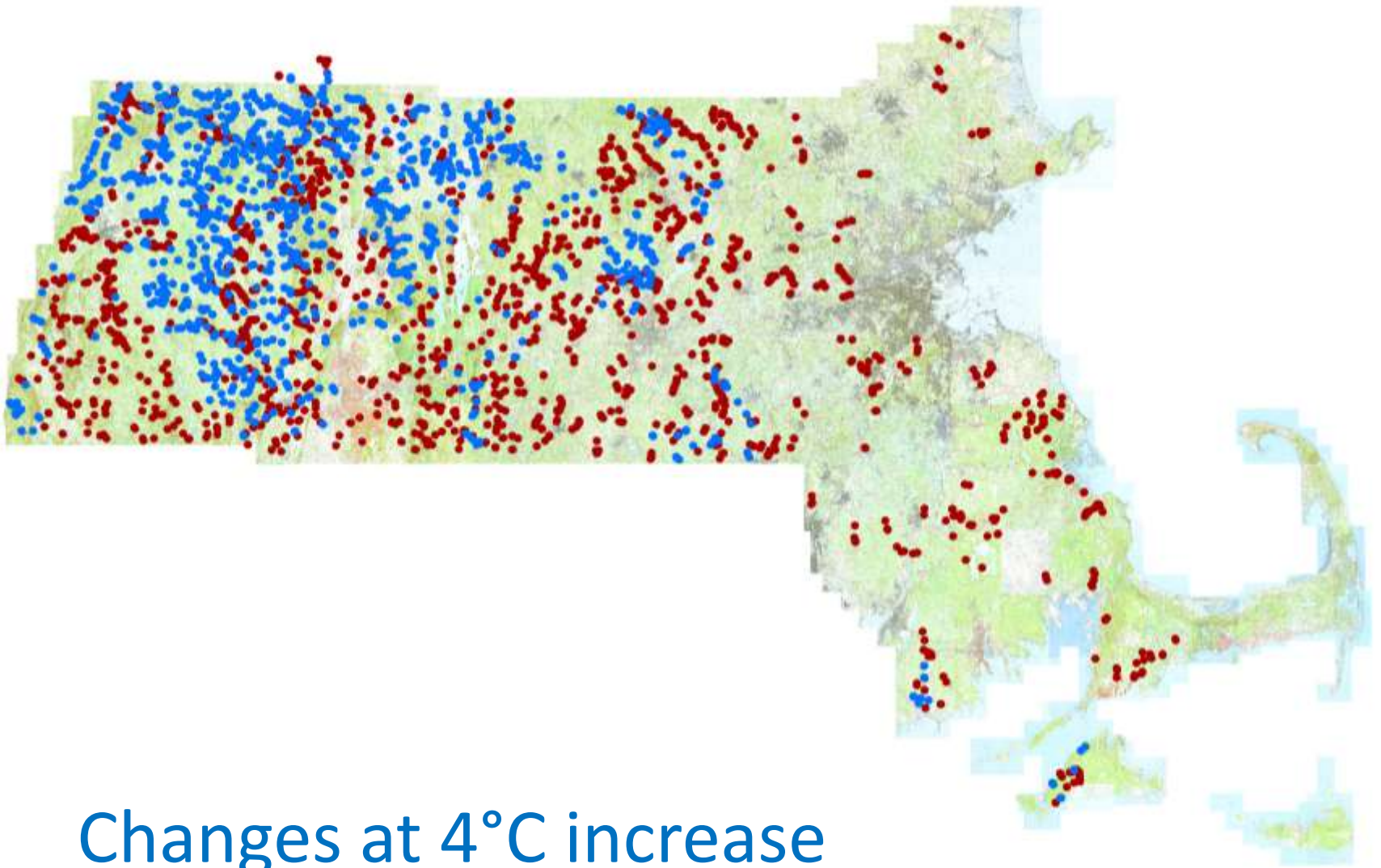
Fish surveys 1998-2018



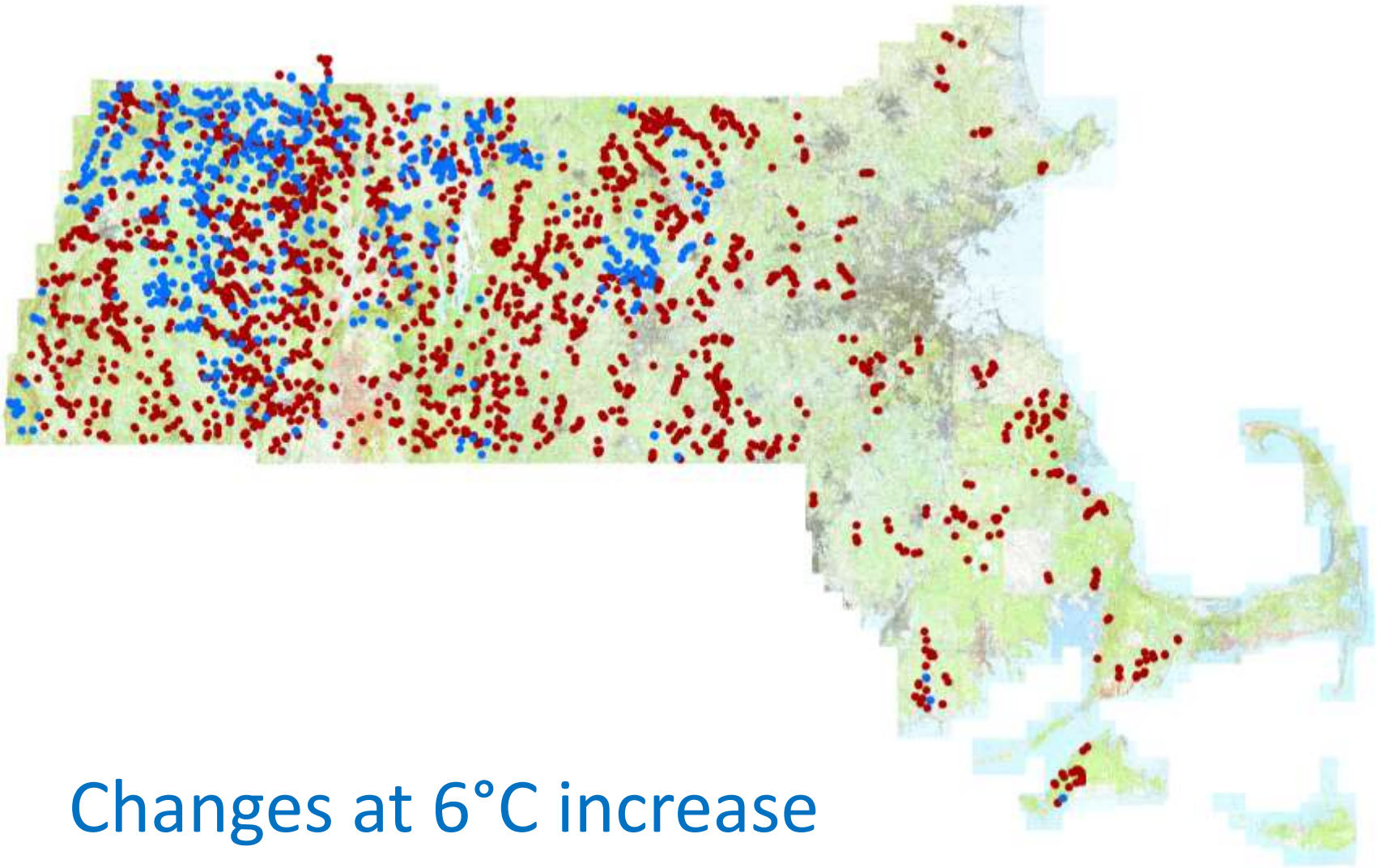
Coldwater surveys



Changes at 2°C increase



Changes at 4°C increase



Changes at 6°C increase

Topographically complex terrain creates varied microclimates and increases the likelihood that current climates will continue to exist nearby.

Deep snow drifts provide insulation to the surface below and provide water later in the season.

Valleys that harbor cold air pools and inversions can decouple local climatic conditions from regional circulation patterns.

Canopy cover can buffer local temperature maximums and minimums throughout the year.

Poleward-facing slopes and aspects result in shaded areas that buffer solar heating, particularly during the low solar angles of winter and early spring.

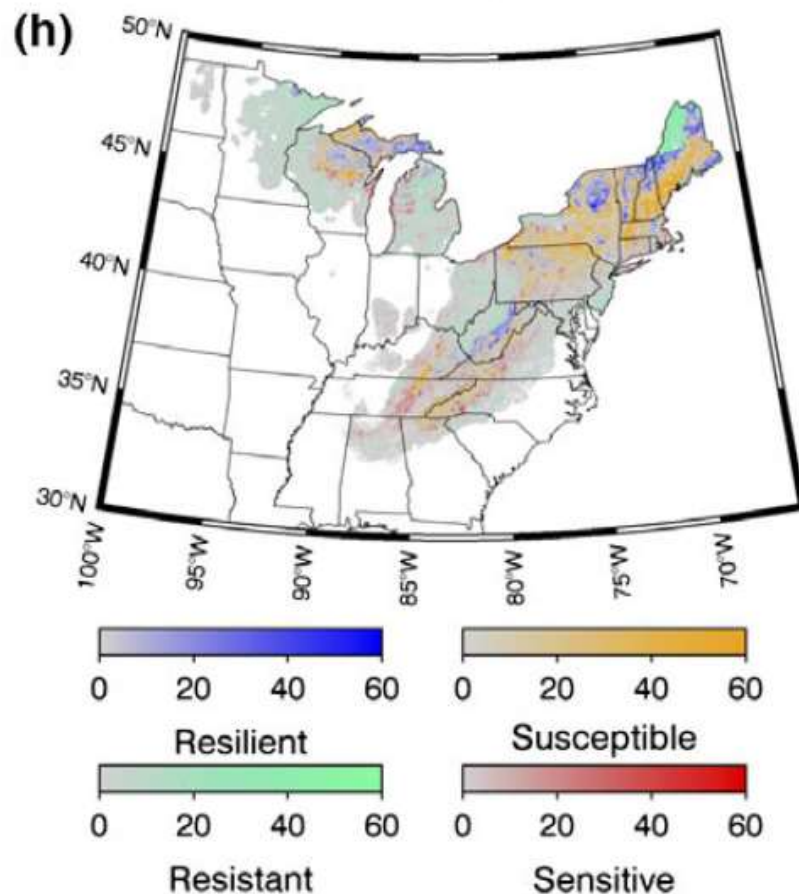
Cold groundwater inputs produce local cold-water refuges in which stream temperature is decoupled from air temperature.

Areas near or in large deep lakes or oceans will warm more slowly due to the high heat capacity of water.

Climate change vulnerability



Rogers et al. 2016. Vulnerability of eastern US tree species to climate change.



Projected vulnerability categories for eastern hemlock under RCP 8.5 2055 scenario. From Rogers, Fig. 2

Species and forest type vulnerability

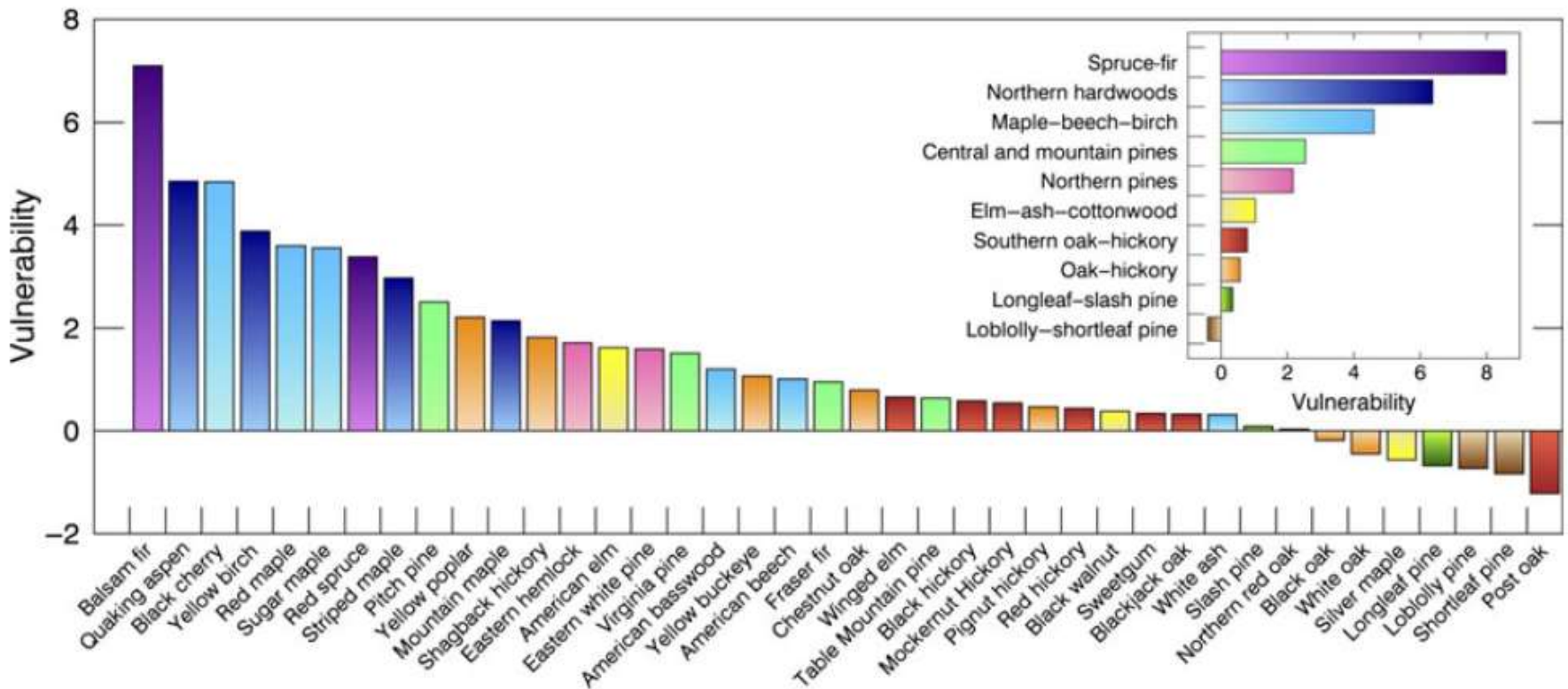
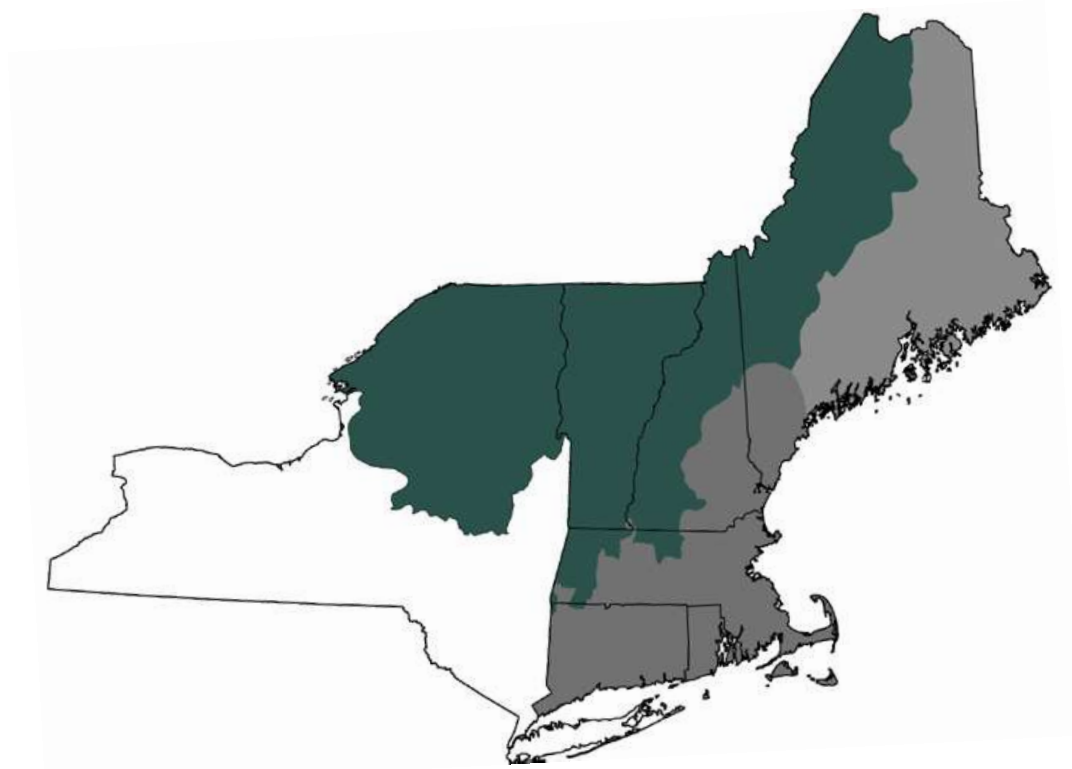


Fig. 3 “Species and forest type vulnerability rankings” from Rogers et al. (2016)

Climate change projections for individual tree species



Janowiak et al. 2018. New England and northern New York forest ecosystem vulnerability assessment and synthesis



CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

NEW ENGLAND AND NORTHERN NEW YORK

The region's forests will be affected by a changing climate during this century. A team of forest managers and researchers created an assessment that describes the vulnerability of forests in New England and northern New York (Janowiak et al. in press). This report includes information on the current landscape, observed climate trends, and a range of projected future climates. It also describes many potential climate change impacts to forests and summarizes key vulnerabilities for major forest types. This handout is summarized from the full assessment.



Remember that models are just tools, and they're not perfect. Model projections don't account for some factors that could be modified by climate change, like droughts, wildfire activity, and invasive species. If a species is rare or confined to a small area, Tree Atlas results may be less reliable. These factors, and others, could cause a particular species to perform better or worse than a model projects. Human choices will also continue to influence forest distribution, especially for tree species that are projected to increase. Planting programs may assist the movement of future-adapted species, but this will depend on management decisions.

TREE SPECIES INFORMATION:

This assessment uses two climate scenarios to "bracket" a range of possible futures. These future climate projections were used with two forest impact models (Tree Atlas and LANDIS) to provide information about how individual tree species may respond to a changing climate. More information on the climate and forest impact models can be found in the assessment. Results for "low" and "high" climate scenarios can be compared on page 2 of this handout.

Despite these limits, models provide useful information about future expectations. It's perhaps best to think of these projections as indicators of possibility and potential change. The model results presented here were combined with information from published reports and local management expertise to draw conclusions about potential risk and change in the region's forests.

SPECIES	ADDITIONAL CONSIDERATIONS
LIKELY TO DECREASE	
Black ash	Emerald ash borer causes mortality
Black spruce	Requires cold climate, susceptible to insect pests and drought
Eastern hemlock	Hemlock woolly adelgid causes mortality
Mountain maple	Able to grow across a variety of sites and tolerate shade
Northern white-cedar	Requires cold climate and susceptible to fire and herbivory
Paper birch	Early-successional colonizer, but susceptible to insects and drought
Red spruce	Needs a particular type of habitat, limited seedling establishment
Tamarack	Requires cold climate and susceptible to drought, fire, and insects
White spruce	Requires cold climate, susceptible to insect pests
MAY DECREASE	
Bigtooth aspen	Early-successional colonizer, but susceptible to drought
Gray birch	Disperses easily, but susceptible to drought, fire, and insects
Pin cherry	Fast-establishing colonizer following fire and disturbance
Quaking aspen	Early-successional colonizer, but susceptible to heat and drought
Striped maple	Shade tolerant and easily established, but susceptible to drought
Yellow birch	Good disperser, but susceptible to fire, insects, and disease

SPECIES	ADDITIONAL CONSIDERATIONS
MIXED MODEL RESULTS	
American beech	Affected by beech bark disease, extremely shade tolerant
Balsam fir	Requires cold climate and susceptible to drought, fire, and insects
Eastern white pine	Good disperser, but susceptible to drought and insects
Red maple	Competitive colonizer tolerant of disturbance and diverse sites
Sugar maple	Grows across a variety of sites and tolerates shade
Yellow birch	Good disperser, but susceptible to fire, insects, and disease
MAY INCREASE	
American basswood	Tolerates shade but susceptible to fire
American elm	Affected by Dutch elm disease, grows across a variety of sites
Black cherry	Susceptible to insects and fire, tolerates some drought
Black oak	Drought-tolerant, but susceptible to insects and disease
Eastern hophornbeam	Grows across a variety of sites and tolerates shade
Northern red oak	Susceptible to some insect pests
Sweet birch	Susceptible to drought, fire topkill, and insects
White ash	Emerald ash borer causes mortality
White oak	Fire-adapted and grows on a variety of sites

SOURCE: Janowiak et al. in review. *New England and New York forest ecosystem vulnerability assessment and synthesis: a report from the New England Climate Change Response Framework*. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. www.forestadaptation.org/new-england/vulnerability-assessment



www.forestadaptation.org



FUTURE PROJECTIONS

Data for the end of the century are summarized for two forest impact models under two climate change scenarios. The Climate Change Tree Atlas (www.fs.fed.us/nrs/atlas) models future suitable habitat, while LANDIS models changes in forest growth over time (future tree density presented in this table; additional data are available in the assessment).

▲ INCREASE
Projected increase of >20% by 2100

● NO CHANGE
Little change (<20%) projected by 2100

▼ DECREASE
Projected decrease of >20% by 2100

★ NEW HABITAT
Tree Atlas projects new habitat for species not currently present

ADAPTABILITY

Factors not included in the models, such as the ability to respond favorably to disturbance, may make a species more or less able to adapt to future stressors.

+ high
Species may perform better than modeled
medium
low
Species may perform worse than modeled

SPECIES	LOW CLIMATE CHANGE (PCM B1)		HIGH CLIMATE CHANGE (GFDL A1FI)		ADAPT	SPECIES	LOW CLIMATE CHANGE (PCM B1)		HIGH CLIMATE CHANGE (GFDL A1FI)		ADAPT
	TREE ATLAS	LANDIS	TREE ATLAS	LANDIS			TREE ATLAS	LANDIS	TREE ATLAS	LANDIS	
American basswood	●		▲		·	Northern red oak	▲	●	▲	●	+
American beech	●	●	▼	▲	·	Northern white-cedar	▼	▼	▼	▼	·
American chestnut	●		●		·	Osage-orange			★		+
American elm	▲		▲		·	Paper birch	▼		▼		·
American holly	●		▲		·	Pignut hickory	▲	●	▲	▼	·
American hornbeam	●		▲		·	Pin cherry	●		▼		·
American mountain-ash	●		▼		-	Pin oak	▲		▲		-
Baldcypress	★		★		·	Pitch pine	●	●	▲	●	·
Balsam fir	▼	▲	▼	▲	-	Pond pine	★		★		-
Balsam poplar	▼		▼		·	Post oak	▲		▲		+
Bigtooth aspen	●		▼		·	Quaking aspen	●	●	▼	●	·
Black ash	▼		▼		-	Red maple	●	●	▼	▲	+
Black cherry	●	●	▲	▲	-	Red pine	●		▲		·
Black hickory			★		·	Red spruce	▼	▼	▼	▼	-
Black oak	▲	●	▲	●	·	Sand pine	★		★		-
Black spruce	▼	▼	▼	▼	·	Sassafras	▲		▲		·
Black walnut	▲		▲		·	Scarlet oak	▲	●	▲	▼	·
Blackgum	●		▲		+	Serviceberry	●		▲		·
Blackjack oak			★		+	Shagbark hickory	▲	●	▲	●	·
Boxelder	●		▲		+	Shingle oak			★		·
Bur oak	●		▲		+	Shortleaf pine	★		★		·
Cherrybark oak	★		★		·	Silver maple	▲		▲		+
Chestnut oak	▲	▲	▲	●	+	Slippery elm	▲		▲		·
Chinkapin oak			★		·	Southern red oak	★		★		+
Common persimmon	★		★		+	Striped maple	●		▼		·
Eastern hemlock	●	●	▼	▼	-	Sugar maple	●	●	▼	▲	+
Eastern hophornbeam	●		▲		+	Sugarberry			★		·
Eastern red cedar	▲		▲		·	Swamp chestnut oak	●		▲		·
Eastern redbud	▲		▲		·	Sweet birch	▲		▲		-
Eastern white pine	●	▼	▼	▲	·	Sweetgum	★		★		·
Flowering dogwood	▲		▲		·	Sycamore	●		▲		·
Gray birch	●		▼		·	Tamarack	▼		▼		-
Green ash	●		▲		·	Virginia pine	★	★	★	★	·
Hackberry	●		▲		+	White ash	▲	●	●	▲	-
Jack pine	▼		▲		·	White oak	▲	●	▲	●	+
Loblolly pine	★	●	★	●	·	White spruce	▼		▼		·
Longleaf pine	★				·	Willow oak			★		·
Mockernut hickory	▲		▲		+	Winged elm	●		▲		·
Mountain maple	▼		▼		+	Yellow birch	●	▼	▼	▲	·
Northern pin oak	●		▲		+	Yellow-poplar	▲	▲	▲	▲	+

Data from Janowiak et al. Table from www.forestadaptation.org



THE NORTHERN FOREST	LOW CLIMATE CHANGE(PCM B1)		HIGH CLIMATE CHANGE (GFDL A1FI)		ADAPT
	TREE ATLAS	LANDIS	TREE ATLAS	LANDIS	
Northern white-cedar	▼	▼	▼	▼	·
Red spruce	▼	▼	▼	▼	—
Black spruce	▼	●	▼	▼	·
White spruce	▼		▼		·
Paper birch	▼		▼		·
Eastern white pine	▼	▼	●	●	·
Eastern hemlock	●	●	●	▼	—
Tamarack	▼		●		—
Quaking aspen	●	●	▼	▲	·
Balsam fir	▼	▲	▼	▲	—

Data from Janowiak et al. Table excerpted from forestadaptation.org

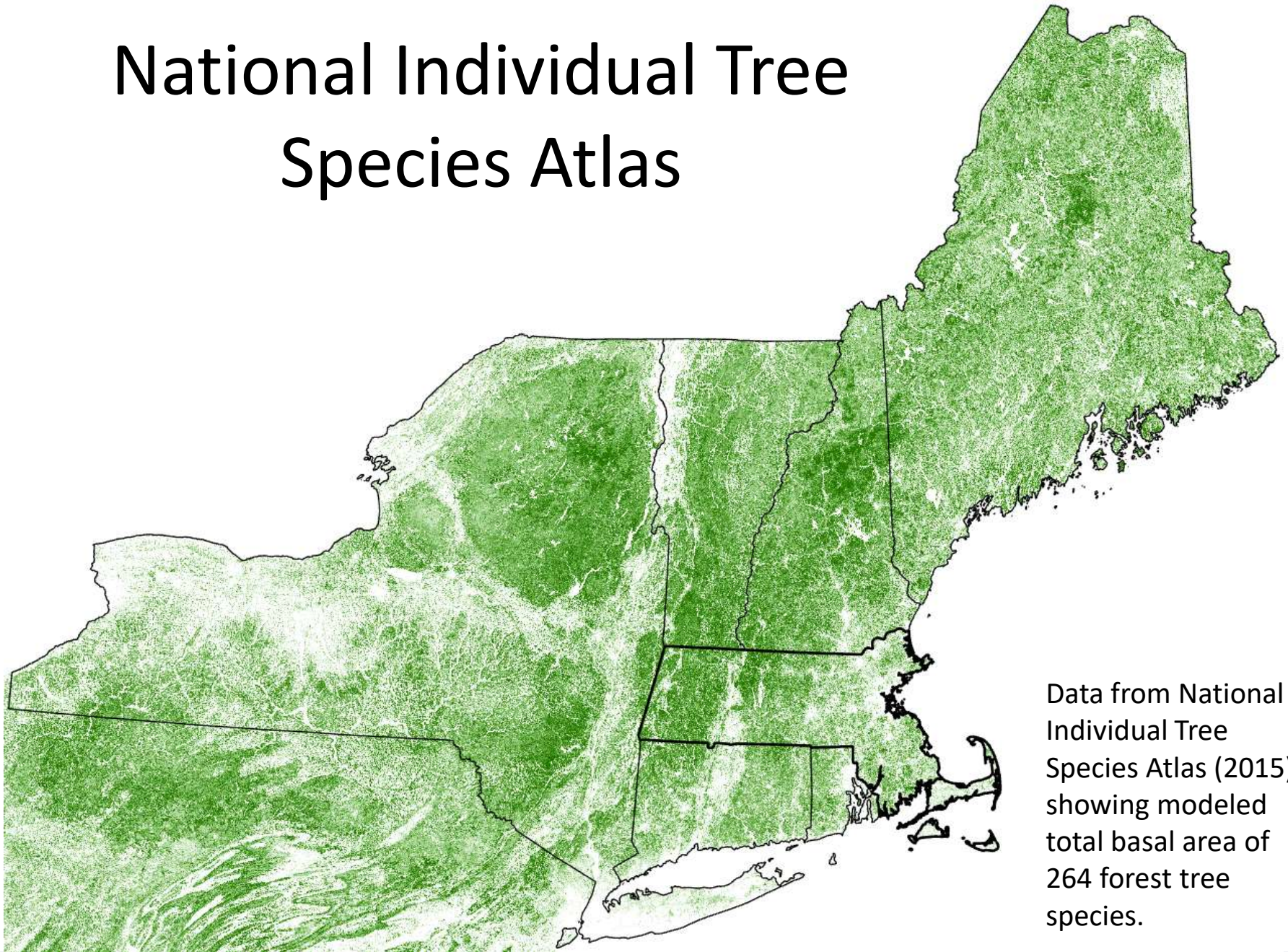


SOUTHERN AND COASTAL NEW ENGLAND	LOW CLIMATE CHANGE(PCM B1)		HIGH CLIMATE CHANGE (GFDL A1FI)		ADAPT
	TREE ATLAS	LANDIS	TREE ATLAS	LANDIS	
Northern white-cedar	▼	▼	▼	▼	·
Red spruce	▼	▼	▼	▼	—
Black spruce	▼	▼	▼	▼	·
White spruce	▼		▼		·
Paper birch	▼		▼		·
Eastern white pine	▼	▼	▼	▼	·
Eastern hemlock	●	●	▼	▼	—
Tamarack	▼		▼		—
Quaking aspen	▼	▼	▼	▼	·
Balsam fir	▼	▼	▼	▼	—

Data from Janowiak et al. Table excerpted from forestadaptation.org

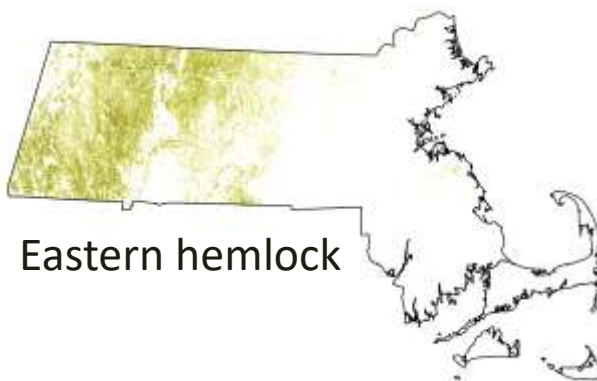
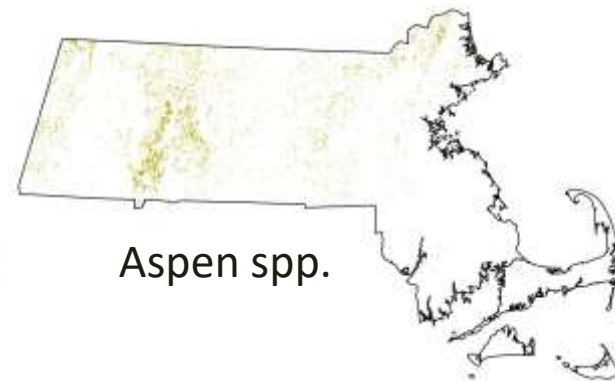
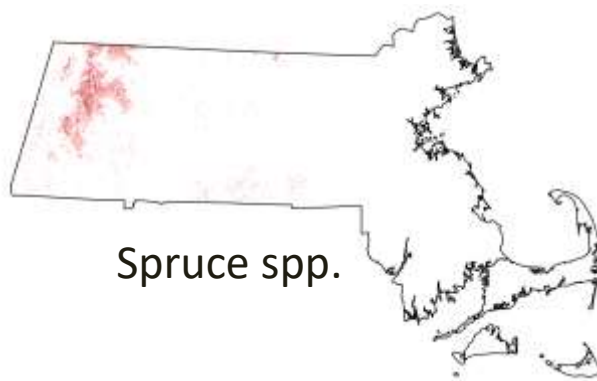
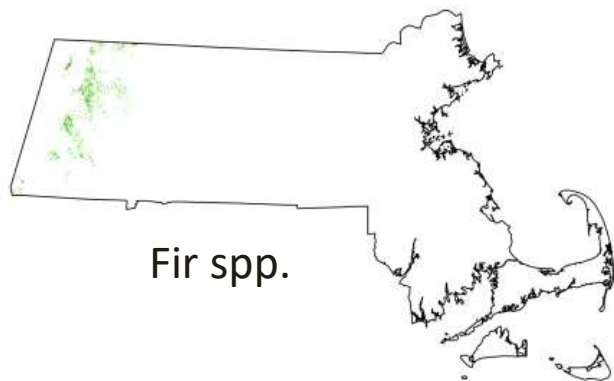


National Individual Tree Species Atlas



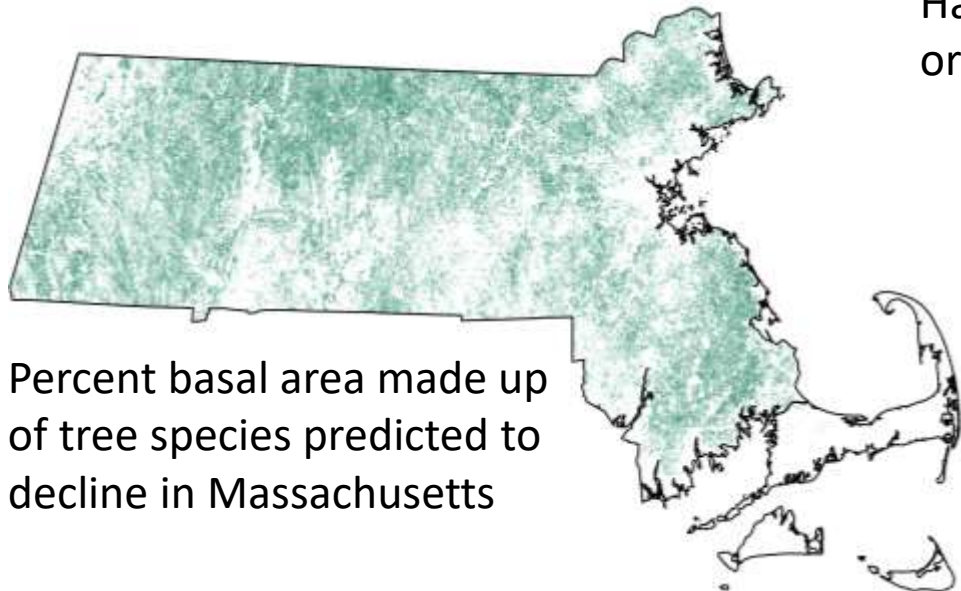
Data from National Individual Tree Species Atlas (2015), showing modeled total basal area of 264 forest tree species.

Individual percent of basal area for tree species predicted to decline

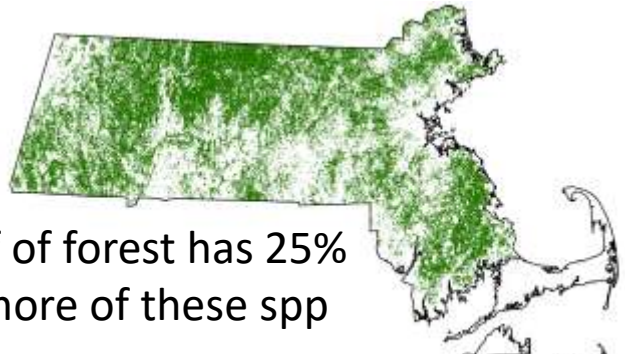


Data derived from National Individual Tree Species Atlas (2015)

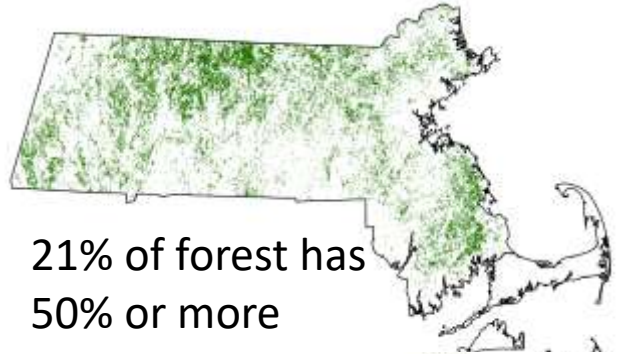
%BA of species predicted to decline



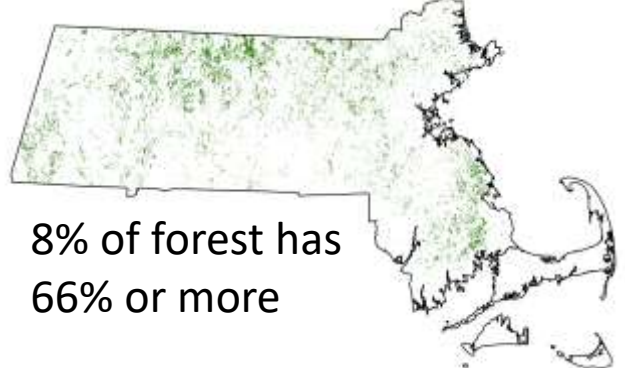
Percent basal area made up of tree species predicted to decline in Massachusetts



Half of forest has 25% or more of these spp



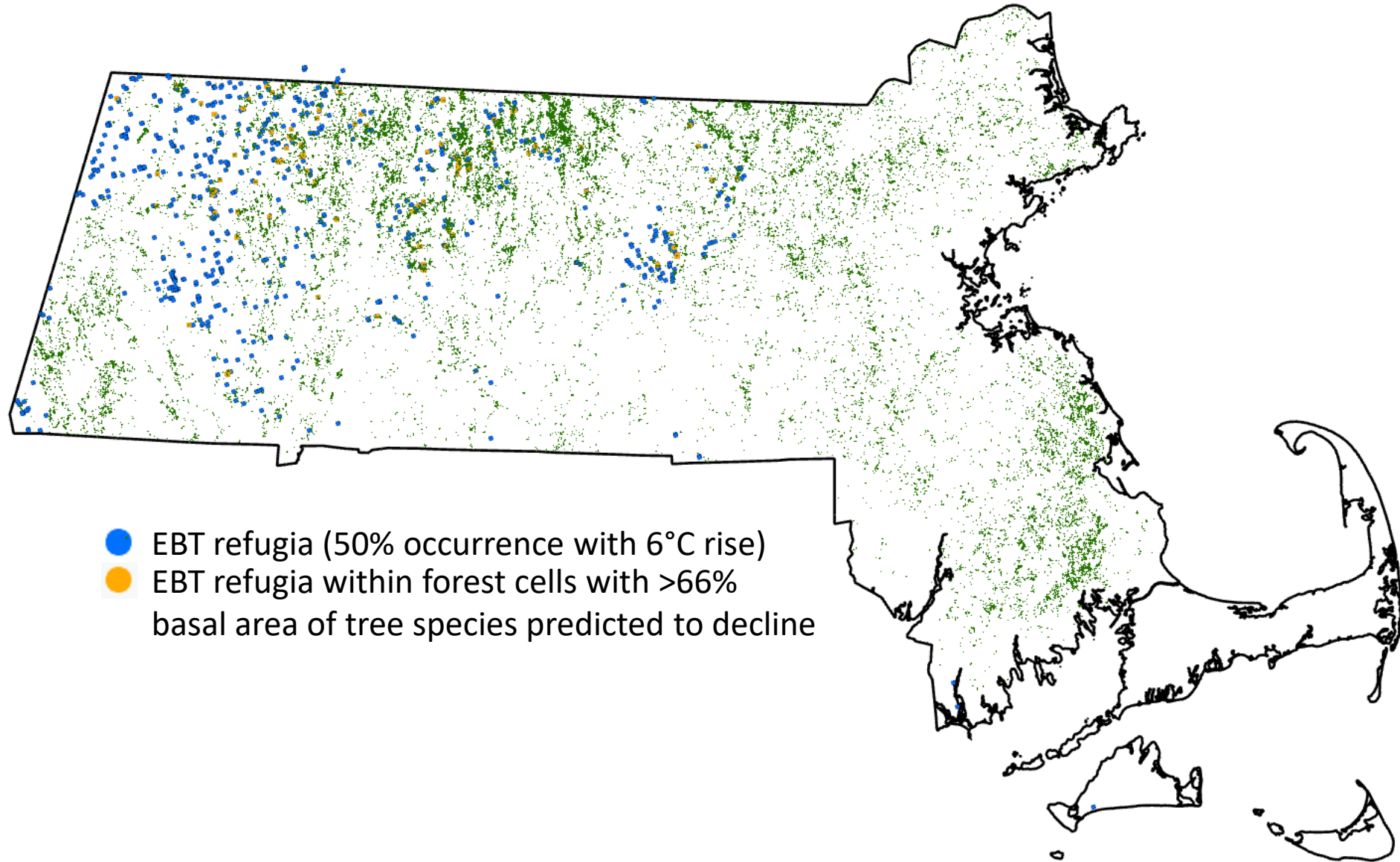
21% of forest has 50% or more



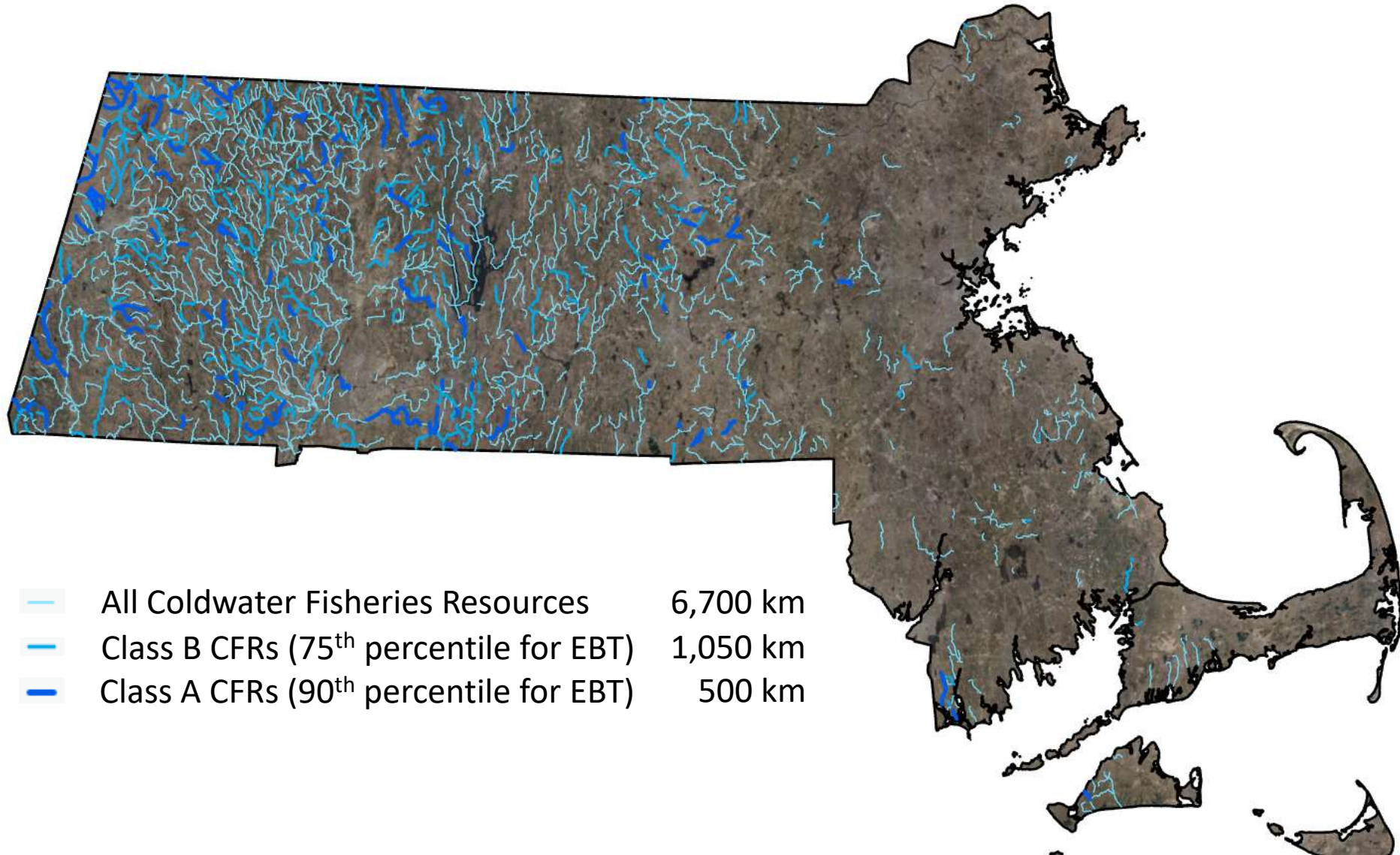
8% of forest has 66% or more




Data derived from National Individual Tree Species Atlas (2015)

Are EBT refugia within forests with vulnerable species?

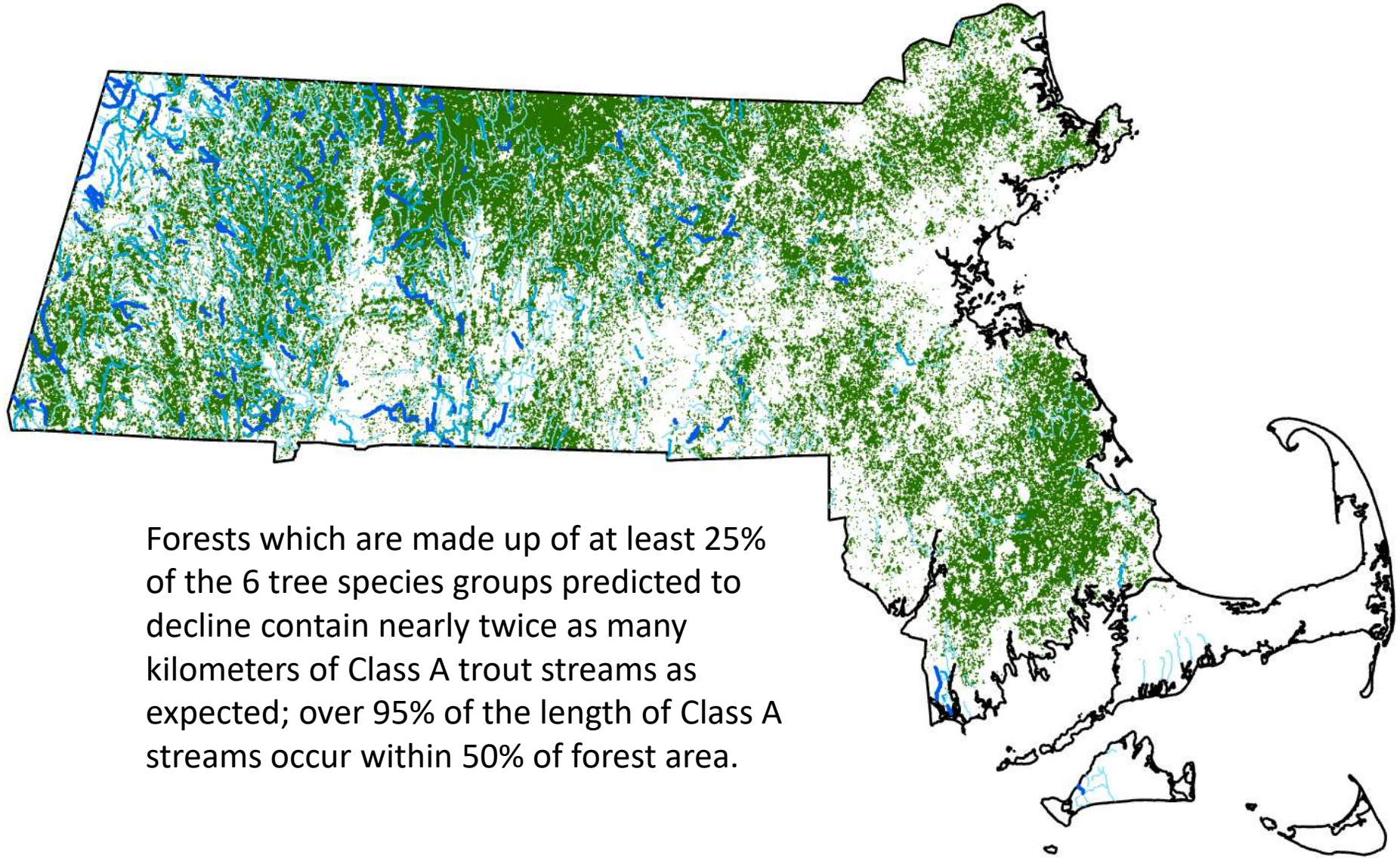


Coldwater fisheries classification



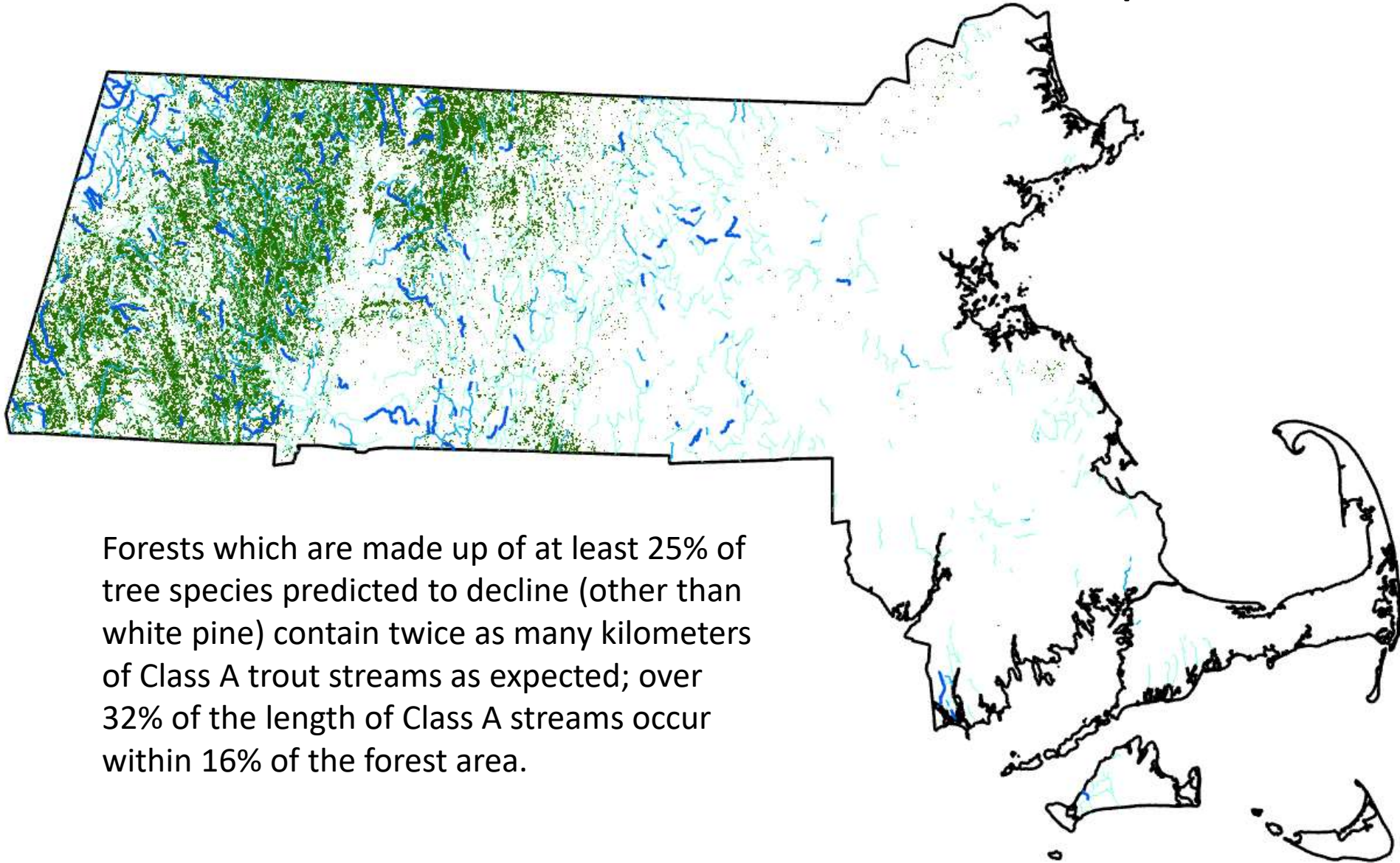
	All Coldwater Fisheries Resources	6,700 km
	Class B CFRs (75 th percentile for EBT)	1,050 km
	Class A CFRs (90 th percentile for EBT)	500 km

Are CFRs within forests with vulnerable species?



Forests which are made up of at least 25% of the 6 tree species groups predicted to decline contain nearly twice as many kilometers of Class A trout streams as expected; over 95% of the length of Class A streams occur within 50% of forest area.

Are CFRs within forests with vulnerable species?



Forests which are made up of at least 25% of tree species predicted to decline (other than white pine) contain twice as many kilometers of Class A trout streams as expected; over 32% of the length of Class A streams occur within 16% of the forest area.

Management implications

COLLECTION PAPER

Managing Climate Change Refugia for Climate Adaptation

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Abstract

Refugia have long been studied from paleontological and biogeographical perspectives to understand their persistence, persistence during past periods of unfavorable climate. Recently, researchers have applied the idea to contemporary landscapes to identify climate change refugia, here defined as areas relatively buffered from contemporary climate change over time that enable persistence of valued physical, ecological, and socio-cultural resources. We synthesize historical and contemporary views, and characterize physical and ecological processes that create and maintain climate change refugia. We then describe how refugia can be used to inform planning, decision support frameworks for climate adaptation and proactive conservation steps for managing them. Finally, we identify challenges and opportunities for operationalizing this concept of climate change refugia. Managing climate change refugia can be an important option for conservation in the face of ongoing climate change.

Introduction

Contemporary climate change is occurring in a world perhaps abated by human activities multiplying challenges for conservation and resource management [1]. To meet these challenges, scientists and natural resource managers are working together to develop guidelines for climate adaptation [2, 3]. A focus on areas resistant to ongoing climate change is increasingly

New England and Northern New York Forest Ecosystem Vulnerability Assessment and Synthesis: A Report from the New England Climate Change Response Framework Project



Forest management for mitigation and adaptation to climate change: Insights from long-term silviculture experiments

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ABSTRACT

Forestry management strategies for addressing global climate change for forests are increasingly important given increasing forest management values, global warming, management approaches for being prepared for future climate change by addressing climate-related issues, and the need to adapt to climate change by reducing emissions, and reducing climate risks. However, there is debate about the responsibility of forest managers in the long-term ability of people, through their actions or inaction, to contribute to climate change. In addition, the need to manage forests for carbon sequestration and storage, and the need to manage forests for other values, such as recreation, aesthetics, and biodiversity, are also important. This paper reviews the current state of knowledge about the role of forests in climate change, and the need to manage forests for carbon sequestration and storage, and the need to manage forests for other values, such as recreation, aesthetics, and biodiversity. The paper also discusses the need to manage forests for carbon sequestration and storage, and the need to manage forests for other values, such as recreation, aesthetics, and biodiversity. The paper also discusses the need to manage forests for carbon sequestration and storage, and the need to manage forests for other values, such as recreation, aesthetics, and biodiversity.

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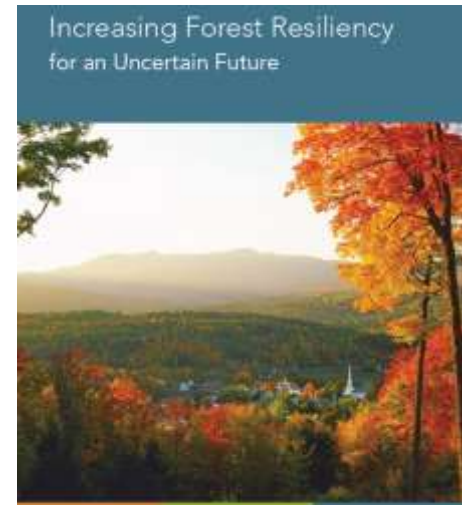
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Other resources

Climate Change Atlas (<https://www.fs.fed.us/nrs/atlas/>)
Includes links to individual tree species life history and disturbance response, silvics manual, and current and modeled distributions.



FEIS (<https://www.feis-crs.org/feis/>)
Fire Effects Information System synthesizes information not just on fire ecology and fire effects, but also on general species information, including associated plant communities, management and silvicultural considerations, and botanical and ecological characteristics.

USDA Fire Effects Information System (FEIS)
Synthesizes about fire ecology and fire regimes in the United States

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fire ecology and fire regimes
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Detailed description of species information in FEIS

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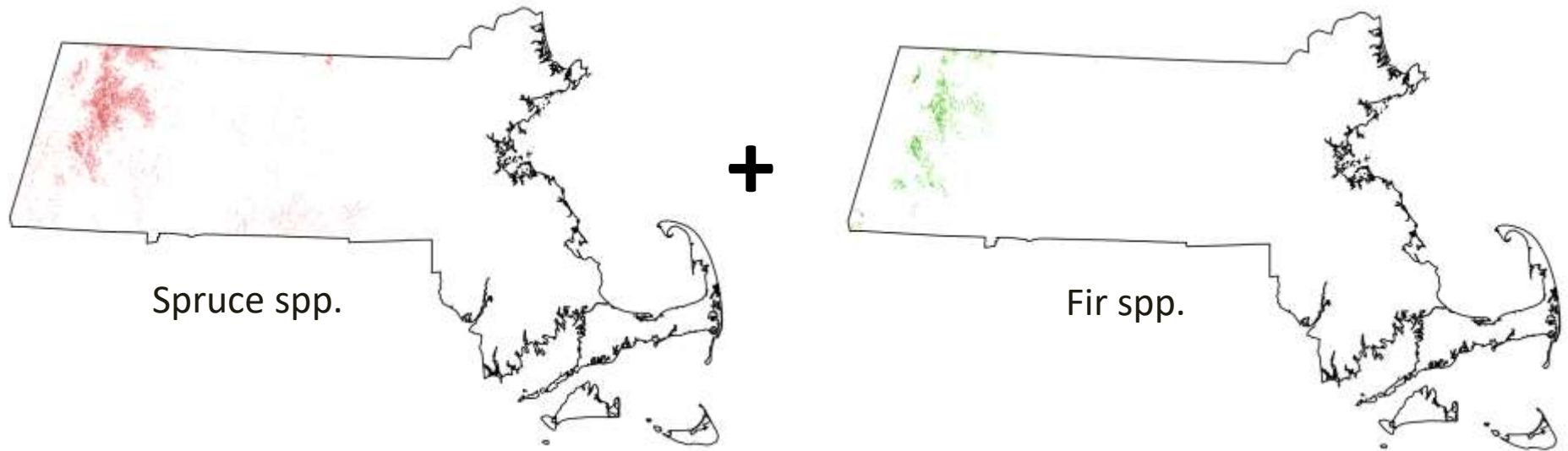
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Future work



Data derived from National Individual Tree Species Atlas (2015)

A photograph of a rocky, moss-covered landscape. The foreground and middle ground are dominated by light-colored, flat rocks of various sizes, many of which are covered in bright green moss. Several small, young evergreen trees are scattered across the rocky terrain. In the background, a dense forest of taller evergreen trees is visible, with some bare, thin branches in the foreground. The overall scene suggests a high-altitude or mountainous environment.

Questions?