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Northern Research Station Scientists Answer Fundamental Questions about Mixedwood Forests

The Mixedwooders: Research Scientists Make Remarkable Connections Across Eastern North America

Today, more than one-quarter of forests in the northeastern and north-central United States are characterized as mixedwoods—a mixture of hardwoods, like oak (*Quercus*) and maple (*Acer*), and softwoods, like pine (*Pinus*) and hemlock (*Tsuga*), with neither type making up more than 80 percent of forest composition. These temperate mixedwood forests spread across nearly 47 million acres in the United States, from North Dakota to Maine and Kansas to Maryland. Yet despite their prevalence, there is much to be learned about temperate mixedwood forests. A group of Northern Research Station (NRS) scientists is working to fill in the gaps. "We call ourselves the Mixedwooders," Laura Kenefic explains. A research forester and team leader based in Maine, Kenefic was tapped in 2014 by NRS leadership, along with NRS research forester John Kabrick in Missouri, to study the northeastern temperate mixedwood forests. Since then, Kenefic and Kabrick have made wide-ranging connections with other research scientists, building a team of partners across the region, from Quebec to Wisconsin to New Jersey. This team of partners includes: Anthony D'Amato, Kenneth Clark, Daniel Dey, Christel Kern, Benjamin Knapp, David MacLean, Patricia Raymond, Nicole Rogers, Lance Vickers, and Justin Waskiewicz. "We could have just looked at a certain mixedwood forest type," Kenefic says, "but we thought, 'this is an integrative concept.' Our approach allows us to make linkages across multiple forest types (and regions) so that we can answer questions at a broader scale."

The foundational work of the NRS mixedwood team is showcased in a recent special issue developed by the Canadian Journal of Forest Research. In four papers, Kenefic and Kabrick, as well as Christel Kern (NRS research forester in Wisconsin) and Ken Clark (NRS research forester in New Jersey), explore the distribution, composition, health, and management of temperate mixedwood forests across eastern North America.

MANAGEMENT CONSIDERATIONS

- Even though mixedwoods currently make up more than one-quarter of forests in the northern United States, a bottleneck in regeneration and recruitment of softwoods has signaled a potential shift to hardwood dominance across the region.
- Foresters need to consider the vertical direction of natural disturbance regime. Mismatching "above" and "below" management actions can lead to instability in mixedwood stands.
- Mixedwood forests are more resilient to, and recover more quickly from, insect infestations. This is particularly significant given the dramatic impact of defoliation and tree mortality on a stand's ability to sequester carbon, which may be reduced to just 20-30 percent of pre-infestation rates.
- Common management recommendations across mixedwood forest types include managing small trees with an eye towards regeneration and recruitment of softwoods, considering species composition during every entry, and managing "two-rotation" species on a longer timeframe.

The Mixedwooders meet at a research site in southern Quebec to examine the effects of different methods for regenerating balsam fir-yellow birch stands. USDA Forest Service photo by John Kabrick.

"What strikes me about this collective body of work is the remarkable connections," says Kabrick. Kenefic agrees. "We found so many common threads," she says. "Folks were working in different places on seemingly different topics, yet it turned out they were actually working on very similar things."

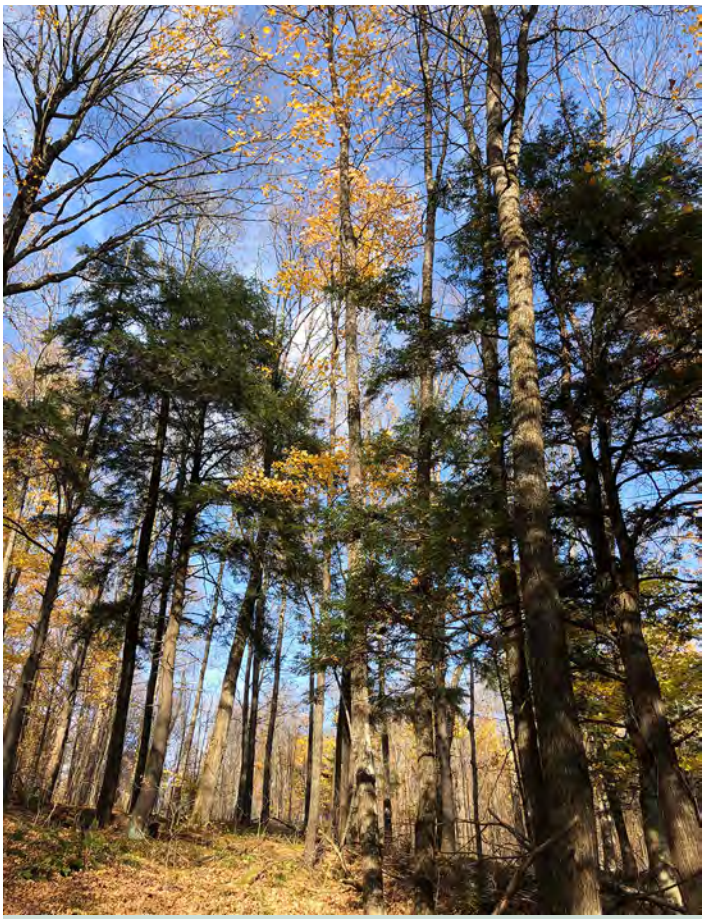
Mapping Northern Mixedwood Forests

Kabrick worked with Lance Vickers and Benjamin Knapp, both from the University of Missouri's School of Natural Resources, to analyze Forest Inventory and Analysis (FIA) data to better understand the abundance and distribution of temperate mixedwood forests across the northeastern United States. "We wanted to provide a basis for understanding how extensive these mixedwood systems are today," Kabrick explains. In examining FIA data, they determined that mixedwood forests are widely found across the northern United States, most commonly in the Adirondack-New England, Laurentian, and Northeast ecological provinces, but also elsewhere in hardwood-dominated ecological provinces. In these mixtures, oak and maple are the most frequently occurring hardwoods, while pine, hemlock, and juniper (*Juniperus*) are the most abundant softwoods.

The analyses also reveal the potential for change ahead. Absent the disturbances that favor regeneration of softwoods and a prominence of hardwood saplings, many mixedwood forests may eventually shift to hardwood dominance. "The data we're seeing through the FIA and other sources suggest that there's a bottleneck in regeneration and recruitment, with mixedwood forests trending towards hardwoods in most locations," says Kabrick. "We need to address this to make sure we have mixedwoods in the future." This work also noted the impact of harvesting on the composition of mixedwood forests, with harvesting frequently prompting a shift to either hardwood or softwood dominance. According to Kabrick, maintaining mixedwood forests in the northeastern states is a critical endeavor. "Mixedwood forests provide so many benefits in terms of resistance and resilience to contemporary and anticipated pests and diseases, and in dealing with projected climate changes," he says.

A New Conceptual Model Guides Mixedwood Management

In her work, Christel Kern examined compositional stability within mixedwood systems to better understand how these forests perpetuate and why they shift away from mixed composition. "Species composition influences the goods and services we expect from forests," Kern explains. "If composition changes, what we expect from these forests changes, too, from wildlife habitat to economic values." Yet, managing mixedwood forests, which by definition contain a mixture of species groups, can be challenging, with recent studies (such as Kabrick's) indicating the potential for widespread shifts to hardwood dominance.



This second-growth hemlock-hardwoods forest in northern Wisconsin regenerated after forest clearing roughly 100 years ago. The stand is now dominated by hardwoods, except for a few pockets of softwoods. The primary disturbance for this mixedwood type is wind, a disturbance from above, with today's chronic browsing, a disturbance from below, keeping the stand from returning to a mixedwood composition. USDA Forest Service photo by Christel Kern.

In her investigation, Kern and others looked at different mixedwood forest types across eastern North America to examine ideas about both high stability (mixedwood forests that experience high levels of disturbance yet remain the same) and sensitive (mixedwood types like pine-oak whose composition is easily altered by disturbance) forests. In pursuing this research, Kern wanted to know: given that mixedwood forests will be disturbed, can foresters capitalize on disturbance principles to manage and stabilize mixed composition?

In addressing this question, Kern and others developed a new conceptual model, which can help foresters match their management actions to the disturbance characteristics of different mixedwood forest types. "We wanted to create an umbrella ecological understanding that could be broken down to build more specific management regimes and conservation practices to maintain mixedwood forests on the landscape," Kern says. According to this new model, both the disturbance severity and its vertical direction are essential to understanding stability in mixedwood forests. "For example," Kern writes,

"where moderate-severity surface fires (which impact forests from below) cease and are replaced by moderate-severity blowdowns (which impact forests from above), instability can occur even when disturbance severity is unchanged." With this knowledge, foresters may choose to alter their management techniques, considering whether a specific practice is an "above" or "below" disturbance, such as clearcutting or prescribed burning.

With this model, Kern hopes that foresters can gain a better understanding of the relationship between compositional stability and disturbance in mixedwood forests, as well as deepening their own knowledge about the impact of their management actions in maintaining or altering forest composition.

Mixedwood Forests Prove More Resistant (and Resilient) to Insect Infestations

Ken Clark, who has spent the last 15 years studying tree vulnerability to insect infestations in forests of high and low species diversity, has recently turned his attention to mixedwood forests, with significant results. In balsam fir (*Abies balsamea*) and spruce (*Picea*) forests, Clark and David MacLean of the University of New Brunswick examined susceptibility and vulnerability to spruce budworms; in mid-Atlantic forests, Clark documented oak mortality following *Lymantria dispar dispar* infestations and pine mortality following southern pine beetle infestations. In all three cases, a more mixed composition—balsam fir and spruce forests with increasing hardwood density and oak-pine mixedwoods—indicated greater resistance to insect infestations. "If you're living with unrelated neighbors, you're safer," Clark explained. "This makes it harder [for trees in mixedwood stands] to be detected and damaged by forest insects."

Clark also found that these mixedwood types recover more rapidly following insect disturbances, allowing these forests to more quickly return to sequestering carbon, a noteworthy characteristic that Clark explores further in a recently submitted paper, which also reduces economic losses. "In the mid-Atlantic region, mixedwood forests are equally as productive as oak- and pine-dominated forests in terms of carbon sequestration, yet they recover more rapidly than monogeneric stands" Clark says.

This is particularly significant, as Clark's work has revealed the extreme impact that defoliation and tree mortality, commonly associated with insect infestations, can have on a forest's ability to sequester carbon. Per year, previously infested forests may only take up 20–30 percent of the carbon that they would have prior to defoliation, with this reduced carbon intake sometimes lasting decades. "The biggest surprise [of my work] was just how extensively insects can impact forest carbon dynamics," Clark shares. "On the larger scale, it indicates that those

Southern pine beetle infestations in the Pinelands National Reserve peaked in 2010–2012 and resulted in >80 percent mortality of large pine trees in infested areas. Infestations totaled >19,500 hectare in the Pinelands National Reserve in New Jersey by 2016 and >13,520 hectare in Long Island, New York, by 2019. USDA Forest Service photo by Ken Clark.

millions of acres of western forests that have been impacted by mountain pine beetle, fir engraver, spruce beetle, and other invasive insects, they may not be sinks for carbon dioxide like we think, or maybe they're only very weak sinks and they'll be that way for quite a while. It was a wake-up call: we better do something."

A Framework for Managing Temperate Mixedwoods

In the final paper in the series, Laura Kenefic and others investigated the commonalities shared across distinct temperate mixedwood forest types, an analysis that ultimately allowed them to present a conceptual framework for how to manage these critical, and potentially imperiled, forests. In her examination, Kenefic and her colleagues place temperate mixedwoods into two categories: those with shade-tolerant softwoods maintained by light to moderate disturbances, such as red spruce (*Picea rubens*) or balsam fir in mixtures with northern hardwood species, and those with shade-intolerant to mid-tolerant softwoods maintained by moderate to severe disturbances, such as pine-oak mixtures.

Despite the abundance of mixedwood forests (more than one-quarter of forests in the northern United States are mixedwoods, as shown by Kabrick's work), Kenefic and her colleagues found that these stands often fall short when it comes to regenerating and recruiting softwoods. Different growth rates and longevities also pose problems for these highly diverse forests. "We determined that there were limiting species [for each type of mixedwood forest]," Kenefic explains. "This is the species that is hard to get to persist." Having identified this key commonality, Kenefic and her colleagues were able to develop management recommendations that, with a little bit of tweaking, can be applied across a broad gradient of mixedwoods.

First, Kenefic and her colleagues determined that it was not enough to manage these stands for only large trees. "We have to be thinking about what we are establishing as regeneration," Kenefic says. Once regeneration becomes established, foresters need to take deliberate steps to manage these small trees to avoid a bottleneck in regeneration and recruitment, a reality also noted by Kabrick. Species composition is also key, regardless of forest type. "It doesn't work to wait until you want to regenerate new trees to think about whether you have the necessary seed sources or seedlings to release," Kenefic explains. Instead, foresters need to consider species composition every time they enter a stand. Lastly, Kenefic observed that certain species, whether due to insects, disease, or other disturbances, will almost always be shorter lived compared to others, meaning that foresters will likely have to manage different species on different timeframes. In fact, managers can plan to grow some long-lived "two-rotation" species for at least twice as long as shorter-lived species in the same stands.

Without suitable management, Kenefic warns, mixedwood forests tend to transition to pure hardwood or softwood compositions, especially when disturbance regimes are altered. "This [work highlights] those critical pivot points that should be considered at all stages of management for mixedwoods," Kenefic says.

Time to Get the Word Out about Mixedwood Forests

Over the last decade, these are the fundamental questions the Mixedwooders have asked—and answered—about mixedwood forests in eastern North America. "It was an intellectual challenge to unwrap," Kern says of her work. "We were exploring new concepts and syntheses that did not exist in current literature." Clark continues to study the relationship between mixedwoods, insect infestations, and carbon sequestration, fascinated by all that has yet to be uncovered.

"Could smaller stands of pure hardwoods or softwoods be embedded in a matrix of mixedwood and still avoid insect disturbance?" he wonders. "Would an uneven checkerboard pattern be effective and still economically viable?" For his part, Kabrick is curious to know who else in the country is studying mixedwoods; he'd like to continue growing the Mixedwooders, envisioning the group pursuing even broader and more collective work. "I think we're going to find that a lot more people are working in mixedwoods than we realized," he says. After years of research, Kenefic is excited to see the Mixedwooders' work put into action by foresters. "We're ready to get the word out to folks on the ground," she says.

Project Leads

Ken Clark is a research forester with the Climate, Fire, and Carbon Cycle Sciences unit. Learn more about Clark's work at https://www.nrs.fs.fed.us/people/kennethclark.

John Kabrick is a research forester for the Sustainable Management of Central Hardwood Ecosystems and Landscapes unit. Learn more about Kabrick's work at https://www.nrs.fs.fed.us/people/Kabrick.

Laura Kenefic is a team leader and research forester with the Northern Forest Science and Applications unit. Learn more about Kenefic's work at https://www.nrs.fs.fed.us/people/lkenefic.

Christel Kern is a research forester with the Northern Forest Science and Applications unit. Learn more about Kern's work at https://www.nrs.fs.fed.us/people/Kern.

FURTHER READING

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