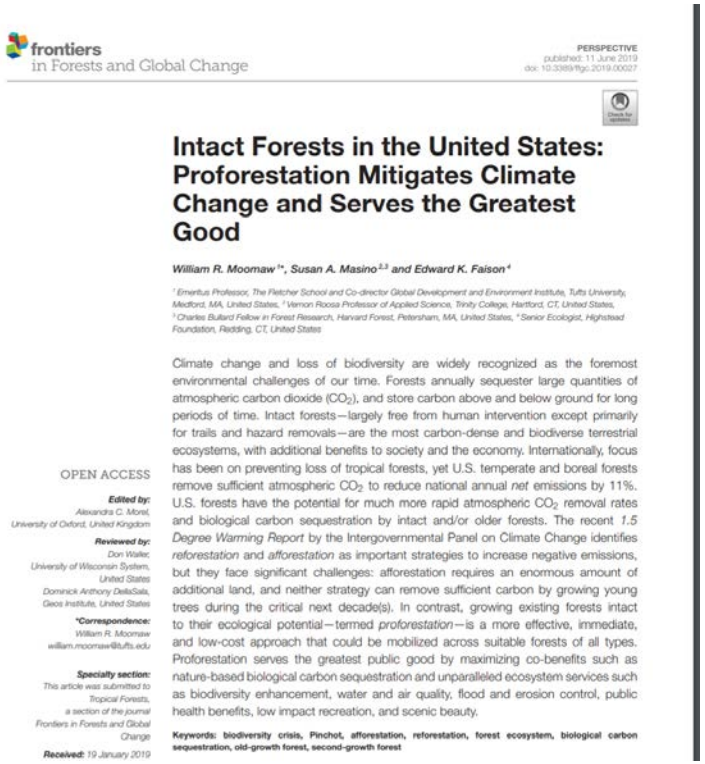
The role of unmanaged forests in climate mitigation and adaptation: the benefits of proforestation

Ed Faison
Senior Ecologist
Highstead Foundation
GC3. April 7, 2020



frontiers in Forests and Global Change

PERSPECTIVE
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Intact Forests in the United States: Proforestation Mitigates Climate Change and Serves the Greatest Good

William R. Moomaw[1], Susan A. Masino[2,3] and Edward K. Faison[4]*

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Climate change and loss of biodiversity are widely recognized as the foremost environmental challenges of our time. Forests annually sequester large quantities of atmospheric carbon dioxide (CO_2), and store carbon above and below ground for long periods of time. Intact forests—largely free from human intervention except primarily for trails and hazard removals—are the most carbon-dense and biodiverse terrestrial ecosystems, with additional benefits to society and the economy. Internationally, focus has been on preventing loss of tropical forests, yet U.S. temperate and boreal forests remove sufficient atmospheric CO_2 to reduce national annual *net* emissions by 11%. U.S. forests have the potential for much more rapid atmospheric CO_2 removal rates and biological carbon sequestration by intact and/or older forests. The recent *1.5 Degree Warming Report* by the Intergovernmental Panel on Climate Change identifies *reforestation* and *afforestation* as important strategies to increase negative emissions, but they face significant challenges: afforestation requires an enormous amount of additional land, and neither strategy can remove sufficient carbon by growing young trees during the critical next decade(s). In contrast, growing existing forests intact to their ecological potential—termed *proforestation*—is a more effective, immediate, and low-cost approach that could be mobilized across suitable forests of all types. Proforestation serves the greatest public good by maximizing co-benefits such as nature-based biological carbon sequestration and unparalleled ecosystem services such as biodiversity enhancement, water and air quality, flood and erosion control, public health benefits, low impact recreation, and scenic beauty.

Keywords: biodiversity crisis, Pinchot, afforestation, reforestation, forest ecosystem, biological carbon sequestration, old-growth forest, second-growth forest

OPEN ACCESS

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Terms

- **Climate Mitigation in forests**– enhancing carbon storage/sequestration in forest ecosystems to alleviate potential adverse effects of climate change

  Carbon **Sequestration** – the rate at which carbon is taken up by plants from the atmosphere

  Carbon **storage** – the accumulated carbon stored in the forest as a result of sequestration

- **Climate Adaptation in forests** – maintaining high levels of compositional, functional, and/or structural complexity to enhance the ability of an ecosystem to respond or adapt to new or changing conditions associated with a changing climate

  Resilience – ability of a system to recover quickly from a disturbance and return to a previous state

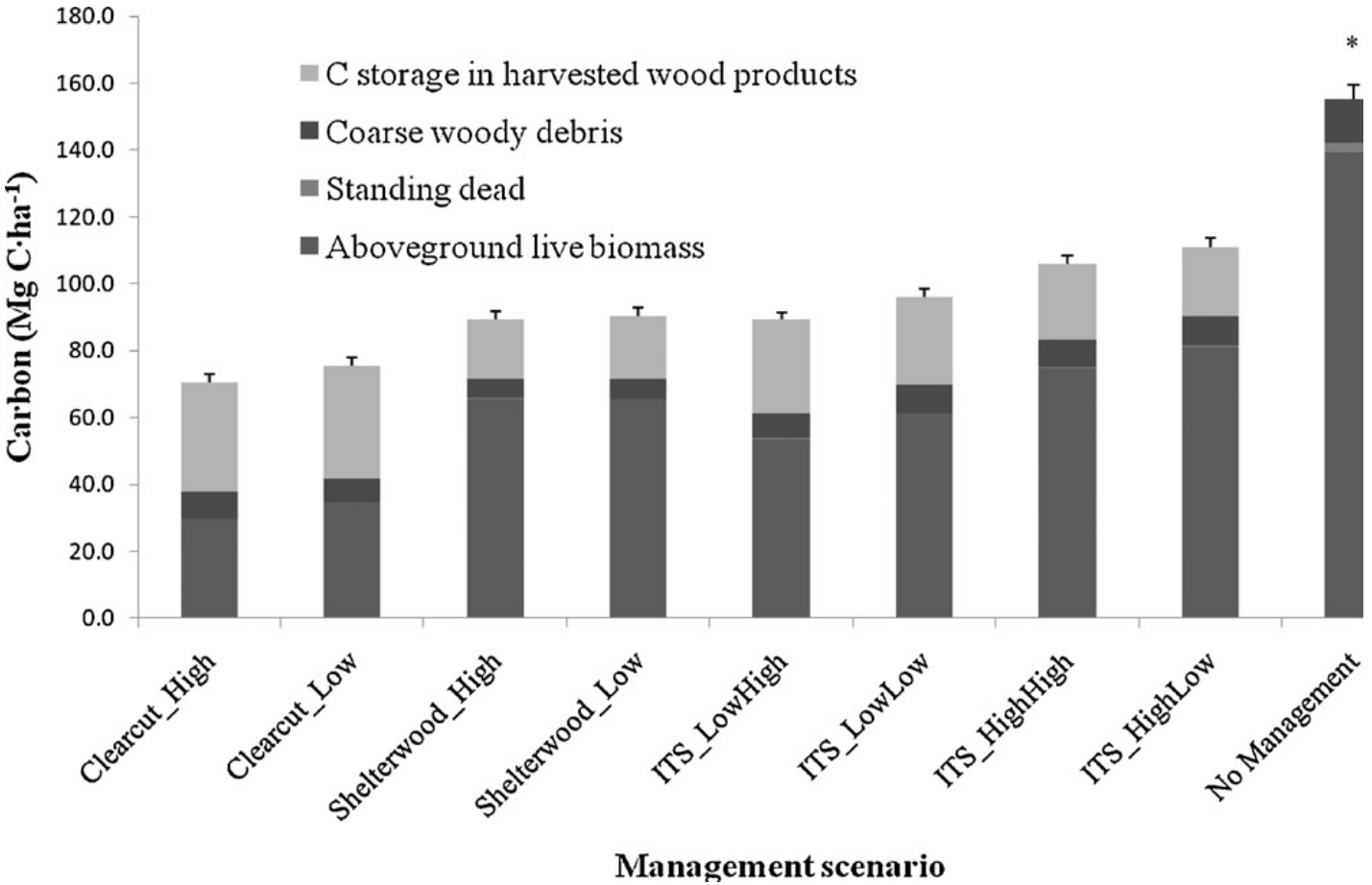
  Resistance - the capacity of a system to absorb disturbance or stress and remain relatively unchanged

From D'Amato et al. 2011
and GC3 working definitions

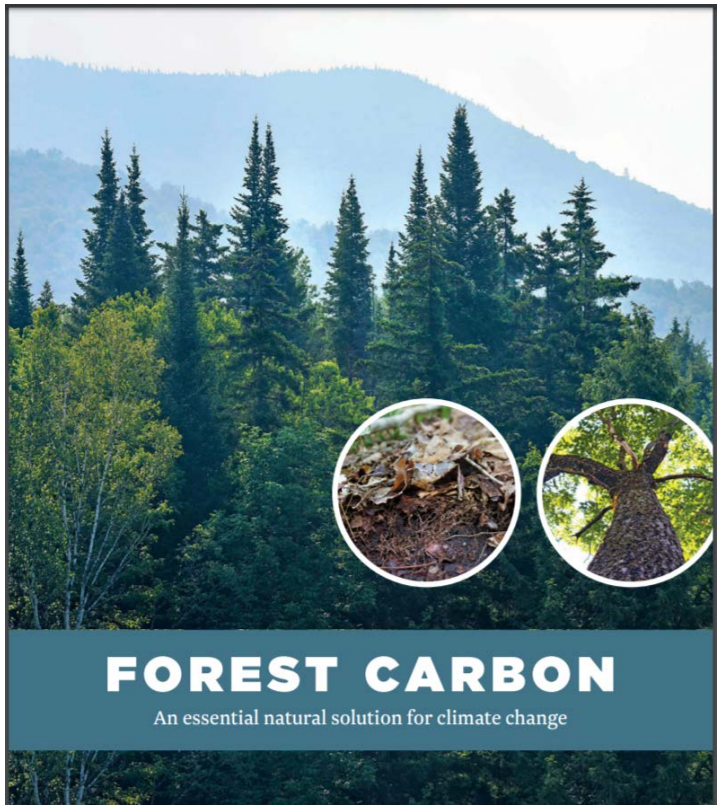
Unmanaged forests store more carbon than do managed forests

Mitigation

'No management' forests stored 39-118% more carbon than managed forests



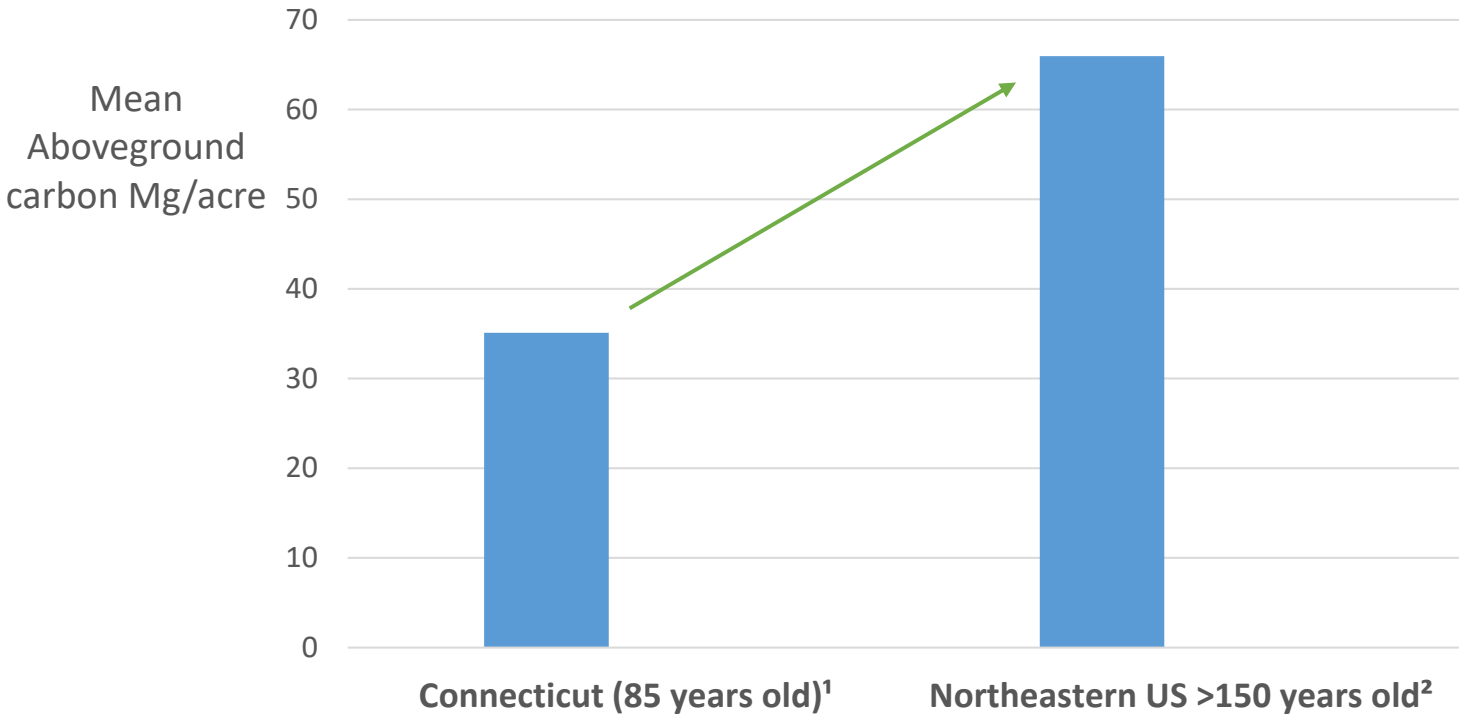
"All harvesting reduces carbon storage of a forest below the maximum potential for the site."
(D'Amato and Catanzaro 2019)



Nunery, J. S., & Keeton, W. S. (2010). Forest carbon storage in the northeastern United States: net effects of harvesting frequency, post-harvest retention, and wood products. *Forest Ecology and Management*, *259*(8), 1363-1375.

Connecticut's forests have the potential to almost double aboveground carbon storage

Mitigation



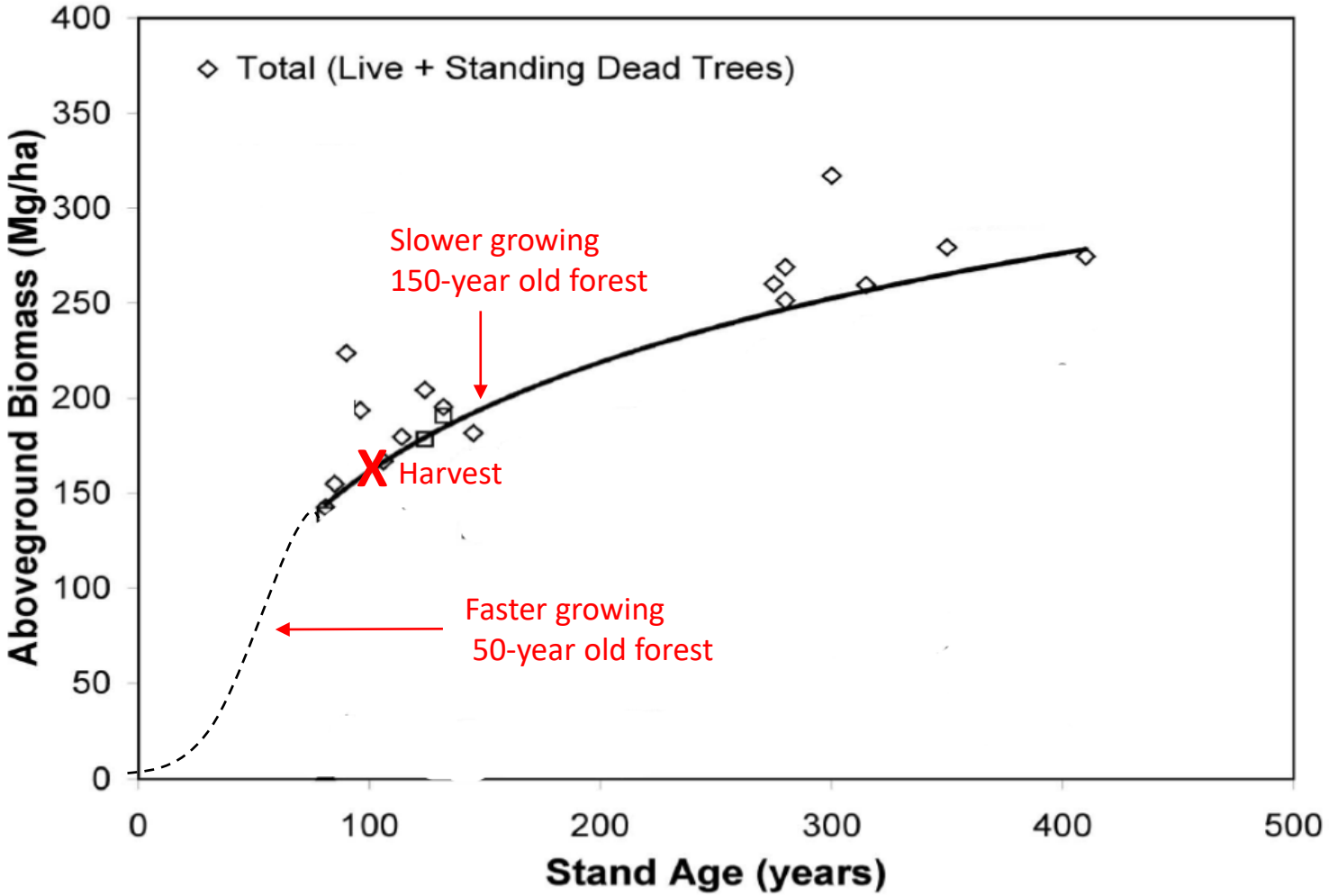
"Stand age was the strongest predictor of [carbon] biomass" (Keeton et al. 2011)

[1]Data from USDA FIA

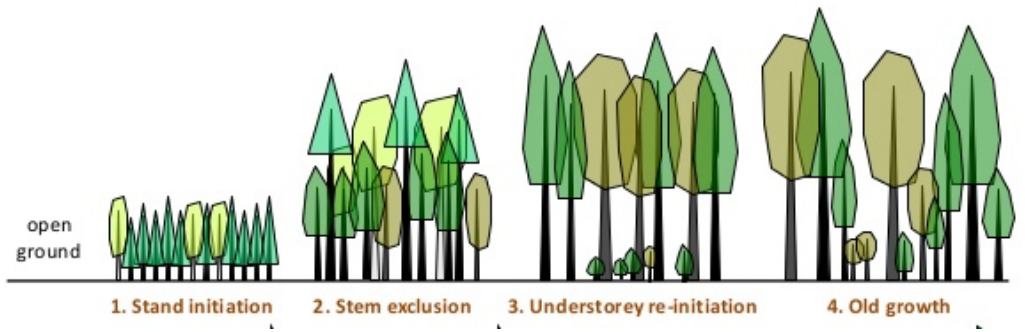
[2]Data from Keeton, W. S., Whitman, A. A., McGee, G. C., & Goodale, C. L. (2011). Late-successional biomass development in northern hardwood-conifer forests of the northeastern United States. *Forest Science*, *57*(6), 489-505. (Maine, New Hampshire, Adirondacks, NY); **and**
McGarvey, J. C., Thompson, J. R., Epstein, H. E., & Shugart Jr, H. H. (2015). Carbon storage in old-growth forests of the Mid-Atlantic: toward better understanding the eastern forest carbon sink. *Ecology*, *96*(2), 311-317 (Pennsylvania, New Jersey, Maryland, Virginia, and West Virginia)

Creating younger forests from older forests does not help climate mitigation

Mitigation



"The mitigation value of forests lies not in their present net uptake of CO2, but in the longevity of their accumulated carbon stocks" (Mackey et al. 2013. *Nature Climate Change)*



https://www.slideshare.net/ERWilson1/teaching-forest-stand-dynamics

Adapted from Keeton, W. S., Whitman, A. A., McGee, G. C., & Goodale, C. L. (2011). Late-successional biomass development in northern hardwood-conifer forests of the northeastern United States. *Forest Science*, *57*(6), 489-505.

Unmanaged lands at early successional stages: leveraging the power of afforestation

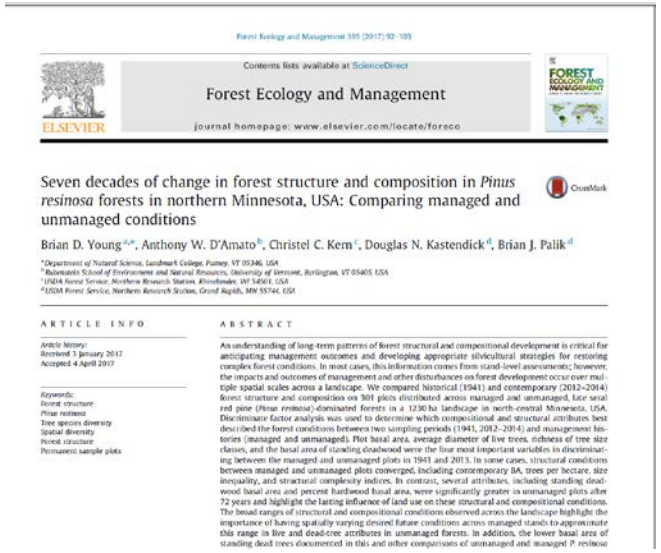
Mitigation

- Afforestation sequesters about 2 metric tons of carbon per acre/year – that's about ~10-20 times the annual carbon sequestration rate in grasslands[1]

[1]Bachelet et al. 2018. https://carbon2018.globalchange.gov/chapter/10/; Potter et al. 2007. Satellite-derived estimates of potential carbon sequestration through afforestation of agricultural lands in the United States

Forest structural complexity is greater in unmanaged forests than in managed forests

Adaptation



Forest Ecology and Management 385 (2017) 92–103

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Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Seven decades of change in forest structure and composition in *Pinus resinosa* forests in northern Minnesota, USA: Comparing managed and unmanaged conditions

Brian D. Young[a,*], Anthony W. D'Amato[b], Christel C. Kern[c], Douglas N. Kastendick[d], Brian J. Palik[d]

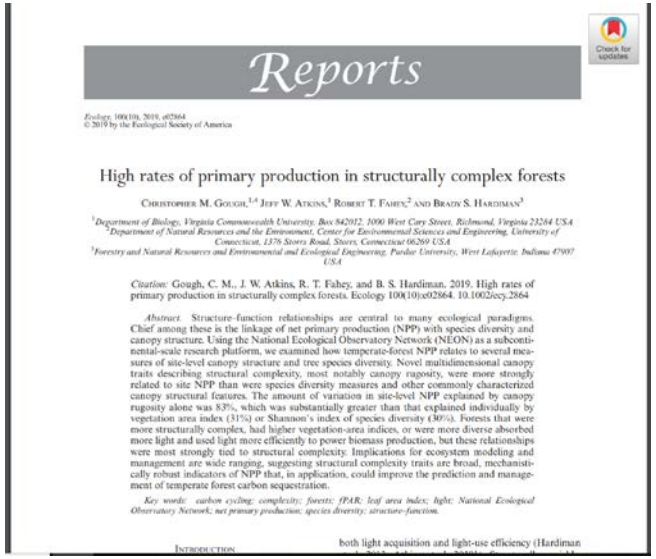
ARTICLE INFO

ABSTRACT

esa ECOSPHERE

SPECIAL FEATURE: SCIENCE FOR OUR NATIONAL PARKS' SECOND CENTURY

National parks in the eastern United States harbor important older forest structure compared with matrix forests



Reports

High rates of primary production in structurally complex forests

"Based on the findings of previous work conducted at the stand-level, we expect more complex forest structure across the landscape will develop over time to a greater degree in unmanaged than managed [forests]" Young et al. 2017

"[we] found [forests in national] parks to have consistently greater structural complexity than surrounding forests…and [thus] potentially be more resilient to climate change" Miller et al. (2018)

Unmanaged forests have greater tree species diversity than do managed forests

Adaptation

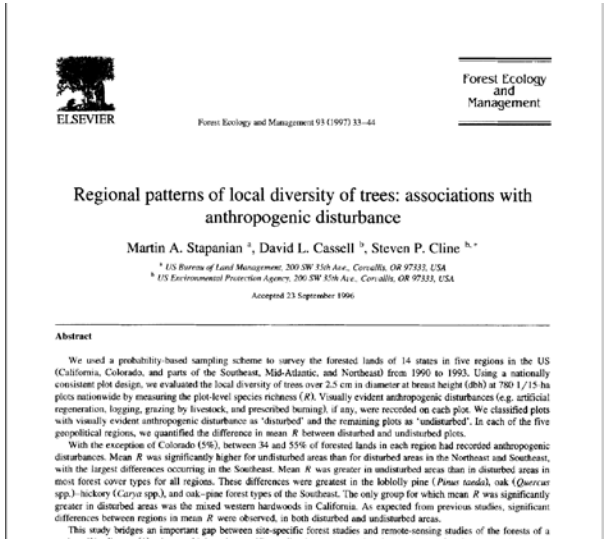
Forest Ecology and Management

Eastern national parks protect greater tree species diversity than unprotected matrix forests

Kathryn M. Miller, Brian J. McGill, Brian R. Mitchell, Jim Comiskey, Fred W. Dieffenbach, Elizabeth R. Matthews, Stephanie J. Perles, John Paul Schmit, Aaron S. Weed

ARTICLE INFO

ABSTRACT



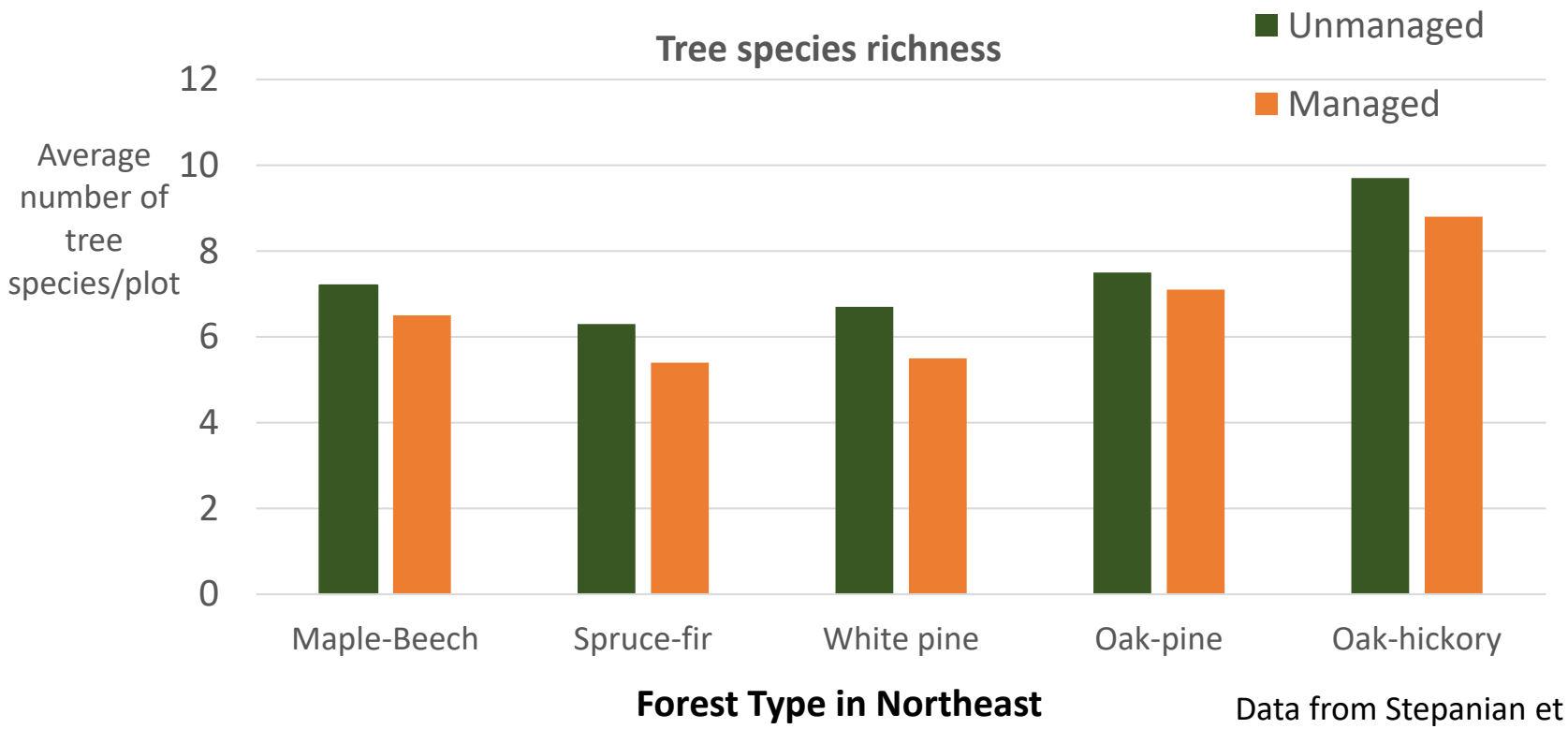
Forest Ecology and Management

Regional patterns of local diversity of trees: associations with anthropogenic disturbance

Martin A. Stapanian, David L. Cassell, Steven P. Cline

Abstract

"higher species richness was observed in 77% of parks compared to matrix forests" Miller et al. 2018

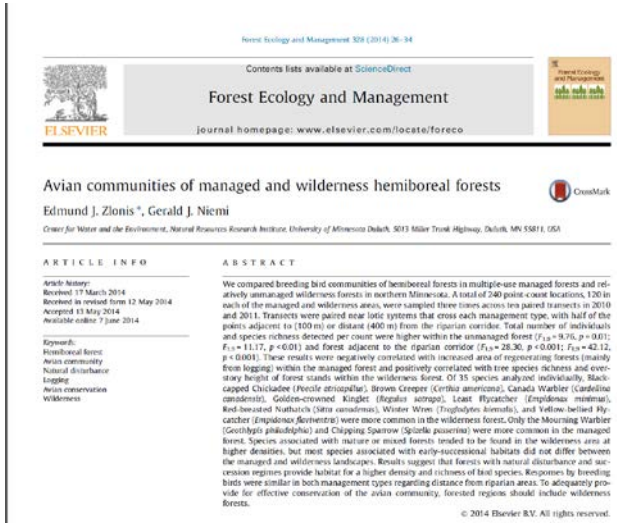


Data from Stepanian et al. 1997

A greater density and diversity of forest birds often occurs in unmanaged than in managed forests

Adaptation

- Total density of birds
- Total number of bird species
- Abundance of individual species



Forest Ecology and Management 328 (2014) 26–34

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Avian communities of managed and wilderness hemiboreal forests

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Keywords:
Hemiboreal forest
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ABSTRACT

We compared breeding bird communities of hemiboreal forests in multiple-use managed forests and relatively unmanaged wilderness forests in northern Minnesota. A total of 240 point-count locations, 120 in each of the managed and wilderness areas, were sampled three times across ten paired transects in 2010 and 2011. Transects were paired near lotic systems that cross each management type, with half of the points adjacent to (100 m) or distant (400 m) from the riparian corridor. Total number of individuals and species richness detected per count were higher within the unmanaged forest ($F_{1,18} = 9.76$, $p = 0.01$; $F_{1,1} = 11.17$, $p < 0.01$) and forest adjacent to the riparian corridor ($F_{1,9} = 28.30$, $p < 0.001$; $F_{1,9} = 42.12$, $p < 0.001$). These results were negatively correlated with increased area of regenerating forests (mainly from logging) within the managed forest and positively correlated with tree species richness and overstory height of forest stands within the wilderness forest. Of 35 species analyzed individually, Black-capped Chickadee (*Poecile atricapillus*), Brown Creeper (*Certhia americana*), Canada Warbler (*Cardellina canadensis*), Golden-crowned Kinglet (*Regulus satrapa*), Least Flycatcher (*Empidonax minimus*), Red-breasted Nuthatch (*Sitta canadensis*), Winter Wren (*Troglodytes hiemalis*), and Yellow-bellied Flycatcher (*Empidonax flaviventris*) were more common in the wilderness forest. Only the Mourning Warbler (*Geothlypis philadelphia*) and Chipping Sparrow (*Spizella passerina*) were more common in the managed forest. Species associated with mature or mixed forests tended to be found in the wilderness area at higher densities, but most species associated with early-successional habitats did not differ between the managed and wilderness landscapes. Results suggest that forests with natural disturbance and succession regimes provide habitat for a higher density and richness of bird species. Responses by breeding birds were similar in both management types regarding distance from riparian areas. To adequately provide for effective conservation of the avian community, forested regions should include wilderness forests.

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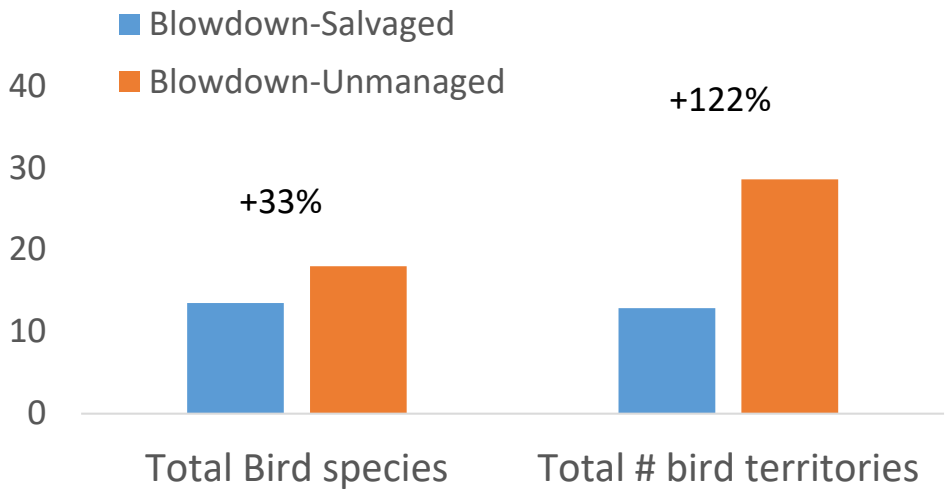
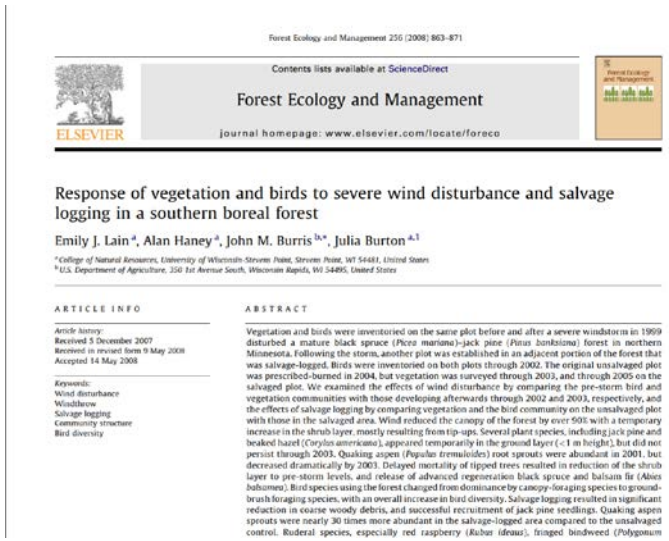
"the richness of early-successional forest species did not vary between wilderness and managed forest…likely because of the presence of natural openings [in the wilderness sites]…that provided appropriate open, shrubby habitat (Zlonis and Niemi 2014)





Forest Ecology and Management 256 (2008) 863–871

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journal homepage: www.elsevier.com/locate/foreco

Response of vegetation and birds to severe wind disturbance and salvage logging in a southern boreal forest

Emily J. Lain [a], Alan Haney [a], John M. Burris [b,*], Julia Burton [a,1]

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[b] U.S. Department of Agriculture, 350 1st Avenue South, Wisconsin Rapids, WI 54495, United States

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Keywords:
Wind disturbance
Windthrow
Salvage logging
Community structure
Bird diversity

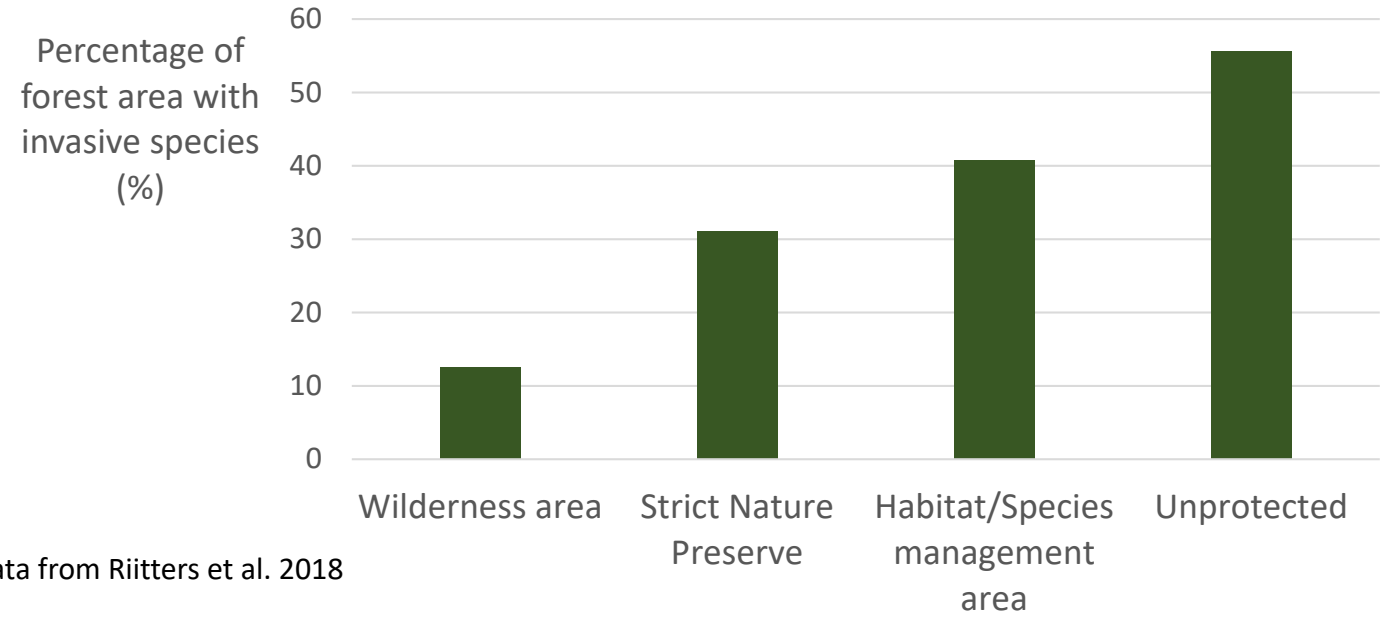
ABSTRACT

Vegetation and birds were inventoried on the same plot before and after a severe windstorm in 1999 disturbed a mature black spruce (*Picea mariana*)–jack pine (*Pinus banksiana*) forest in northern Minnesota. Following the storm, another plot was established in an adjacent portion of the forest that was salvage-logged. Birds were inventoried on both plots through 2002. The original unsalvaged plot was prescribed-burned in 2004, but vegetation was surveyed through 2003, and through 2005 on the salvaged plot. We examined the effects of wind disturbance by comparing the pre-storm bird and vegetation communities with those developing afterwards through 2002 and 2003, respectively, and the effects of salvage logging by comparing vegetation and the bird community on the unsalvaged plot with those in the salvaged area. Wind reduced the canopy of the forest by over 90% with a temporary increase in the shrub layer, mostly resulting from tip-ups. Several plant species, including jack pine and beaked hazel (*Corylus americana*), appeared temporarily in the ground layer (<1 m height), but did not persist through 2003. Quaking aspen (*Populus tremuloides*) root sprouts were abundant in 2001, but decreased dramatically by 2003. Delayed mortality of tipped trees resulted in reduction of the shrub layer to pre-storm levels, and release of advanced regeneration black spruce and balsam fir (*Abies balsamea*). Bird species using the forest changed from dominance by canopy-foraging species to ground-brush foraging species, with an overall increase in bird diversity. Salvage logging resulted in significant reduction in coarse woody debris, and successful recruitment of jack pine seedlings. Quaking aspen sprouts were nearly 30 times more abundant in the salvage-logged area compared to the unsalvaged control. Ruderal species, especially red raspberry (*Rubus idaeus*), fringed bindweed (*Polygonum*

Data from: Lain, E. J., Haney, A., Burris, J. M., & Burton, J. (2008). Response of vegetation and birds to severe wind disturbance and salvage logging in a southern boreal forest. *Forest Ecology and Management*, *256*(5), 863-871.

Less management results in fewer invasive plant species

Adaptation



Data from Riitters et al. 2018

forests

MDPI

Article

Exposure of Protected and Unprotected Forest to Plant Invasions in the Eastern United States

Kurt Riitters [1,*], Kevin M. Potter [2], Basil V. Iannone III [3], Christopher Oswalt [4], Qinfeng Guo [5] and Songlin Fei [5]

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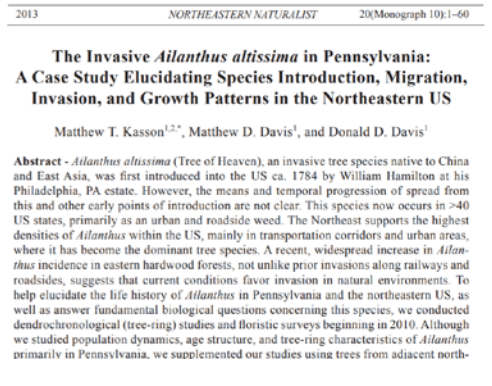
Received: 24 October 2018; Accepted: 17 November 2018; Published: 20 November 2018

Abstract: *Research Highlights*: We demonstrate a macroscale framework combining an invasibility model with forest inventory data, and evaluate regional forest exposure to harmful invasive plants under different types of forest protection. *Background and Objectives*: Protected areas are a fundamental component of natural resource conservation. The exposure of protected forests to invasive plants can impede achievement of conservation goals, and the effectiveness of protection for limiting forest invasions is uncertain. We conducted a macroscale assessment of the exposure of protected and unprotected forests to harmful invasive plants in the eastern United States. *Materials and Methods*: Invasibility (the probability that a forest site has been invaded) was estimated for 82,506 inventory plots from site and landscape attributes. The invaded forest area was estimated by using the inventory sample design to scale up plot invasibility estimates to all forest area. We compared the invasibility and the invaded forest area of seven categories of protection with that of de facto protected (publicly owned) forest and unprotected forest in 13 ecological provinces. *Results*: We estimate approximately 51% of the total forest area has been exposed to harmful invasive plants, including



2013 NORTHEASTERN NATURALIST 20(Monograph 10):1–60

The Invasive *Ailanthus altissima* in Pennsylvania: A Case Study Elucidating Species Introduction, Migration, Invasion, and Growth Patterns in the Northeastern US

Matthew T. Kasson[1,2,*], Matthew D. Davis[1], and Donald D. Davis[1]

Abstract - *Ailanthus altissima* (Tree of Heaven), an invasive tree species native to China and East Asia, was first introduced into the US ca. 1784 by William Hamilton at his Philadelphia, PA estate. However, the means and temporal progression of spread from this and other early points of introduction are not clear. This species now occurs in >40 US states, primarily as an urban and roadside weed. The Northeast supports the highest densities of *Ailanthus* within the US, mainly in transportation corridors and urban areas, where it has become the dominant tree species. A recent, widespread increase in *Ailanthus* incidence in eastern hardwood forests, not unlike prior invasions along railways and roadsides, suggests that current conditions favor invasion in natural environments. To help elucidate the life history of *Ailanthus* in Pennsylvania and the northeastern US, as well as answer fundamental biological questions concerning this species, we conducted dendrochronological (tree-ring) studies and floristic surveys beginning in 2010. Although we studied population dynamics, age structure, and tree-ring characteristics of *Ailanthus* primarily in Pennsylvania, we supplemented our studies using trees from adjacent north-

Journal of the Torrey Botanical Society 135(2), 2008, pp. 260–271

Assessing the influence of historical factors, contemporary processes, and environmental conditions on the distribution of invasive species[1]

Robert I. McDonald[2]
Graduate School of Design, Harvard University, Cambridge, MA 02138

Glenn Motzkin and David R. Foster
Harvard Forest, Harvard University, Petersham, MA 01366

McDonald, R. I. (Graduate School of Design, Harvard University, Cambridge, MA 02138), G. Motzkin and D. R. Foster (Harvard Forest, Harvard University, Petersham, MA 01366). Assessing the influence of historical factors, contemporary processes, and environmental conditions on the distribution of invasive species. *J. Torrey Bot. Soc.* 135: 260–271. 2008.—Despite concern over potential detrimental effects of non-native invasive species on human and natural systems, the factors controlling regional distributions of invasive species remain unresolved. Few studies have evaluated the influence of both environmental factors and disturbance history on invasive species distributions, or assessed synthetically the importance of landscape-level disturbances like historical land-use, forest harvesting, and contemporary forest fragmentation. We analyzed vegetation, soils, and recent and historical land-use and landscape context for forests across central and western Massachusetts to identify controls on invasive species distributions. Almost half (49.3%) of 148 randomly selected sites had at least one non-native invasive plant present, and invasive species occurred more frequently on former agricultural sites than in continuous woodlands. We used logistic regression to model the probability of finding the four most common species: Japanese barberry (*Berberis thunbergii* DC), glossy buckthorn (*Rhamnus frangula* L.), multiflora rose (*Rosa multiflora* Thunb. ex Murr.), and oriental bittersweet (*Celastrus orbiculata* Thunb.). Soil richness was the most important predictor of invasive presence, with rich soils (i.e., lower C:N) being more likely to have these species. The structure of the current forested landscape (i.e., the amount of forest within a 10 km buffer around a site) is also important, with sites that are surrounded by more forest being less likely to have invasives. After accounting for variation in C:N ratios and the structure of the current forested landscape, historical land-use was not a significant predictor of non-native species occurrence; however, C:N ratios may be influenced by historical land-use and by current vegetation, thus complicating interpretations of this edaphic variable. Recent forest harvesting increased the likelihood of invasive occurrence for some but not all species. Overall, our results suggest that regional patterns of invasive plant distributions result from a complex function of edaphic conditions, and present and historical land-uses.

"[In Pennsylvania] the most significant *Ailanthus* invasions closely followed large scale clearcuts in the aftermath of oak roller defoliation as well as subsequent salvage logging following statewide gypsy moth defoliations…" (Kasson et al. 2013)

"[In Massachusetts] more intensive harvests were more likely to have *Berberis thunbergii* and *Rosa multiflora*" McDonald et al. 2008

Unmanaged forests are generally far more resilient than we realize: tree regeneration and deer

Adaptation

"As trees mature and die, or topple over during storms, gaps in the canopy become larger and more numerous. There are no young trees to fill the gaps."
Rawinski, TJ 2008. *Impacts of White-Tailed Deer Overabundance in Forest Ecosystems: An Overview*

2003

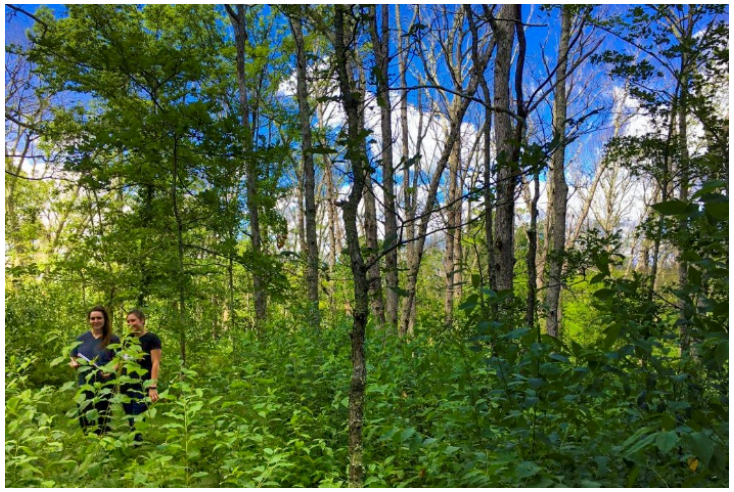
2018

Uttertown Forest,
New Jersey

(photos by Neil Pederson)

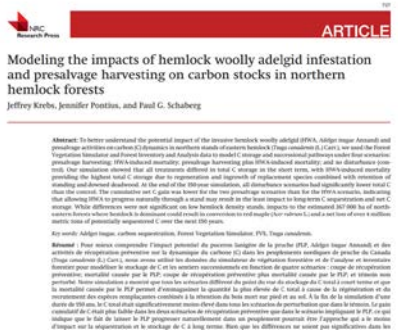
Forest stressors result in a host of benefits: dense regeneration, diversity of structures, abundant dead wood, and habitat for shrubland species

Adaptation



https://today.uconn.edu/2019/06/uconn-collaborates-gypsy-moth-cleanup/
T. Worthley photo

Photo by Santoro and Laflower 2018



ARTICLE

Modeling the impacts of hemlock woolly adelgid infestation and presalvage harvesting on carbon stocks in northern hemlock forests

Jeffrey Krebs, Jennifer Pontius, and Paul G. Schaberg

"…our results suggest that allowing the insect [HWA] to progress naturally may have lower impacts on long-term net Carbon flux than conducting presalvage harvests over the next 50 years" (Krebs et al. 2017)

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Structural, compositional, and functional responses to tornado and salvage logging disturbance in southern New England hemlock-hardwood forests

Jennifer A. Santoro, Anthony W. D'Amato

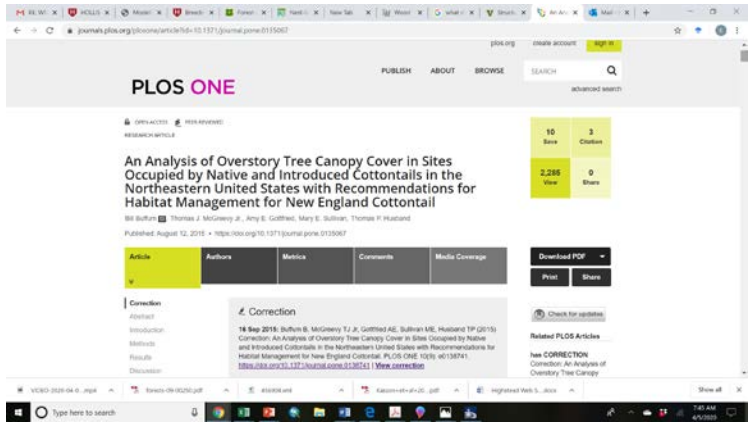
"tree regeneration layer diversity…was higher in the tornado-damaged sites than salvaged sites, but levels of sapling density and richness were the same" (Santoro and D'Amato 2019)

Forest stressors also benefit rare species

New England Cottontail
IUCN red list “vulnerable”

“…the New England cottontail is not limited to…young forests as other authors have suggested, but also occupies sites in maturing forests with overstory canopy cover of up to 80%”

“more New England cottontail [were detected]in the 61%-80% tree canopy class than any other canopy class” Buffum et al. 2015



Insect outbreaks often do not increase fire risk and may reduce it

"Interestingly, many…studies have found that insect outbreaks **reduce** the risk of fire (e.g., Flower et al. 2014, Meigs et al. 2016) or **do not affect it** at all (e.g.,Hart et al. 2015). Similarly, a…study in the eastern spruce budworm system also found no evidence for an effect of defoliation on area burned (James et al. 2011)." (James et al. 2017. *Ecological Applications)*

Ecological Applications, 27(2), 2017, pp. 532–544

Lagged cumulative spruce budworm defoliation affects the risk of fire ignition in Ontario, Canada

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Abstract. Detailed understanding of forest disturbance interactions is needed for effective forecasting, modelling, and management. Insect outbreaks are a significant forest disturbance that alters forest structure as well as the distribution and connectivity of combustible fuels at broad spatial scales. The effect of insect outbreaks on fire activity is an important but contentious issue with significant policy consequences. The eastern spruce budworm (*Choristoneura fumiferana*) is a native defoliating insect in eastern North America whose periodic outbreaks create large patches of dead fir and spruce trees. Of particular concern to fire and forest managers is whether these patches represent an increased fire risk, if so, for how long, and how the relationship between defoliation and fire risk varies through space and time. Previous work suggests a temporary increase in flammability in budworm-killed forests, but regional and seasonal variability in these relationships has not been examined. Using an extensive database on historical lightning-caused fire ignitions and spruce budworm defoliation between 1963 and 2000, we assess the relative importance of cumulative defoliation and fire weather on the probability of ignition in Ontario, Canada. We modeled fire ignition using a generalized additive logistic regression model that accounts for temporal autocorrelation in fire weather. We compared two ecoregions in eastern Ontario (Abitibi Plains) and western Ontario (Lake of the Woods) that differ in terms of climate, geomorphology, and forest composition. We found that defoliation has the potential to both increase and decrease the probability of ignition depending on the time scale, ecoregion, and season examined. Most importantly, we found that lagged spruce budworm defoliation (8–10 yr) increases the risk of fire ignition whereas recent defoliation (1 yr) can decrease this risk. We also found that historical defoliation has a greater influence on ignition risk during the spring than during the summer fire season. Given predicted increases in forest insect activity due to global change, these results represent important information for fire management agencies that can be used to refine existing models of fire risk.

Key words: boreal forest; disturbance interactions; forest fire; forest management; general additive model;

"to date most available evidence indicates that bark beetle outbreaks do not substantially increase the risk of active crown fire in…forests under most conditions" (Black et al. 2013. *Natural Areas Journal)*

CONSERVATION ISSUES

Do Bark Beetle Outbreaks Increase Wildfire Risks in the Central U.S. Rocky Mountains? Implications from Recent Research

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ABSTRACT: Appropriate response to recent, widespread bark beetle (*Dendroctonus* spp.) outbreaks in the western United States has been the subject of much debate in scientific and policy circles. Among the proposed responses have been landscape-level mechanical treatments to prevent the further spread of outbreaks and to reduce the fire risk that is believed to be associated with insect-killed trees. We review the literature on the efficacy of silvicultural practices to control outbreaks and on fire risk following bark beetle outbreaks in several forest types. While research is ongoing and important questions remain unresolved, to date most available evidence indicates that bark beetle outbreaks do not substantially increase the risk of active crown fire in lodgepole pine (*Pinus contorta*) and spruce (*Picea engelmannii*/*P. glauca*) (*Abies* spp.) forests under most conditions. Instead, active crown fires in these forest types are primarily contingent on dry conditions rather than variations in stand structure, such as those brought about by outbreaks. Preemptive thinning may reduce susceptibility to small outbreaks but is unlikely to reduce susceptibility to large, landscape-scale epidemics. Once beetle populations reach widespread epidemic levels, silvicultural strategies aimed at stopping them are not likely to reduce forest susceptibility to outbreaks. Furthermore, such silvicultural treatments could have substantial, unintended short- and long-term ecological costs associated with road access and an overall degradation of natural areas.

Index terms: bark beetles, *Dendroctonus*, forest health, forest management, wildfire

INTRODUCTION

Forests in the western United States are being affected by the largest outbreaks of bark beetles in at least a century, which has caused concern about forest health and wildfire risk and led to proposals for tree removal in natural areas such as roadless forests. Such proposals stem in part from the rationale that bark beetle outbreaks increase wildfire risks due to increased dead fuels and that widespread treatment in beetle-affected forests is needed to lower such risks. Here, we review available peer-reviewed literature to determine if: (1) bark beetle outbreaks are associated with a higher incidence of wildfires in forest types in the central Rockies and (2) if silvicultural treatments are effective at lowering beetle-associated tree mortality before, during, and after outbreaks. We briefly review the impacts that additional logging roads associated with broad-scale tree removal may have on the ecology of roadless natural areas. Our results may have broader policy implications in western forests as concerns over insect outbreaks have led to proposals to reduce environmental protections in favor of widespread thinning and post-disturbance tree removal.

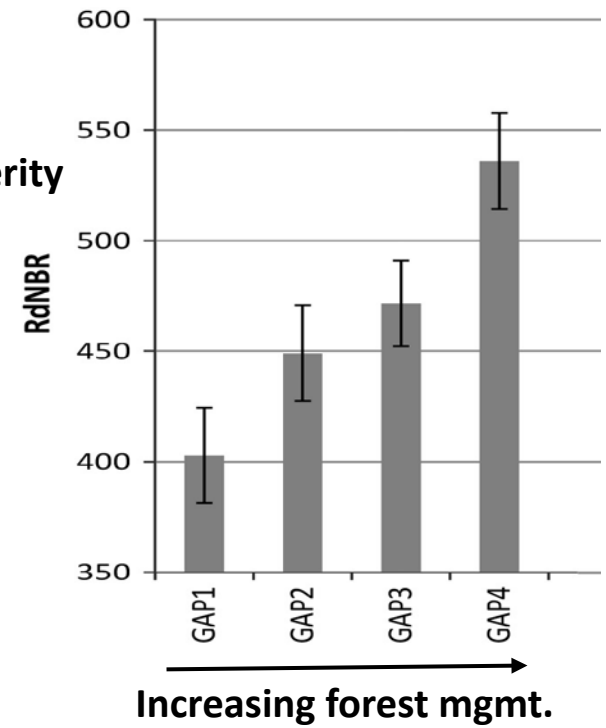
INTERACTIONS AMONG FOREST INSECTS AND FIRES

We examined the long-standing belief that insect outbreaks lead to increased risk of fire (USDA Forest Service 2011). A [illegible] since the outbreak occurred (Romme et al. 2006). For example, it is reasonable to expect that foliar moisture in trees killed by beetles will decrease and canopy density will be reduced during and immediately after an outbreak. In subsequent years, canopy density may be further reduced as dead needles and small branches fall

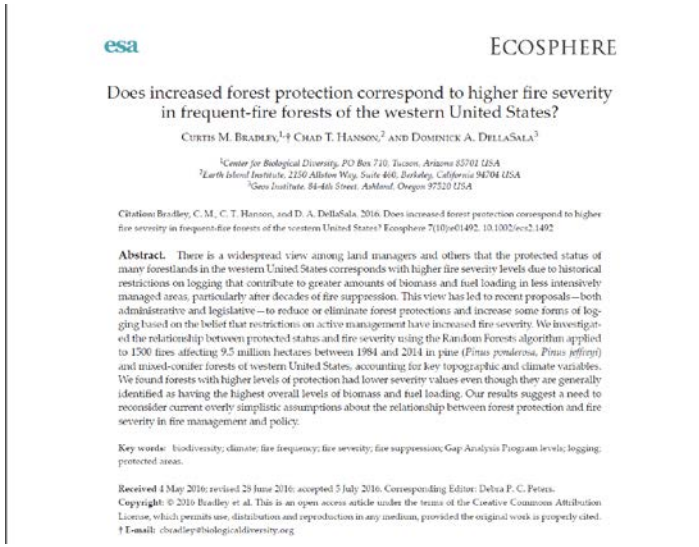
since of large, severe fires in subalpine lodgepole pine (*Pinus contorta*), and spruce (*Picea engelmannii*)-fir (*Abies* spp.) forests is strongly contingent on climatic conditions, especially drought (e.g., Kipfmueller and Baker 2000, Romme et al. 2006, Sibold and Veblen 2006, Schoennagel et al. 2007, Jenkins et al. 2008, Simard et al. 2008, 2011).

The debate on how outbreaks affect fire risk and hazard is ongoing, but recent work emphasizes that the effect of outbreaks on subsequent fire risk is complex and is contingent on time since last outbreak and on biophysical setting. To date, the majority of studies have found no increase in fire occurrence, extent, or severity following outbreaks of spruce beetle (*Dendroctonus rufipennis*) and mountain pine beetle (*Dendroctonus ponderosae*) in Colorado, Wyoming, and other areas (Bebi et al. 2003, Kulakowski et al. 2003, Bigler et al. 2005, Kulakowski and Veblen 2007, Jenkins et al. 2008, Simard et al. 2008, 2011).

Less management often reduces the risk of fire severity



Adapted from Bradley et al. 2016



esa ECOSPHERE

Does increased forest protection correspond to higher fire severity in frequent-fire forests of the western United States?

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Abstract. There is a widespread view among land managers and others that the protected status of many forestlands in the western United States corresponds with higher fire severity levels due to historical restrictions on logging that contribute to greater amounts of biomass and fuel loading in less intensively managed areas, particularly after decades of fire suppression. This view has led to recent proposals—both administrative and legislative—to reduce or eliminate forest protections and increase some forms of logging based on the belief that restrictions on active management have increased fire severity. We investigated the relationship between protected status and fire severity using the Random Forests algorithm applied to 1500 fires affecting 9.5 million hectares between 1984 and 2014 in pine (*Pinus ponderosa, Pinus jeffreyi*) and mixed-conifer forests of western United States, accounting for key topographic and climate variables. We found forests with higher levels of protection had lower severity values even though they are generally identified as having the highest overall levels of biomass and fuel loading. Our results suggest a need to reconsider current overly simplistic assumptions about the relationship between forest protection and fire severity in fire management and policy.

Key words: biodiversity; climate; fire frequency; fire severity; fire suppression; Gap Analysis Program; logging; protected areas.

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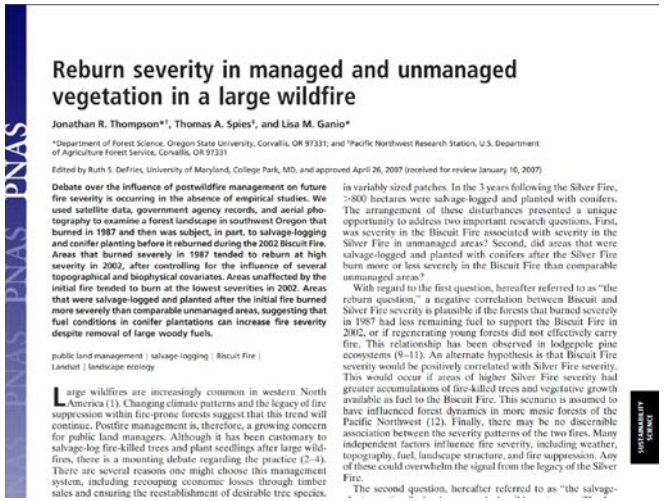

PNAS

Reburn severity in managed and unmanaged vegetation in a large wildfire

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Debate over the influence of postwildfire management on future fire severity is occurring in the absence of empirical studies. We used satellite data, government agency records, and aerial photography to examine a forest landscape in southwest Oregon that burned in 1987 and then was subject, in part, to salvage-logging and conifer planting before it reburned during the 2002 Biscuit Fire. Areas that burned severely in 1987 tended to reburn at high severity in 2002, after controlling for the influence of several topographical and biophysical covariates. Areas unaffected by the initial fire tended to burn at the lowest severities in 2002. Areas that were salvage-logged and planted after the initial fire burned more severely than comparable unmanaged areas, suggesting that fuel conditions in conifer plantations can increase fire severity despite removal of large woody fuels.

public land management | salvage-logging | Biscuit Fire | Landsat | landscape ecology

Large wildfires are increasingly common in western North America (1). Changing climate patterns and the legacy of fire suppression within fire-prone forests suggest that this trend will continue. Postfire management is, therefore, a growing concern for public land managers. Although it has been customary to salvage-log fire-killed trees and plant seedlings after large wildfires, there is a mounting debate regarding the practice (2–4). There are several reasons one might choose this management system, including recouping economic losses through timber sales and ensuring the reestablishment of desirable tree species, in variably sized patches. In the 3 years following the Silver Fire, >800 hectares were salvage-logged and planted with conifers. The arrangement of these disturbances presented a unique opportunity to address two important research questions. First, was severity in the Biscuit Fire associated with severity in the Silver Fire in unmanaged areas? Second, did areas that were salvage-logged and planted with conifers after the Silver Fire burn more or less severely in the Biscuit Fire than comparable unmanaged areas?

With regard to the first question, hereafter referred to as "the reburn question," a negative correlation between Biscuit and Silver Fire severity is plausible if the forests that burned severely in 1987 had less remaining fuel to support the Biscuit Fire in 2002, or if regenerating young forests did not effectively carry fire. This relationship has been observed in lodgepole pine ecosystems (9–11). An alternate hypothesis is that Biscuit Fire severity would be positively correlated with Silver Fire severity. This would occur if areas of higher Silver Fire severity had greater accumulations of fire-killed trees and vegetative growth available as fuel to the Biscuit Fire. This scenario is assumed to have influenced forest dynamics in more mesic forests of the Pacific Northwest (12). Finally, there may be no discernible association between the severity patterns of the two fires. Many independent factors influence fire severity, including weather, topography, fuel, landscape structure, and fire suppression. Any of these could overwhelm the signal from the legacy of the Silver Fire.

The second question, hereafter referred to as "the salvage-

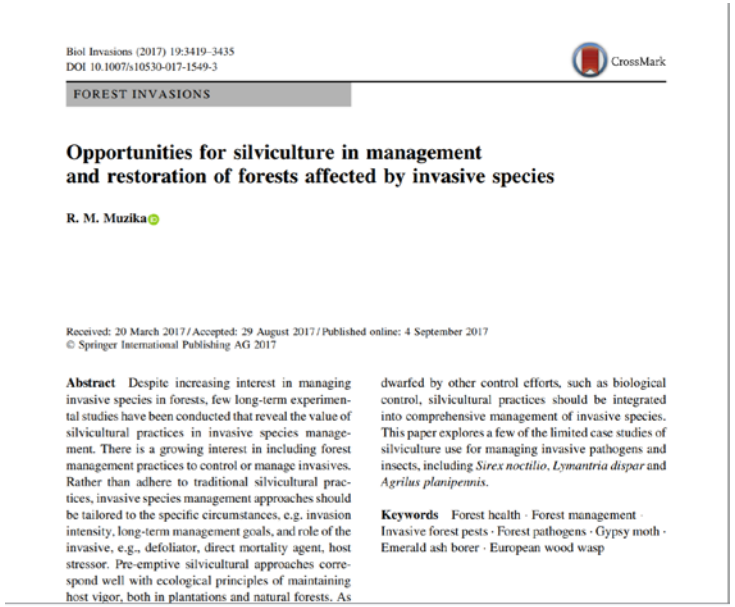
SUSTAINABILITY SCIENCE

"Areas that were salvage-logged and planted after the initial fire burned more severely than comparable unmanaged areas" Thompson et al. 2006 PNAS

Preemptive management for resilience: uncertain success and the 'cure' may be worse than the stressor

Adaptation

"Evidence of successful use of silviculture to minimize damage from invasive species remains limited…Despite decades of research and extensive implementation, there remains uncertainty about how successful these established approaches are for limiting damage" (Muzika 2017)



Biol Invasions (2017) 19:3419–3435
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FOREST INVASIONS

Opportunities for silviculture in management and restoration of forests affected by invasive species

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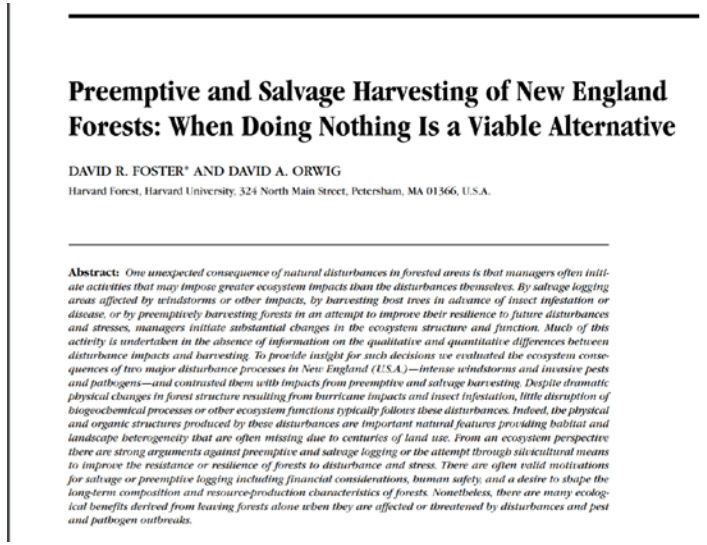
Abstract Despite increasing interest in managing invasive species in forests, few long-term experimental studies have been conducted that reveal the value of silvicultural practices in invasive species management. There is a growing interest in including forest management practices to control or manage invasives. Rather than adhere to traditional silvicultural practices, invasive species management approaches should be tailored to the specific circumstances, e.g. invasion intensity, long-term management goals, and role of the invasive, e.g., defoliator, direct mortality agent, host stressor. Pre-emptive silvicultural approaches correspond well with ecological principles of maintaining host vigor, both in plantations and natural forests. As dwarfed by other control efforts, such as biological control, silvicultural practices should be integrated into comprehensive management of invasive species. This paper explores a few of the limited case studies of silviculture use for managing invasive pathogens and insects, including *Sirex noctilio*, *Lymantria dispar* and *Agrilus planipennis*.

Keywords Forest health · Forest management · Invasive forest pests · Forest pathogens · Gypsy moth · Emerald ash borer · European wood wasp

"…little evidence exists to suggest that it is possible to manage for increased resistance or resilience to the array of disturbances and stresses that temperate forests may experience. Many studies suggest that forests are…more vulnerable to exogenous impacts following management" (Foster and Orwig 2006)



Preemptive and Salvage Harvesting of New England Forests: When Doing Nothing Is a Viable Alternative

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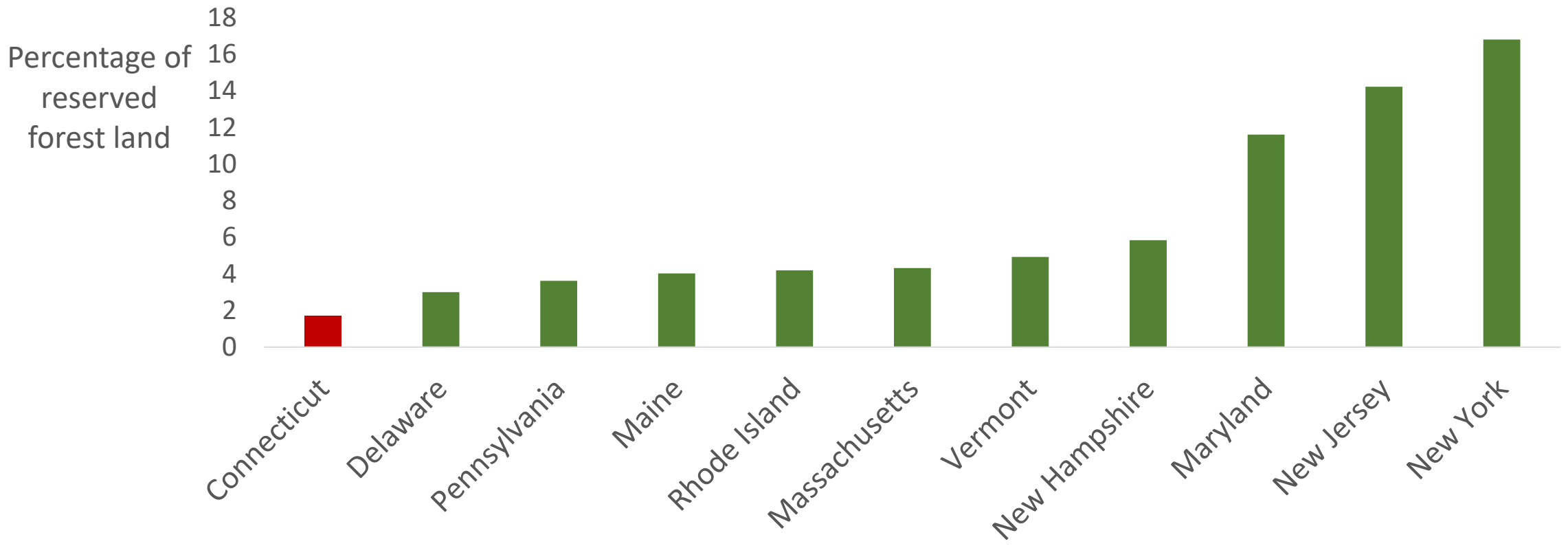
Abstract: *One unexpected consequence of natural disturbances in forested areas is that managers often initiate activities that may impose greater ecosystem impacts than the disturbances themselves. By salvage logging areas affected by windstorms or other impacts, by harvesting host trees in advance of insect infestation or disease, or by preemptively harvesting forests in an attempt to improve their resilience to future disturbances and stresses, managers initiate substantial changes in the ecosystem structure and function. Much of this activity is undertaken in the absence of information on the qualitative and quantitative differences between disturbance impacts and harvesting. To provide insight for such decisions we evaluated the ecosystem consequences of two major disturbance processes in New England (U.S.A.)—intense windstorms and invasive pests and pathogens—and contrasted them with impacts from preemptive and salvage harvesting. Despite dramatic physical changes in forest structure resulting from hurricane impacts and insect infestation, little disruption of biogeochemical processes or other ecosystem functions typically follows these disturbances. Indeed, the physical and organic structures produced by these disturbances are important natural features providing habitat and landscape heterogeneity that are often missing due to centuries of land use. From an ecosystem perspective there are strong arguments against preemptive and salvage logging or the attempt through silvicultural means to improve the resistance or resilience of forests to disturbance and stress. There are often valid motivations for salvage or preemptive logging including financial considerations, human safety, and a desire to shape the long-term composition and resource-production characteristics of forests. Nonetheless, there are many ecological benefits derived from leaving forests alone when they are affected or threatened by disturbances and pest and pathogen outbreaks.*

Connecticut is ranked last in the northeastern US in ‘reserved’ forests – public lands protected from management



Reserved forest - permanently prohibited from being managed for the production of wood products through statute or agency mandate; prohibition cannot be changed through decision of the land manager. [However] logging may occur to meet protected area objectives” (O’Connell et al. 2015).

Data from USDA Forest Inventory and Analysis Program. 2019

Summary and Recommendations

1. Set aside **a lot** more forest land as unmanaged reserves to **store the most carbon (mitigation)** and **to create the most complex and diverse forests** (**adaptation**)

-- e.g., 50% of state, county, and municipal lands protected as reserves = 14-15% of CT's total forest area.
(Connecticut should be a leader in forest reserve protection, not bringing up the rear)

-- Prohibit management after natural disturbance (windstorms, insect/pathogen outbreaks, fire etc.) in forest reserves
Natural disturbances will:

-- provide habitat diversity in the forest
-- better resist invasive plant species than managed areas
-- store abundant carbon in deadwood,
-- have far less ecosystem impacts than pre or post salvage harvesting
-- have little effect on the forest's ability to recover

2. Increase afforestation on abandoned agricultural land, vacant lots, and other unused fields

3. Continue to manage some of Connecticut's forests for **local** wood products.