MASSACHUSETTS DIVISION OF FISHERIES & WILDLIFE EST.1866

MASSWILDLIFE

Climate Change Refugia: Coldwater fisheries and associated forests

Rebecca Quiñones, Stream Biologist Project Leader

Brian Hawthorne, Habitat Planning Coordinator

MassWildlife

- Mission:

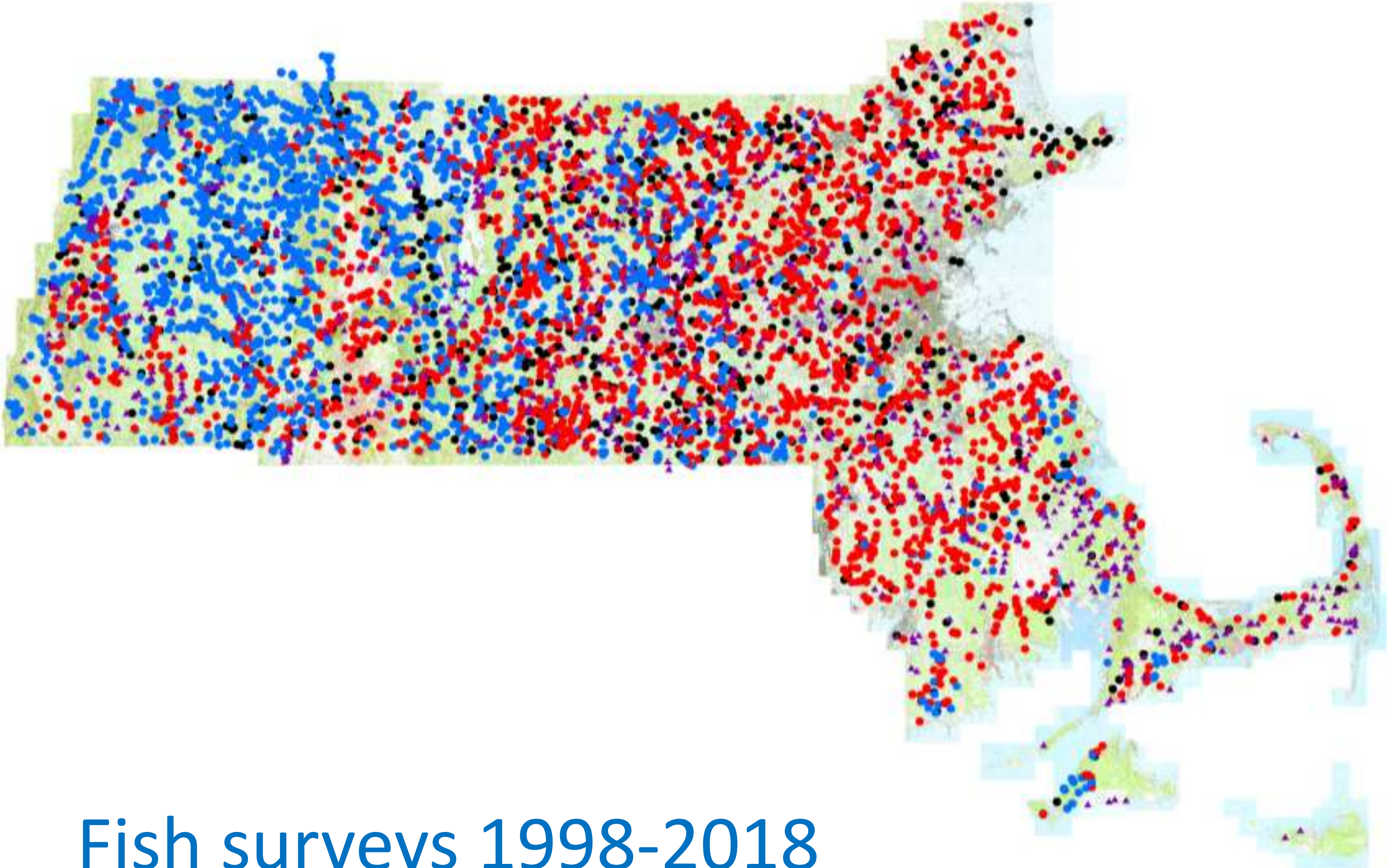
The conservation—including restoration, protection, and management—of freshwater fish and wildlife resources for the benefit and enjoyment of the public



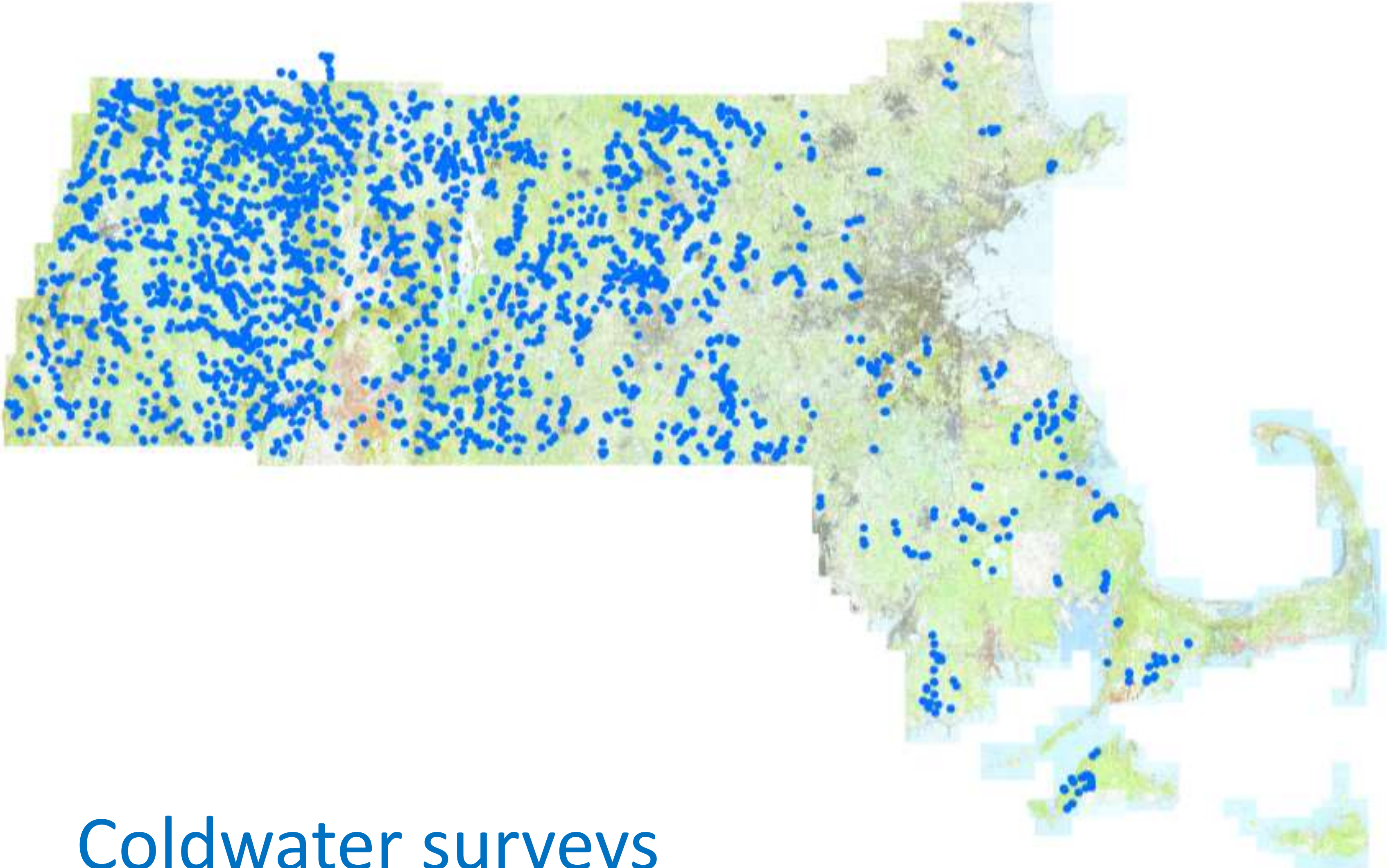




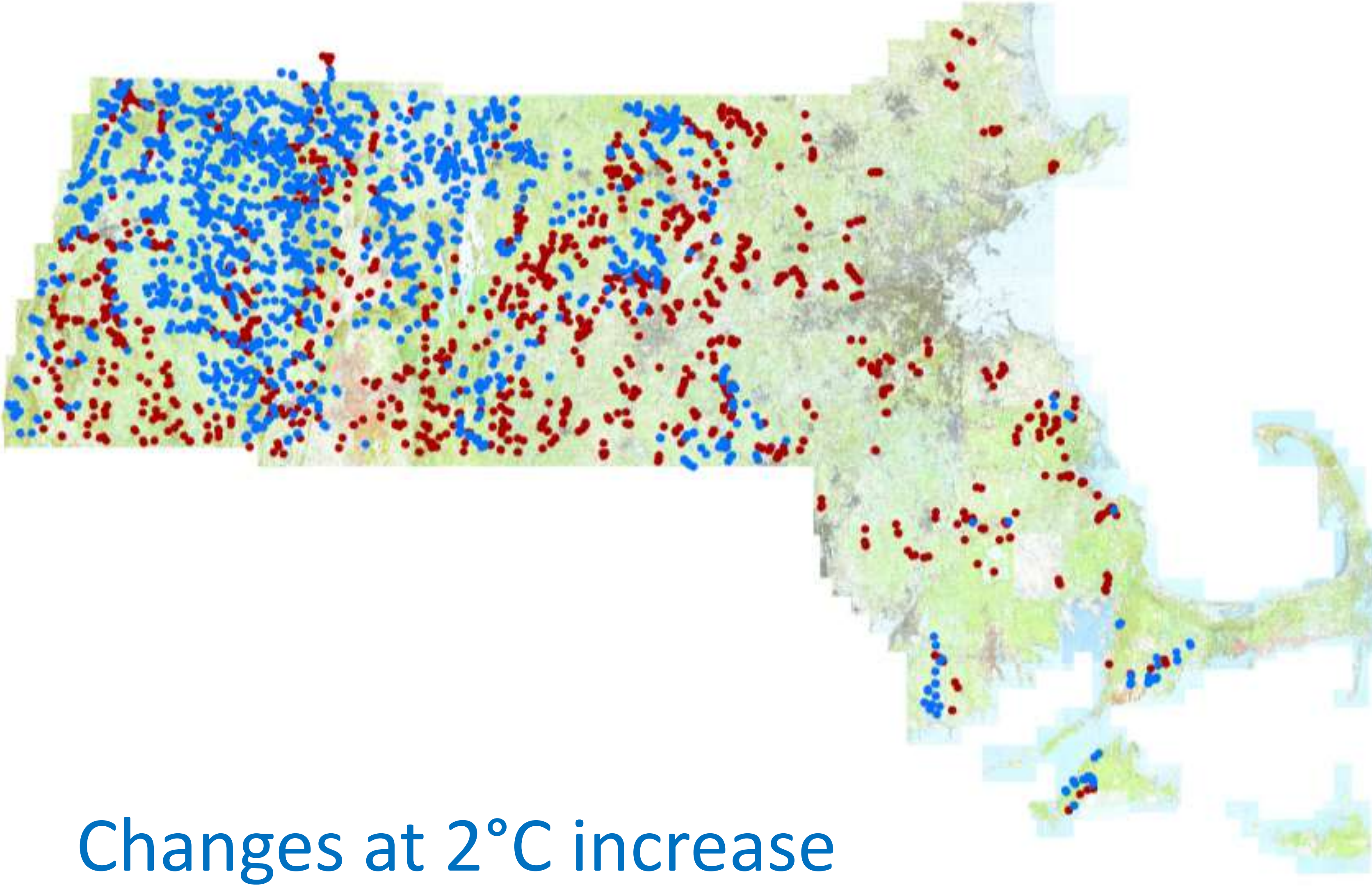


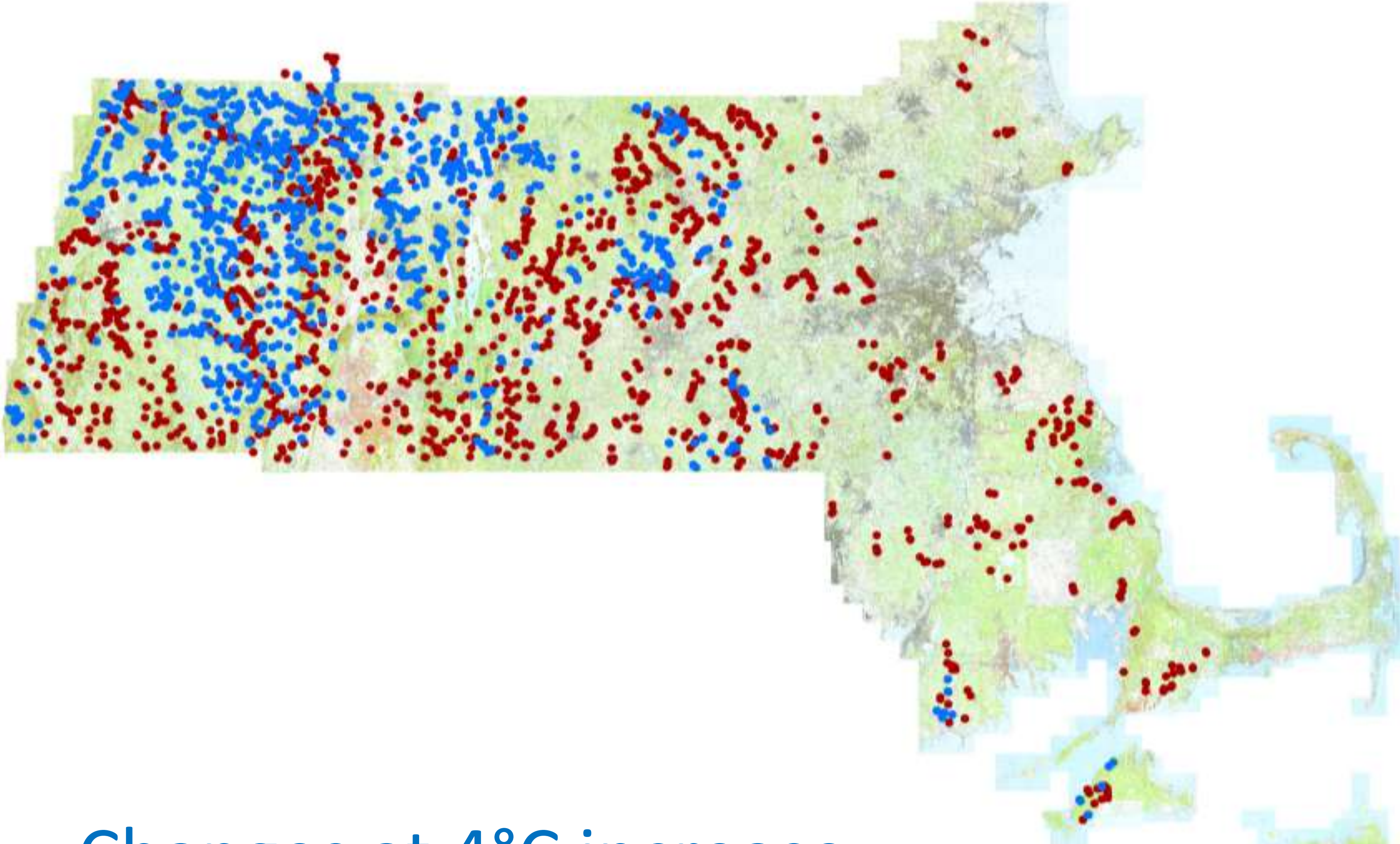
Fish surveys 1998-2018



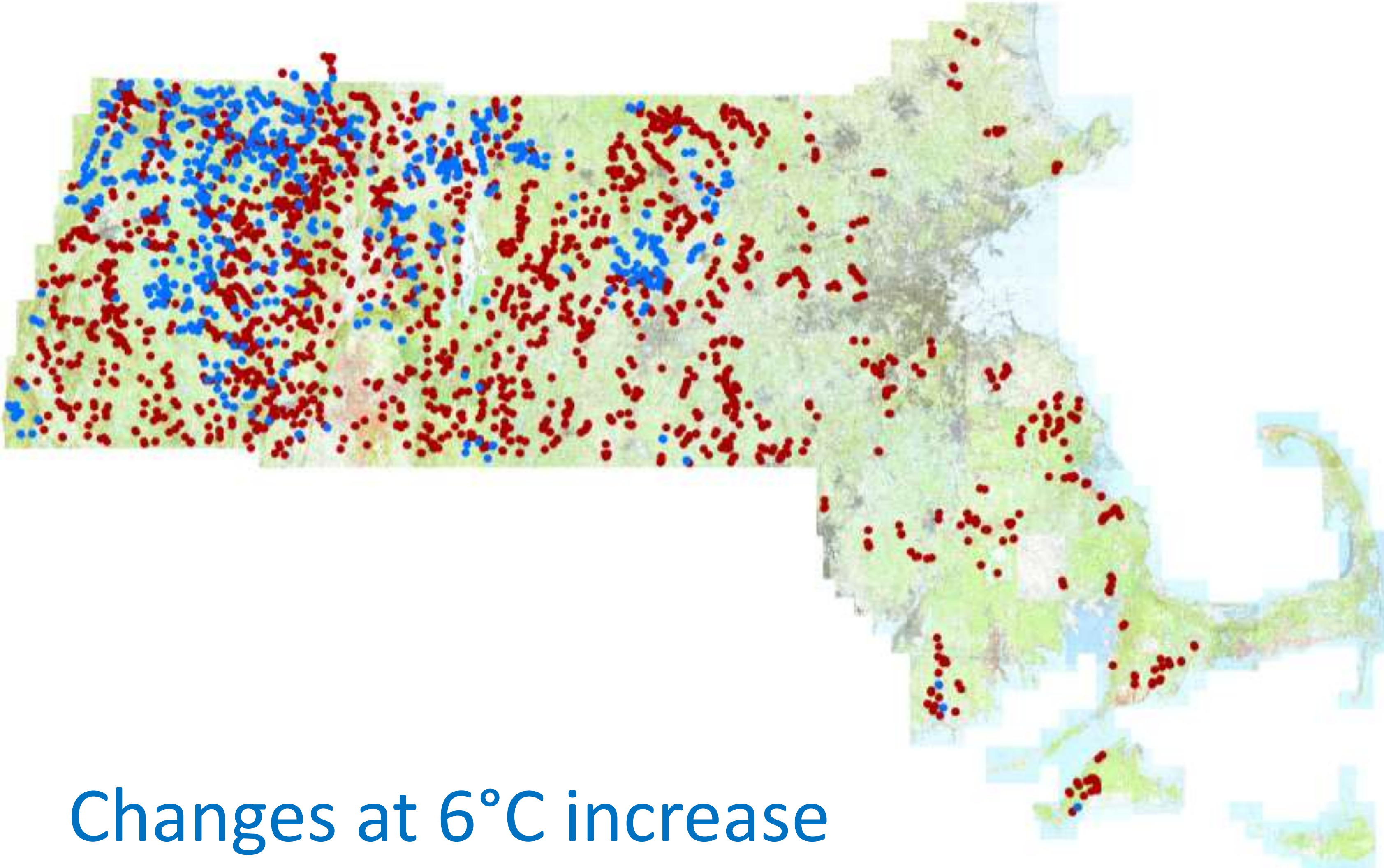
Coldwater surveys



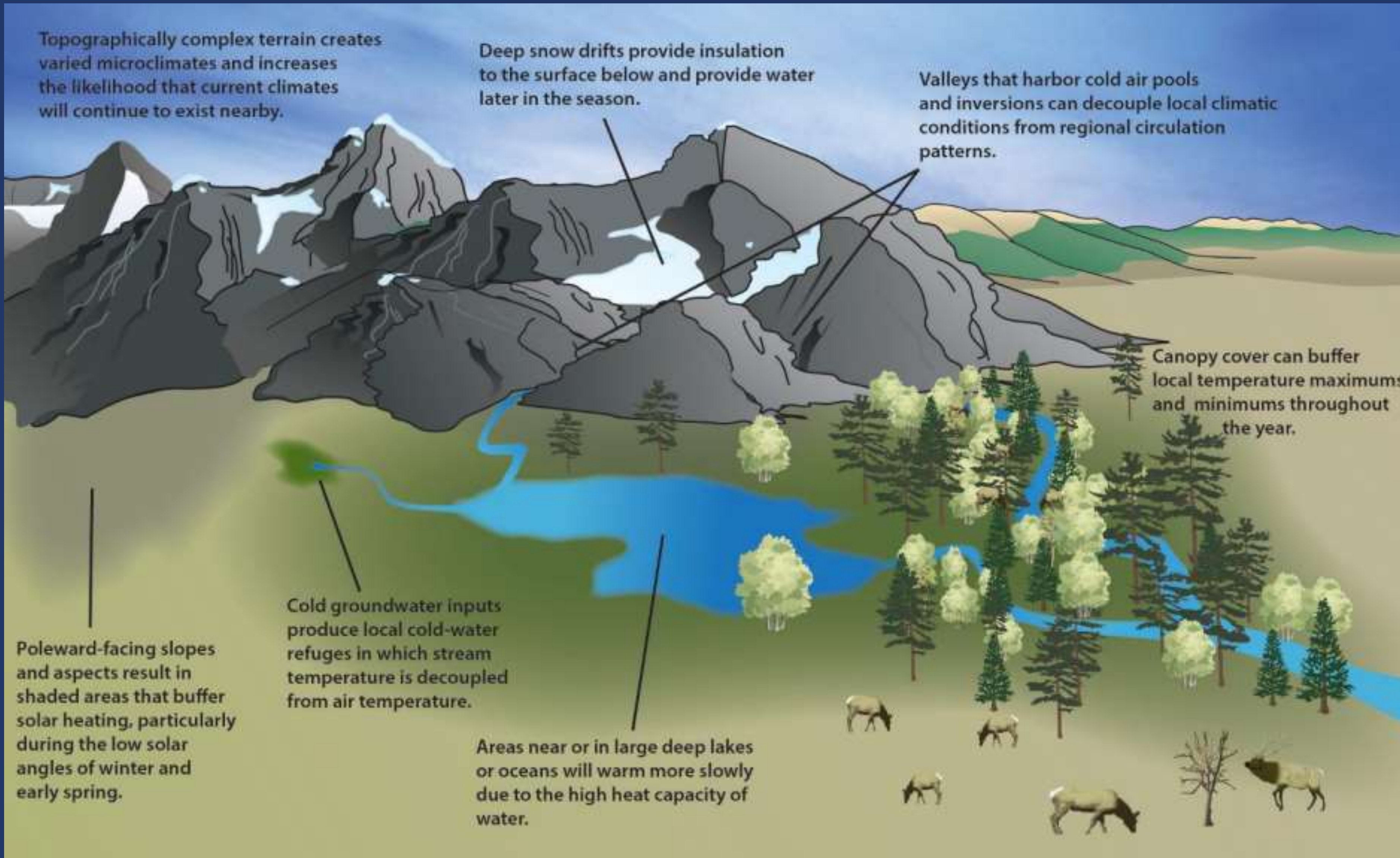
Changes at 2°C increase



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

Global Change Biology

Global Change Biology (2016), doi: 10.1111/gcb.13585

Vulnerability of eastern US tree species to climate change

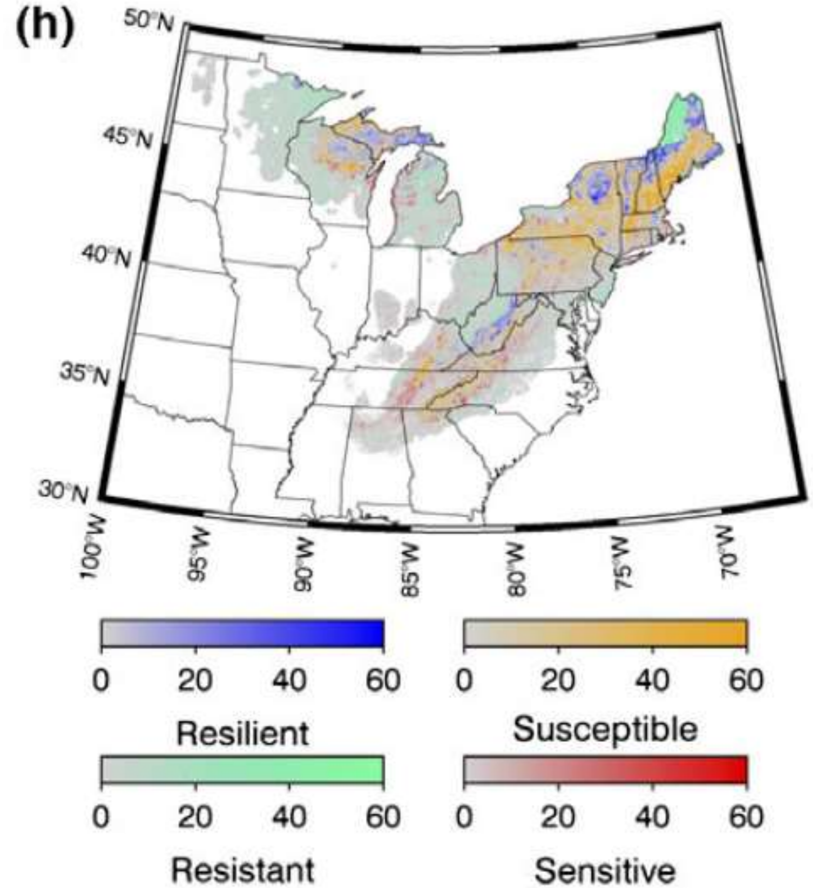
BRENDAN M. ROGERS, PATRICK JANTZ* and SCOTT J. GOETZ*
Woods Hole Research Center, 149 Woods Hole Road, Falmouth, MA, USA

Abstract

Climate change is expected to alter the distribution of tree species because of critical environmental tolerances related to growth, mortality, reproduction, disturbances, and biotic interactions. How this is realized in 21st century remains uncertain, in large part due to limitations on plant migration and the impacts of landscape fragmentation. Understanding these changes is of particular concern for forest management, which requires information at an appropriately fine spatial resolution. Here we provide a framework and application for tree species vulnerability to climate change in the eastern United States that accounts for influential drivers of future distributions. We used species distribution models to project changes in habitat suitability at 800 m for 40 tree species that vary in physiology, range, and environmental niche. We then developed layers of adaptive capacity based on migration potential, forest fragmentation, and propagule pressure. These were combined into metrics of vulnerability, including an overall index and spatially explicit categories designed to inform management. Despite overall favorable changes in suitability, the majority of species and the landscape were considered vulnerable to climate change. Vulnerability was significantly exacerbated by projections of pests and pathogens for some species. Northern and high-elevation species tended to be the most vulnerable. There were, however, some notable areas of particular resilience, including most of West Virginia. Our approach combines some of the most important considerations for species vulnerability in a straightforward framework, and can be used as a tool for managers to prioritize species, areas, and actions.

Keywords: biodiversity, dispersal, distribution model, forecast, fragmentation, management, migration, pests and pathogens

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

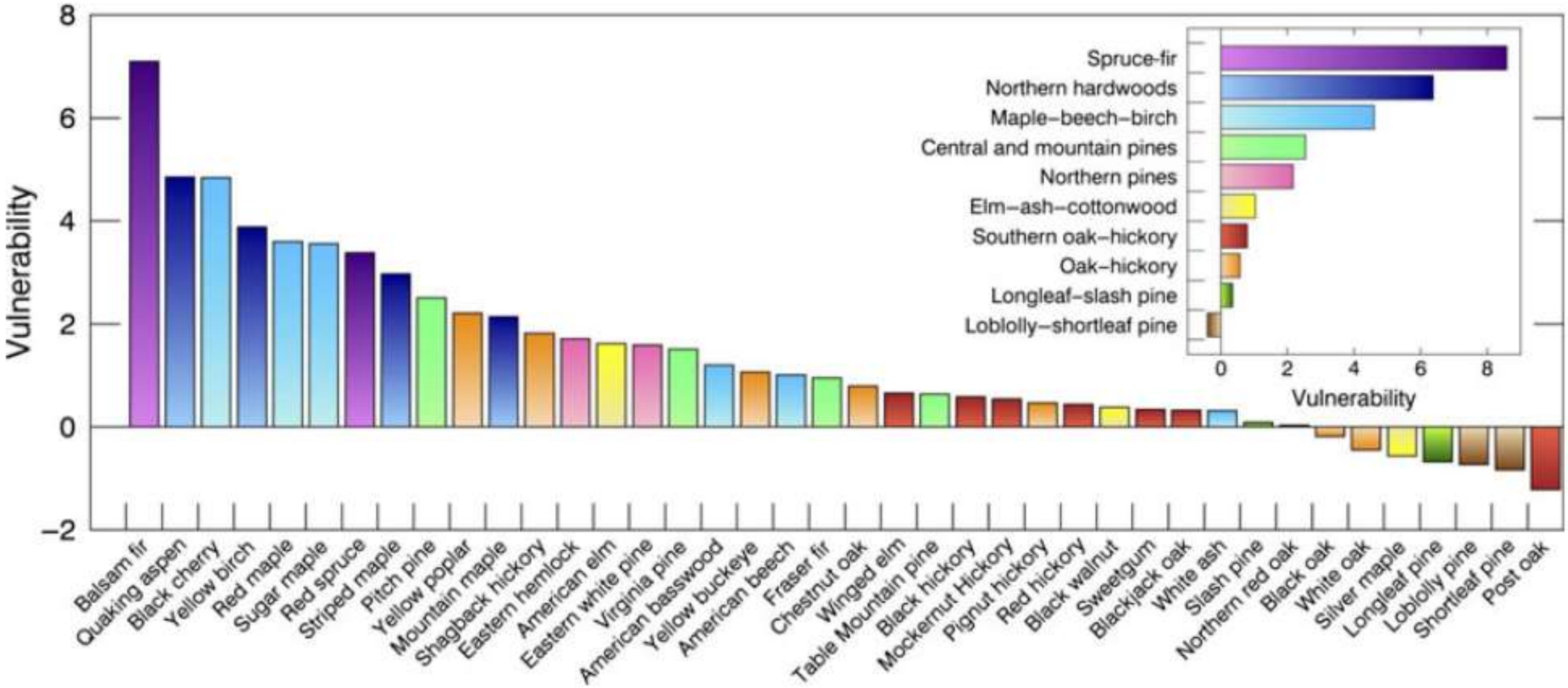
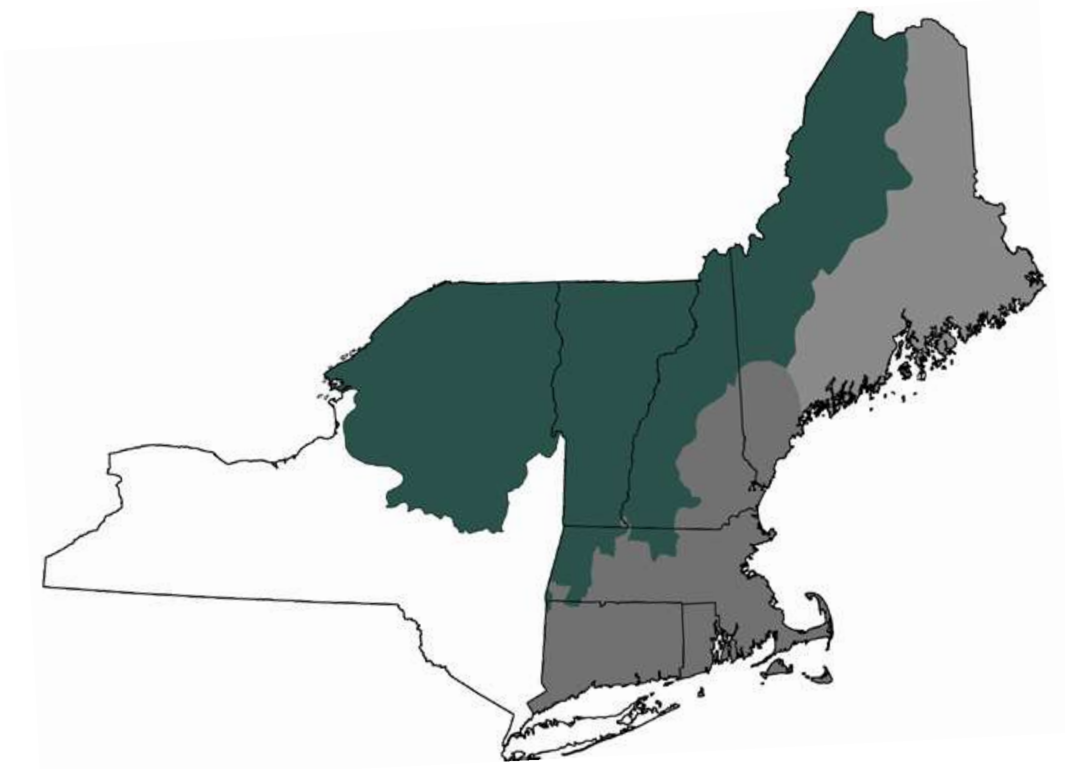


Fig. 3 “Species and forest type vulnerability rankings” from Rogers et al. (2016)

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-sucessional 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-sucessional 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-sucessional 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 diseaset
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

NIACS
Northern Institute of Applied Climate Science

www.forestadaptation.org

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

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

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

THE NORTHERN FOREST	LOW CLIMATE CHANGE(PCM B1)		HIGH CLIMATE CHANGE (GFDL A1FI)		
SPECIES	**TREE ATLAS**	**LANDIS**	**TREE ATLAS**	**LANDIS**	**ADAPT**
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)		
SPECIES	TREE ATLAS	LANDIS	TREE ATLAS	LANDIS	ADAPT
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

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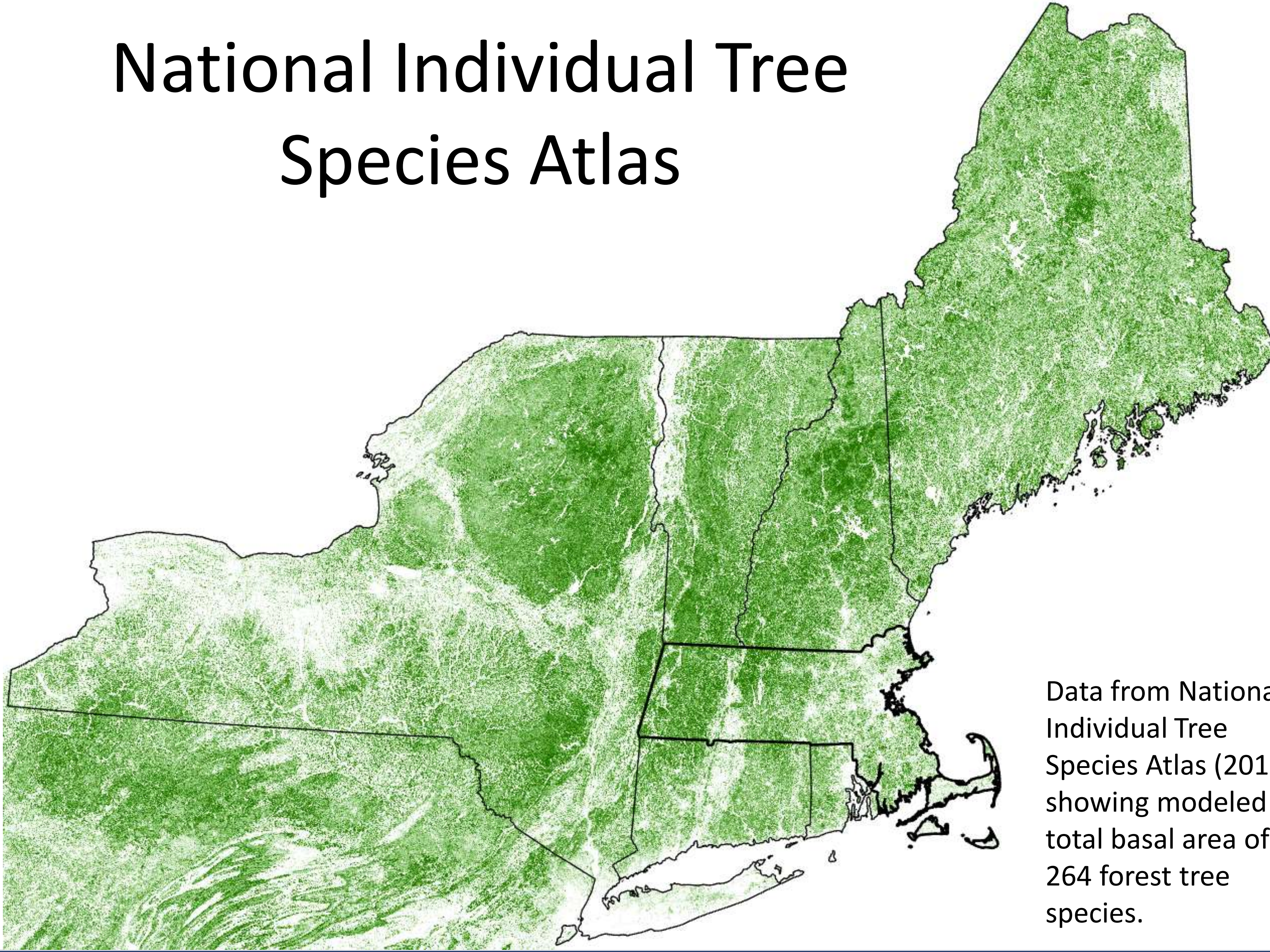
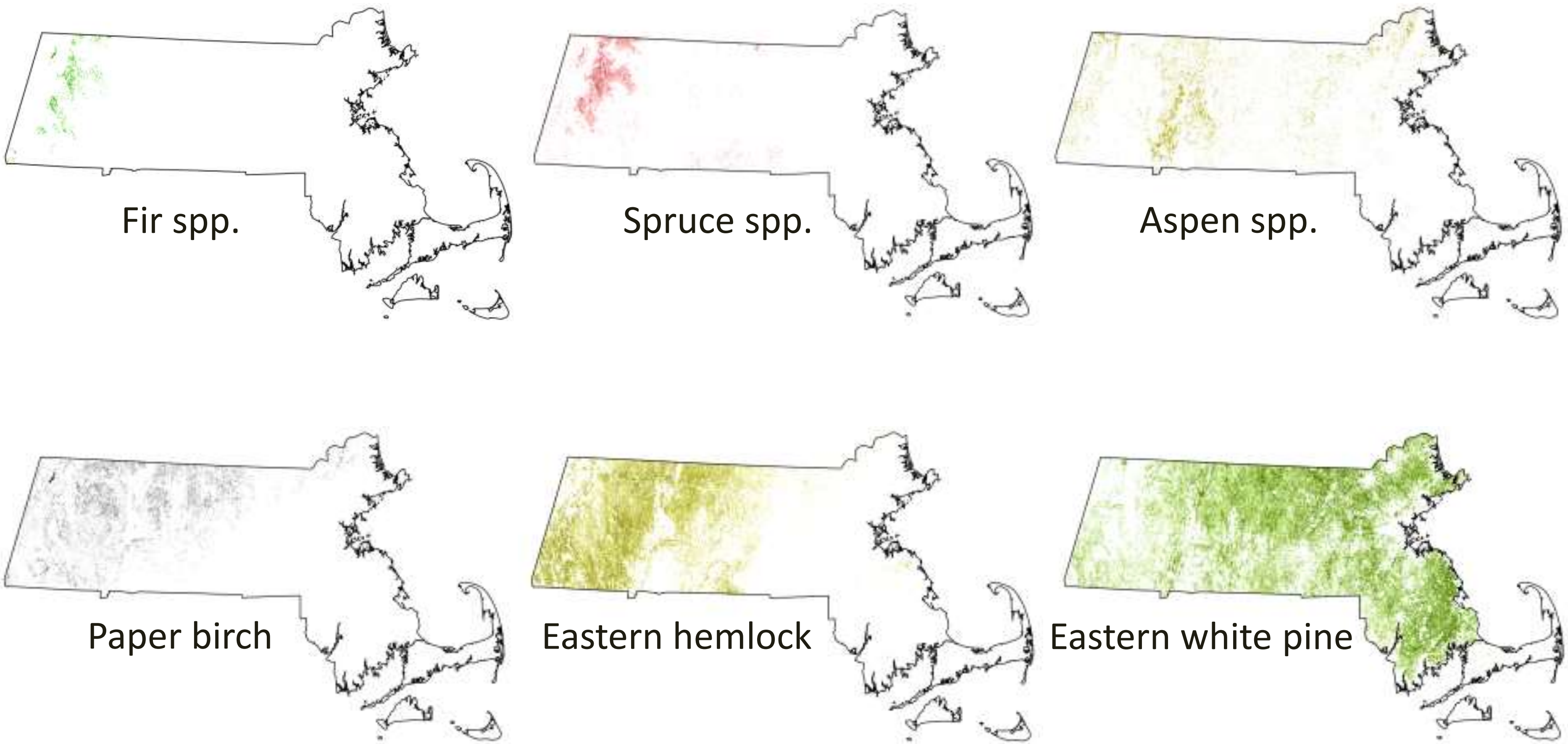
National Individual Tree Species Atlas



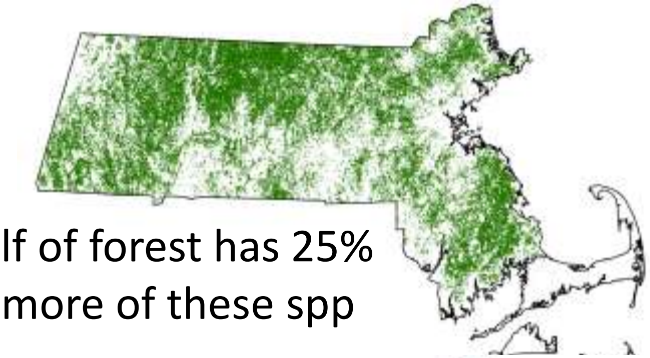
Data from National Individual Tree Species Atlas (2015), showing modeled total basal area of 264 forest tree species.

Individual percent of basal area for tree species predicted to decline

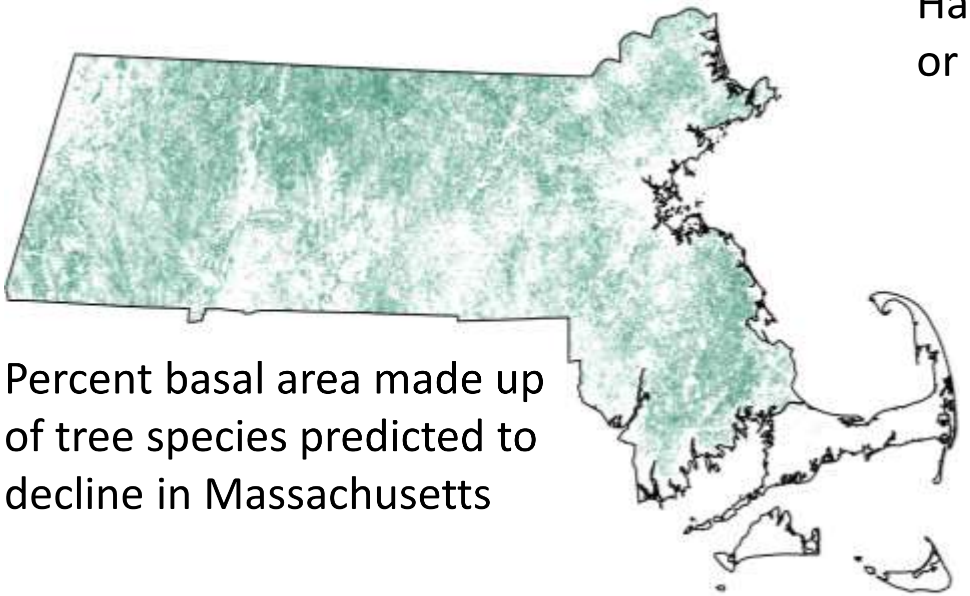


Data derived from National Individual Tree Species Atlas (2015)

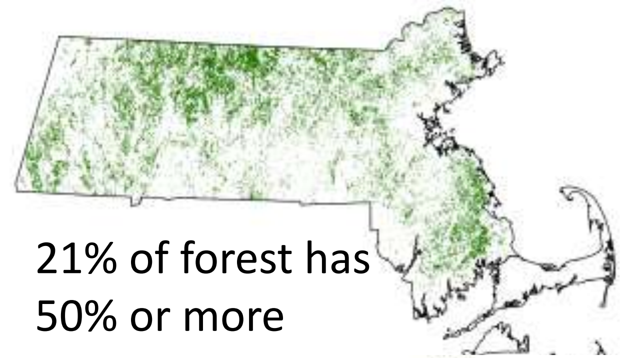
%BA of species predicted to decline



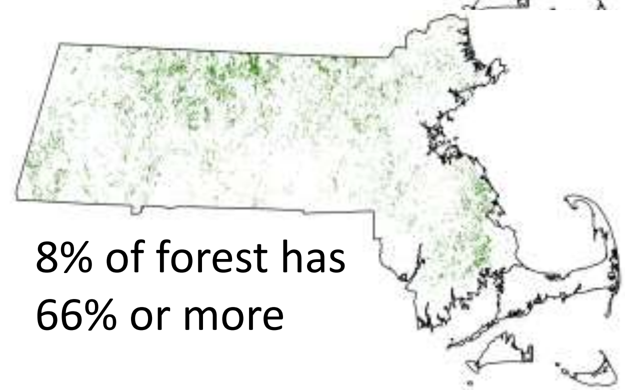
Half of forest has 25% or more of these spp



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



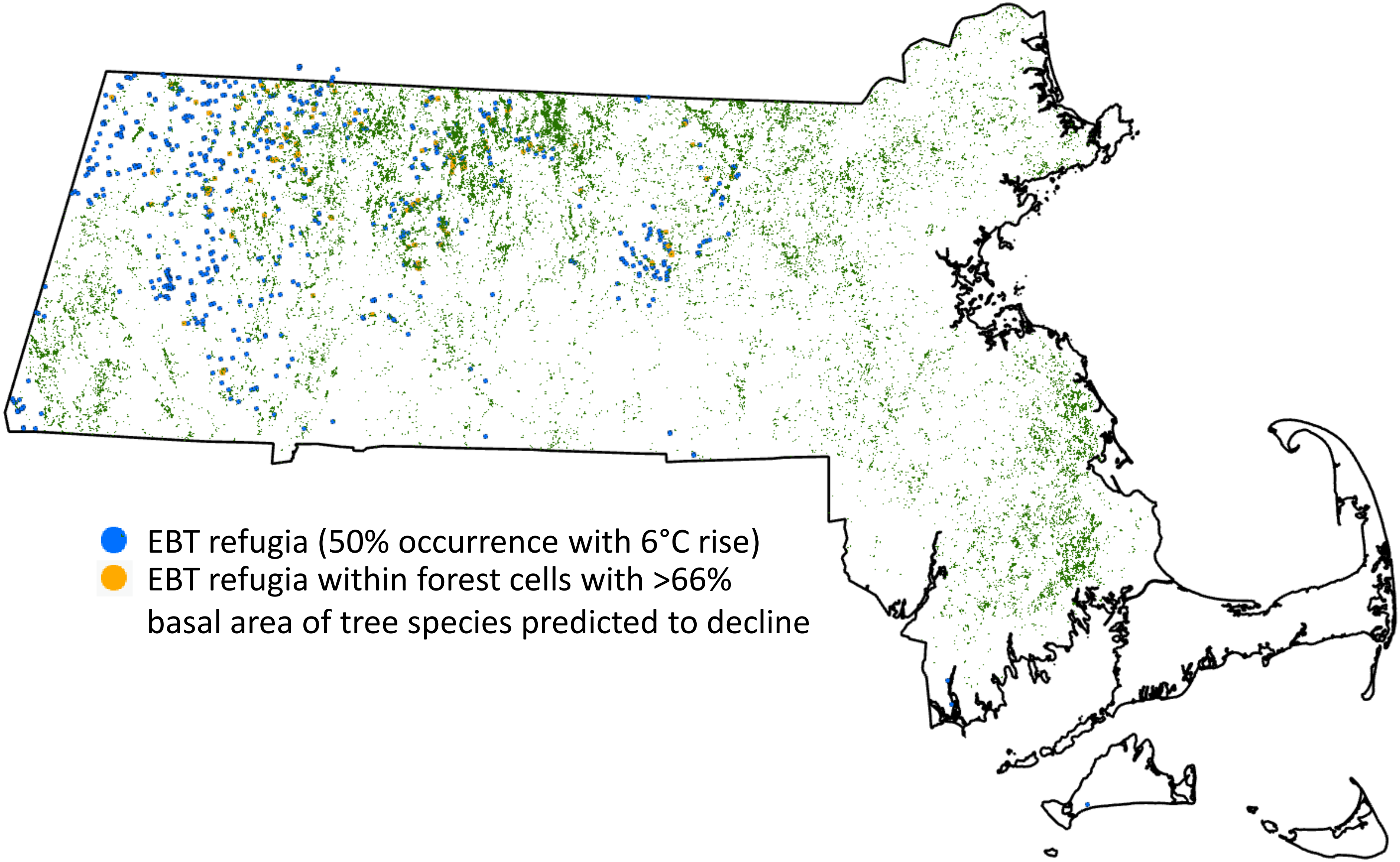
21% of forest has 50% or more



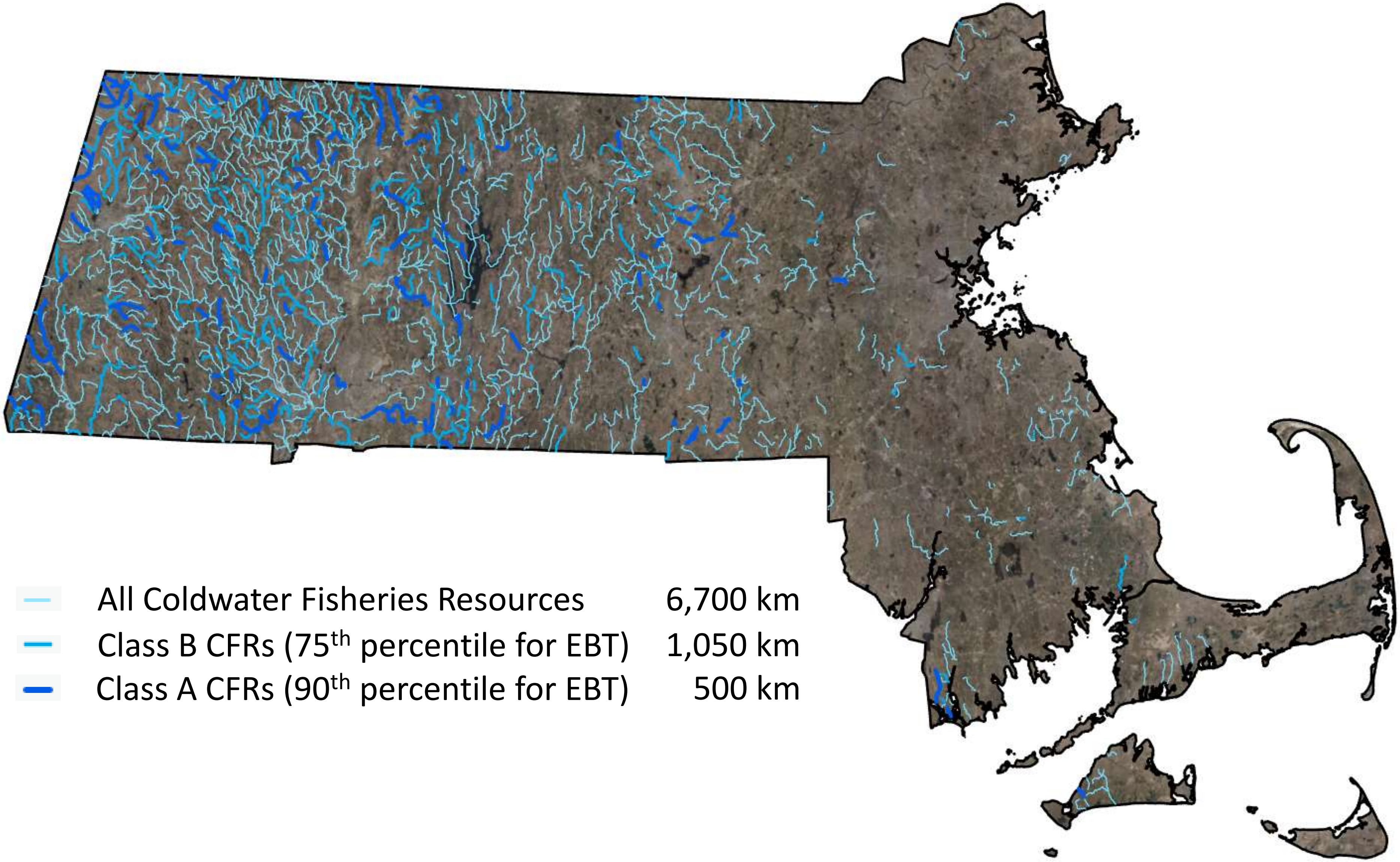
8% of forest has 66% or more

Data derived from National Individual Tree Species Atlas (2015)

Are EBT refugia within forests with vulnerable species?

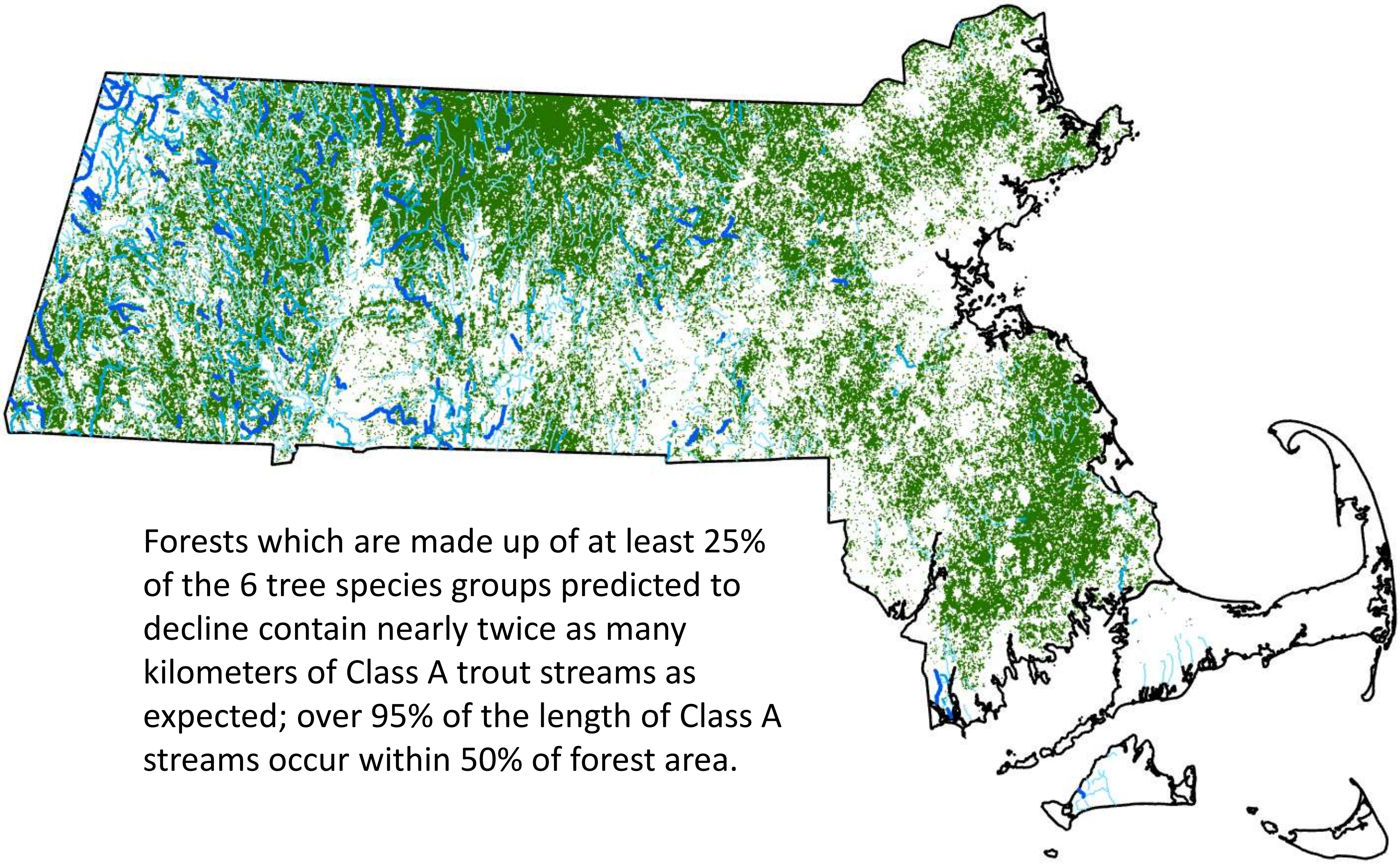


Coldwater fisheries classification



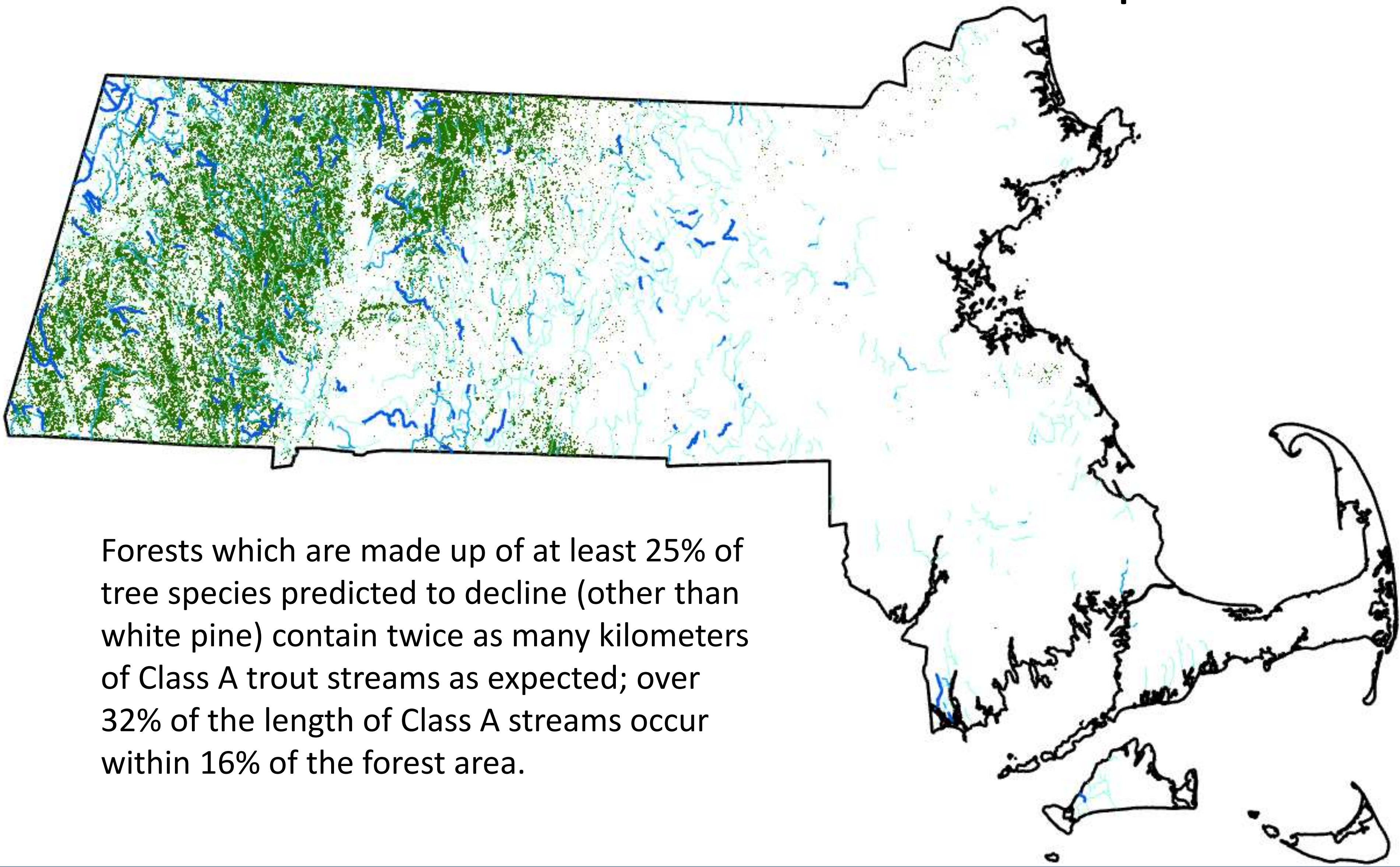
	All Coldwater Fisheries Resources	6,700 km
	Class B CFRs (75th percentile for EBT)	1,050 km
	Class A CFRs (90th percentile for EBT)	500 km

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

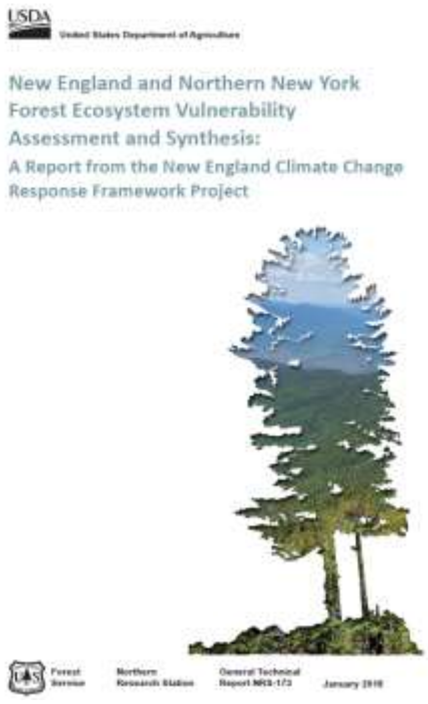

PLOS ONE

COLLECTION REVIEW

Managing Climate Change Refugia for Climate Adaptation

Abstract

Introduction

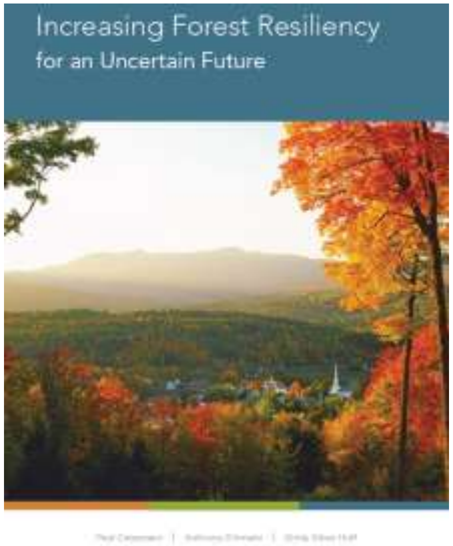

USDA United States Department of Agriculture

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

Forest Service | Northern Research Station | General Technical Report NRS-173 | January 2018


Forest Ecology and Management

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

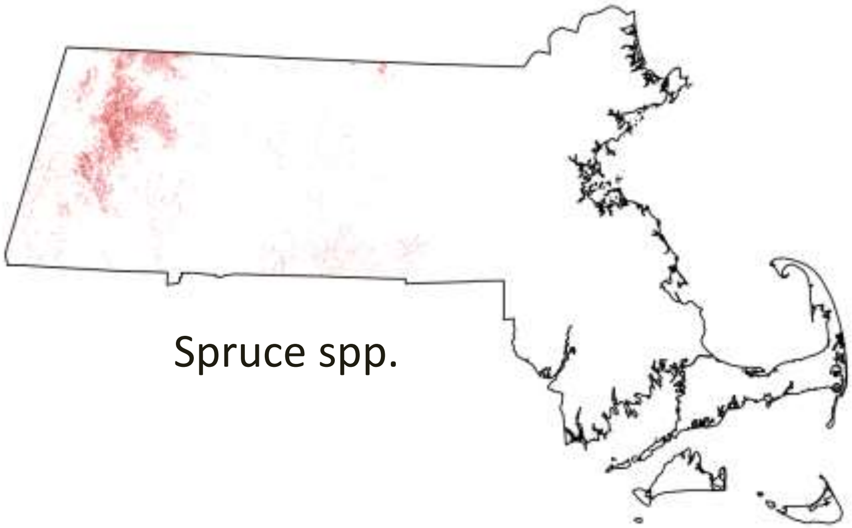


Other resources

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.

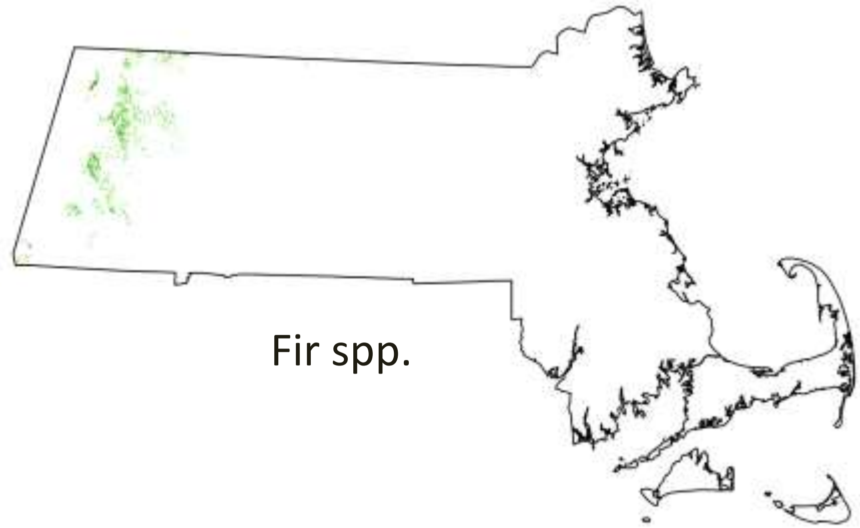
FEIS (https://www.feis-crs.org/feis/)
Fire Effects Information System synthesizes information not just on fire ecology and fire effects, but also on general species information, including associated plant communities, management and silvicultural considerations, and botanical and ecological characteristics.

Future work



Spruce spp.

+



Fir spp.

Data derived from National Individual Tree Species Atlas (2015)

Questions?