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Forest-clearing to create early-successional habitats: Questionable benefits, significant costs

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A campaign is underway to clear established forests and expand early-successional habitats—also called young forest, pre-forest, early seral, or open habitats—with the intention of benefitting specific species. Coordinated by federal and state wildlife agencies, and funded with public money, public land managers work closely with hunting and forestry interests, conservation organizations, land trusts, and private landowners toward this goal. While forest-clearing has become a major focus in the Northeast and Upper Great Lakes regions of the U.S., far less attention is given to protecting and recovering old-forest ecosystems, the dominant land cover in these regions before European settlement. Herein we provide a discussion of early-successional habitat programs and policies in terms of their origins, in the context of historical baselines, with respect to species' ranges and abundance, and as they relate to carbon accumulation and ecosystem integrity. Taken together, and in the face of urgent global crises in climate, biodiversity, and human health, we conclude that public land forest and wildlife management programs must be reevaluated to balance the prioritization and funding of early-successional habitat with strong and lasting protection for old-growth and mature forests, and, going forward, must ensure far more robust, unbiased, and ongoing monitoring and evaluation.

1. Introduction

In this paper we conduct a wide-ranging and integrated assessment of the campaign to expand early-successional forest habitats in two regions of the United States: (1) the Northeast, i.e., New England states (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont) and mid-Atlantic states (New York, Pennsylvania, New Jersey, Maryland, Delaware); and (2) the Upper Great Lakes areas of Michigan, Wisconsin, and Minnesota north and east of the prairie-forest border [see Cochrane and Iltis (2000), Frelich and Reich (2010), Anderson et al. (2018)]. We review the history of forest disturbance and biodiversity research, the genesis of the forest-clearing campaign and the conservation rationales, the contrasts between natural old-growth forests and intensively managed forests, the impacts of forest-clearing projects, and the current balance of activity between forest management and protection. We conclude that instead of intensive and costly management to create additional early-successional habitats, a new "natural" alternative should be considered which would protect and allow the dynamic growth of established aggrading, mature, and old-growth forests alongside maintaining existing early-successional habitats, where appropriate, for targeted species and cultural values. Although the focus of our analysis is two regions, we believe it offers useful lessons for many other parts of the U.S. and world experiencing similar situations (DellaSala et al., 2022b).

1.1. History of forest development and disturbance

Every place on Earth has a dynamic ecological trajectory based on temperature, rainfall, soils, natural disturbances, and other conditions. In the Northeast and Upper Great Lakes regions of the United States the predominant ecological trajectory of the landscape in the absence of intensive human activity is toward "old-growth" forests: a resilient, diverse, carbon-dense, and self-sustaining "shifting mosaic" of tree ages, microhabitats, and native species above and below ground (Pelley, 2009; Thom et al., 2019; Raiho et al., 2022).

For thousands of years before European settlement, vast "primary" forests were inhabited by a thriving Native human population and harbored many exceptionally large trees, and ecosystems that would be characterized as "old-growth" today (Lorimer, 1977; Whitney, 1994; Lorimer and White, 2003). Up to 90% of the Northeast was covered by such forests, and dominated by shade-tolerant and moderately shade-tolerant species (Foster, 1995; Cogbill, 2000; Cogbill et al., 2002; Shuman et al., 2004; Thompson et al., 2013; Foster et al., 2017; Oswald et al., 2020b). Approximately 50–60% of the Upper Great Lakes landscape, and 40–50% of the Southern Great Lakes landscape, consisted of old-growth forests (Cottam and Loucks, 1965;

Frelich, 2002). These percentages in the Great Lakes regions pertain to older even-aged and multi-aged forests (generally more than 120 years old). Old-growth forests in the East include sites with trees more than 380 years old, established in the 1640s and earlier (Lorimer, 1980; McCarthy and Bailey, 1996; Abrams et al., 1998; Abrams and Copenheaver, 1999; Pederson, 2013; Heeter et al., 2019), and studies of remnant old-growth stands indicate they are adapted to long-intervals between catastrophic disturbances. Young trees of late-successional species (e.g., sugar maple, hemlock, beech) released from suppression combined with new seedlings of mid-tolerant tree species (e.g., white pine, yellow birch, American basswood, black cherry, white ash, northern red oak) after windstorms, and high intensity fires in conifer forests or blown down hardwood forests are followed by early-successional shade-intolerant species (e.g., paper birch, quaking, and bigtooth aspen) with some mid-tolerant species as listed above.

The terms "primary forest," "old-growth forest," and "mature forest," are not standardized (Leverett, 1996; Buchwald, 2005; Mackey et al., 2014; DellaSala et al., 2022a). For this analysis, we use the following definitions:

- Primary forest. A forest composed of native species that has never been logged and has developed following natural disturbances and under natural processes, regardless of its age (Kormos et al., 2018; FAO, 2020).
- Old-growth forest. A forest affected primarily by the forces of nature, with dominant canopy tree species at or beyond half their lifespan, and with structural characteristics such as canopy gaps, pit and mounds, large snags, gnarled tree crowns, a thick duff layer, and accumulated large coarse woody debris (Martin, 1992; Frelich, 1995; Dunwiddie and Leverett, 1996; Mosseler et al., 2003b; D'Amato et al., 2006; Mackey et al., 2014; USDA Forest Service and Bureau of Land Management, 2022).
- Mature forest. A forest with trees of intermediate age and lower levels of old-growth structural characteristics, but from which old-growth conditions are likely to develop over time if allowed to continue to grow (Spies and Franklin, 1991, Frelich, 1995; Strittholt et al., 2006; Keeton et al., 2011).

Old-growth forests not only have a high degree of structural diversity, but also contain a wide variety of tree species, herbaceous plants, insects, mosses and fungi, and deep, carbon-rich soil with an associated soil microbiome (Frelich, 1995; Davis, 1996; Lapin, 2005; D'Amato et al., 2009; Maloof, 2023). Permanent and semi-permanent large openings are rare in old-growth forests of these regions, associated mainly with cliffs and scree slopes, ridge tops, wetlands, peat bogs, serpentine barrens, avalanche tracks, river margins, pond and lake margins, and coastal shrublands and bluffs (Whitney, 1994; Foster and Motzkin, 2003; Fraver et al., 2009). Old-growth forests contain

natural gaps of different sizes, which can be location-specific (wet, rocky, sandy) or part of a dynamic ecological trajectory due to disturbances, such as fire, windstorms, beaver activity, and insect outbreaks (Whitney, 1994; Boose et al., 2001; Frelich, 2002; Seymour et al., 2002; D'Amato et al., 2017). As a result the forest ecosystem remains intact and resilient, supporting widespread re-sprouting and recovery of trees.

Openland and early-successional habitats were not common before the arrival of Europeans in the Northeast or Upper Great Lakes (Cooper-Ellis et al., 1999; Foster et al., 2002; Faison et al., 2006; Anderson et al., 2018; Oswald et al., 2020b; Frelich et al., 2021). Early-successional habitats characterized about 1–4.5% of the Northeast, with greater amounts in coastal pine barren communities of Cape Cod, Long Island, and New Jersey (Lorimer and White, 2003). About 32% of the entire states of Minnesota, Wisconsin, and Michigan was represented by early-successional habitats, mostly in the savannas and prairies in the southern and western parts of the region. To the north, early-successional habitats were found in tens of thousands of patches of shorelines, marshes, sloughs, bogs, cliffs, and fire-prone sand plains (Veatch, 1928; Curtis, 1959; Marschner, 1975). Thus, the region had both dense forests and permanently open habitats maintained by the physiography of the landscape, including prairies and savannas maintained before European settlement by frequent fires—now almost absent due to agricultural conversion of the land. It is important to note that these open habitats were not early-successional stages for forests.

Native people living in the Great Lakes and the Northeast practiced subsistence hunting, fishing, and plant gathering, as well as burning and small-scale farming. Their population was less than 1% of the current population and largely centered along the coast and in major river valleys, with localized and modest impacts across most of the region (Whitney, 1994; Lorimer and White, 2003; Milner and Chaplin, 2010; Oswald et al., 2020b; Frelich et al., 2021; Tulowiecki et al., 2022).

The arrival of Europeans generated a radical landscape transformation. Upland areas, densely forested for thousands of years, were cleared for agriculture and kept open by crop cultivation, cattle and sheep grazing, increased burning of (dry) cleared land, and intensive use of remaining woodlands (Foster and Motzkin, 2003; Faison et al., 2006; Rhemtulla and Mladenoff, 2007; Scheller et al., 2008; Curtis and Gough, 2018; Oswald et al., 2020b). By the height of deforestation from 1850 to 80, 30% of northern New England and 40–50% of southern New England had been cleared (Foster et al., 2017), and by 1920 more than 90% of the Upper Great Lakes region was cutover (Greeley, 1925; Frelich, 1995).

Widespread deforestation caused a major shift in vegetation from long-lived and interior forest species to generalist and early-successional species (Thompson et al., 2013; Foster et al., 2017). Many of the latter species had been uncommon before European settlement, others migrated to the region, and some plants that had previously grown only on extreme and rare

sites expanded their distribution and became common "old field" species (Marks, 1983). Early naturalists recognized that populations of some wildlife species had increased greatly due to this abundance of human-created early-successional habitats (Peabody, 1839). By the late 19th century, New England agriculture was declining, leaving countless abandoned and overgrown fields, grasslands, heathlands, and shrublands, as well as old-field white pine forests, and dense sprout woodlands. By the mid–20th century, significant areas of cutover forests were acquired by the public and allowed to begin growing back on state and federal lands (Titus, 1945; Jones, 2011; Knowlton, 2017). Today, millions of acres of forest are a globally significant example of ecological recovery, and the extent of early-successional habitats has declined accordingly (McKibben, 1995; Foster et al., 2002; Litvaitis, 2003; Foster et al., 2017). Consequently, species that depend on early-successional habitats have been returning to more historic levels, including the Bobolink *(Dolichonyx oryzivorus),* Eastern Meadowlark *(Sturnella magna),* Golden-winged Warbler *(Vermivora chrysoptera)*, Yellow-breasted Chat *(Icteria virens)*, and New England Cottontail *(Sylvilagus transitionalis)* (**Figure 1**; Litvaitis, 1993; Foster, 2002; Askins, 2011; Foster, 2017).

Although old-growth forests were the predominant ecological condition before European settlement, they are extremely rare today (Frelich, 1995; Dunwiddie et al., 1996; Davis, 2003; D'Amato et al., 2006; DellaSala et al., 2022b), much less common than younger habitats (**Figure 2**). A few relatively large tracts of old-growth and protected recovering forests survive in New York, Michigan, and Minnesota, but just small fragments remain across vast regions including all of New England. However, many mature forests are poised to transition to old-growth, and some are undergoing this transition (Ducey et al., 2013; Gunn et al., 2014). This can occur through a straightforward process of forest development and maturation.

In the Northeast, forests older than 150 years of age cover only about 0.3% of New England and 0.2% of the Mid-Atlantic region (USDA Forest Service, 2022b). Old-growth forests cover a scant 0.06% of Connecticut (Ruddat, 2022). A Massachusetts survey found a mere 1,100 acres of old-growth forest in 33 small stands, comprising just 0.02% of the land base (D'Amato et al., 2006). Most of the old-growth forest in the Northeast is found in the Adirondack and Catskill parks in New York (Dunwiddie et al., 1996; Davis, 2003; Keeton et al., 2011; New York Department of Environmental Conservation, 2021). In the Upper Great Lakes region, only about 1.9% of the currently forested area remains as primary forest that was never logged. Including secondary forests, approximately 5.5% of the northern hardwood forest type is older than 120 years of age, compared to 89% in the presettlement forest; for red-white pine this is 2.5% versus 55%. For all forest types, about 5.2%
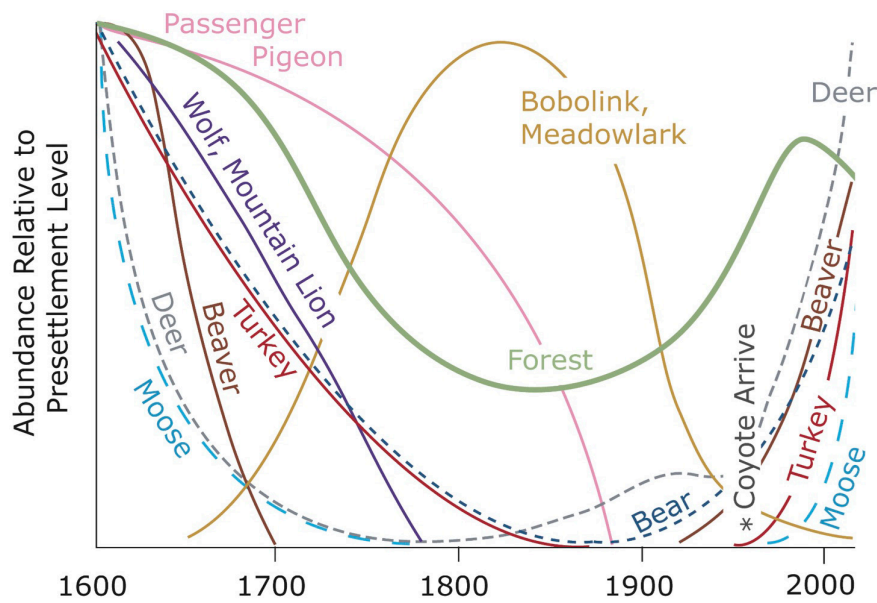
FIGURE 1
Changes in land cover and wildlife dynamics in New England from ∼1600−2000. The green line shows the abundance, decline and then recovery of forest in New England, which paralleled the population changes in moose, beaver, and deer. The inverse trend is found in openland (early-successional) species, typified by bobolink and meadowlark. The inverted U shows the low population densities of these and other early-successional species before European settlement, increasing populations of these species as forests were cleared, and a return to lower populations as the forests have grown back. *The coyote is not native to New England. Adapted from Foster et al. (2002); also see **Figure 2**.

is old-growth compared with 68% before European settlement (Frelich, 1995).

1.2. Genesis and rationales of the early-successional habitat campaign

1.2.1. Genesis of the campaign and the "Young Forest Initiative"

A concerted campaign is working to slow and reverse the natural decline in early-successional habitat and species that accompanied the regional reduction in deforestation, intensive forestry, and agriculture. This campaign is promoting early-successional habitat through multiple activities: clearcutting, "group selection," and other forms of patch clearfelling in established forests; intensive "mechanical treatments" such as brushhogging and mowing; and herbicide application and prescribed fire in successional habitats and younger forests, which are often accompanied by other mechanical treatments (DeGraaf and Yamasaki, 2003; Oehler et al., 2006; American Bird Conservancy, 2007; Schlossberg and King, 2007; King et al., 2011; Yamasaki et al., 2014).

These intensive management activities have long been advocated to benefit popular game species that favor early-successional habitats, such as the American Woodcock (*Scolopax minor*), Ruffed Grouse (*Bonasa umbellus*), and White-tailed Deer (*Odocoileus virginianus*) (Lenarz, 1987;

Caron, 2009; Derosier et al., 2015). In the last decade, an expanded management campaign has included popular non-game species that also use these habitats (see Section "1.2.2 Rationale for forest-clearing: halt the decline of specific wildlife species" below). This campaign involves an increasing number and diversity of agencies and organizations, and captures rising amounts of public money from state and federal sources. The goal is to maintain the recent historical and degraded condition of the natural forests of the region.

A key milestone in the genesis of this campaign was the 2008 American Woodcock Conservation Plan (AWCP; see **Table 1** for Abbreviations), published by the Wildlife Management Institute (WMI) in collaboration with game management agencies and sportsmen's organizations (Kelley et al., 2008). The goal is to increase American Woodcock populations to early 1970s levels by clearcutting 11.2 million acres of forest in the Northeast and Upper Great Lakes regions—an area larger than the state of Maryland. WMI also launched the Upper Great Lakes Woodcock and Young Forest Initiative (YFI) to gain public support for the creation of early-successional habitats in Michigan, Minnesota, and Wisconsin (Wildlife Management Institute, 2009, 2010).

Wildlife Management Institute (WMI) soon began expanding the YFI to a national campaign (Gassett, 2018; Weber and Cooper, 2019). Recognizing the controversial nature of such widespread forest-clearing, the organization hired a marketing firm to "shape an overall communications
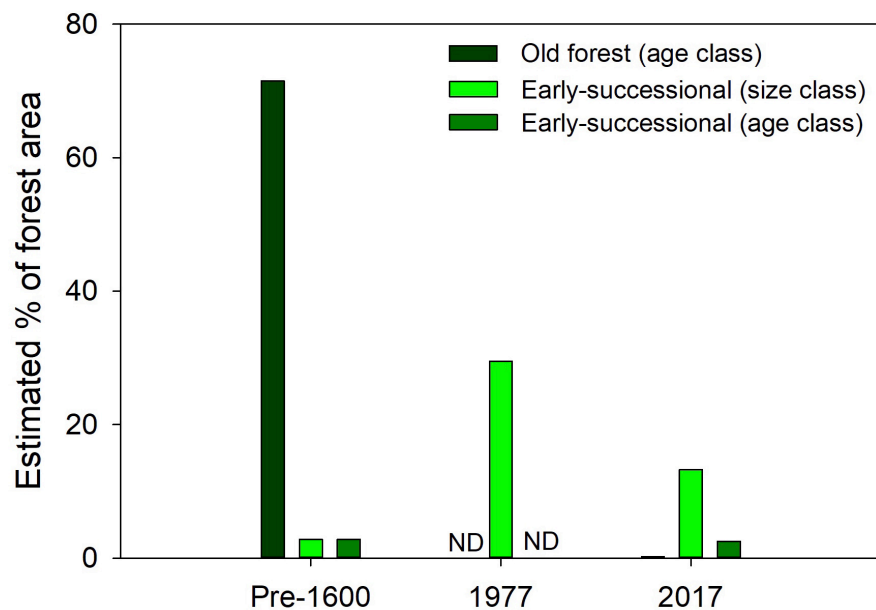
FIGURE 2

Estimated change in average % of early-successional and old forest habitat from pre-European settlement to current times in the Northeast US as extracted from multiple sources. Old forest is defined > 150 years old. The 1600 estimate for early successional forest is based on "seedling-sapling (1–15 years)" age class (Lorimer and White, 2003). The 1977 estimate is based only on "seedling-sapling" size class as reported in Oswalt et al. (2019); age class data were unavailable (ND = no data). Current estimates (2017) reflect two sources: Oswalt et al. (2019) and USDA Forest Service (2022b) wherein early successional forest (size class) reflects "seedling-sapling," the smallest class defined by the USDA Forest Service; and early successional forest (age class) reflects the 1–15 year age class. Note that while early-successional forest declined since 1977, it is similar and perhaps multiple times higher than pre-settlement values; and recent accounting is likely an underestimate: it does not include areas such as highway medians, small patches, or corridors (< 0.4 ha or < 36.5 m wide) that may be found on properties such as golf courses, farms, public and private institutions, and private yards. In contrast, old forest habitat has decreased dramatically (old forest data are barely visible in 2017 on this scale).

strategy" (Seng and Case, 2019). This firm administered opinion surveys and focus groups that showed most forest landowners value beauty, scenery, nature, and biodiversity far more than logging or financial return. A plan was then devised to promote early-successional habitats through an extensive network of partnerships. Terms which focus group participants found unappealing, such as clearcutting, early-successional habitats, shrub, and scrub, were replaced with the more appealing "young forests." Simple and positive language emphasized forest "health," wildlife, habitat diversity, and scientific-sounding outcomes. A pseudo-historical pitch was crafted to emphasize the decline of once common and familiar species without acknowledging the highly artificial and historically anomalous nature of their former abundance (see Table 2 for more details). Numerous publications were produced, such as, "Talking About Young Forests," to help "natural resource professionals…effectively advocate for creating and managing young forest habitat on public and private lands" (Oehler et al., 2013).

In 2012, YFI inaugurated the "youngforest.org" website, aimed at persuading target audiences to support the campaign (Young Forest Project, 2012). Within a decade, the YFI had recruited more than 100 "partners" (Supplementary material 1, Young Forest Project, 2022a). These are primarily traditional forestry and game species management interests, such as timber companies (Lyme Timber Company, 2017; Weyerhaeuser Company, 2020), federal and state forestry agencies (New York Department of Environmental Conservation, 2015; USDA Forest Service, 2018), federal and state wildlife agencies (U.S. Fish and Wildlife Service, 2015c; Connecticut Department of Energy and Environmental Protection, 2021b), and sportsmen's organizations (Russell, 2017; Weber and Cooper, 2019). All of these partners benefit from forest-clearing through increased profits from timber sales, larger agency budgets, more staff, direct payments for creating young forest habitat, or elevated populations of desired game species (see Supplementary material 1 for state-by-state examples of forest-clearing).

The YFI has attracted generous financial support from a wide range of public agencies, private organizations, and large corporations such as Richard King Mellon Foundation, U.S. Forest Service, U.S. Fish and Wildlife Service, American Forest Foundation, and Shell Oil Company [see Connecticut Department of Energy and Environmental Protection (2018); New Jersey Audubon (2018);

TABLE 1 Abbreviations.

AWCP	American Woodcock Conservation Plan.
BBS	North American Breeding Bird Survey.
GAP 1	Gap Analysis Project Status 1. An area permanently protected from conversion of natural land cover, where ecosystems are allowed to function and develop predominantly under the influence of natural processes. Examples include National Parks, Wilderness Areas [see U.S. Geological Survey (2022b)].
GAP 2	Gap Analysis Project Status 2. An area permanently protected from conversion of natural land cover, but which may allow management practices that degrade the quality of existing natural communities. Examples include National Wildlife Refuges, State Parks, and Nature Conservancy preserves [see U.S. Geological Survey (2022b)].
GAP 3	Gap Analysis Project Status 3. An area predominantly protected from conversion of natural land cover, but subject to extractive uses. Examples include National Forests, Bureau of Land Management lands, most State Forests, and some State Parks [see U.S. Geological Survey (2022b)].
GAP 4	Gap Analysis Project Status 4. Lands with no mandates to prevent conversion of natural habitat types to unnatural land cover. Examples include agricultural and developed lands [see U.S. Geological Survey (2022b)].
IUCN	International Union for the Conservation of Nature.
SGCN	Species of Greatest Conservation Need.
SWAP	State Wildlife Action Plan.
WMI	Wildlife Management Institute.
YFI	Young Forest Initiative.

National Fish and Wildlife Foundation (2022b)]. In addition to activities on public lands, money is directed to land trusts (New England Cottontail, 2021) and private landowners (Natural Resources Conservation Service, 2018) through numerous state and federal sources. Much of this activity, supported by the significant money available for forest-clearing for early successional habitats (American Bird Conservancy, 2015; Natural Resources Conservation Service, 2019; Ruffed Grouse Society, 2022), engages broad support

by well-intentioned landowners and conservationists by portraying this clearing as "restoration" to retain or save declining species (Smith, 2017; Weidensaul, 2018). There is little acknowledgment that, although these species are truly declining, they were artificially elevated in their abundance by colonial and relatively modern land-use practices that were abandoned in 19th and especially the 20th century.

Currently, every state in the Northeast receives substantial funding for early-successional habitat projects, either through direct federal programs or shared stewardship agreements (Fergus, 2014; USDA Forest Service, 2021b, 2022e; National Fish and Wildlife Foundation, 2022a; Sharon, 2022; Young Forest Project, 2022b). Even as forests are naturally recovering and helping to mitigate climate change in the absence of intensive logging, the momentum and money to clear forests and create open habitats is growing. For instance, the Infrastructure Investment and Jobs Act (2021) authorizes billions of dollars to increase logging for "wildfire risk reduction," "ecosystem restoration," and production of "mass timber" buildings (Parajuli, 2022; USDA Forest Service, 2022a). These massive programs will significantly increase early-successional forest habitats across the country, including in the Northeast and Upper Great Lakes regions. In contrast, there appear to be few resources devoted to protecting and expanding mature and old-growth forests.

Meanwhile, forest and wildlife managers–and a surprisingly large number of scientists—contend that the campaign to artificially expand early-successional habitats is vital because: (1) numerous wildlife species that depend on these habitats are declining and potentially endangered (Fergus, 2014), (2) the "restoration" of such habitats is needed to halt and reverse this decline (Young Forest Project, 2022c), and (3) the history of the region includes significant disturbance and presence of early successional habitats (Oehler et al., 2006). However, as noted previously, targeted population increases in specific species are mismatched generally with longer historical trends (Figure 1). Below is a more specific review of the rationales for these

TABLE 2 Marketing and communication strategies used by Young Forest Initiative.

Strategies	Recommendations	Actions and outcomes
Identify public values	Mobilize opinion surveys and host focus groups of landowners and the public to identify values. Set up regional pilot campaigns.	Recognize that forest owners and the public value beauty, scenery, nature, and biodiversity more than logging or financial return. Promote these values as enhanced by young forests.
Change language	Avoid terms with negative or unclear or connotations, i.e., "clearcutting," "early successional," "scrub," or "shrub."	Refocus language to emphasize "young forest" and emphasize that "a diversity of wildlife requires a diversity of habitats."
Create websites	Focus on target audiences such as private landowners, conservation professionals, residents of forested communities, and hunters.	Establish the Young Forest Project website as a central information hub that emphasizes benefits and collaboration to promote campaign goals.
Recruit partners	Identify partners with an interest in "young forest" species (i.e., deer, Ruffed Grouse, Wild Turkey, and Golden-winged Warbler).	Use the Young Forest Project website to build an extensive network of "partners" and include links to their websites (see Supplementary 2).
Persuade the public	Promote timber harvesting and active management to create young forests as a benefit to plants and wildlife.	Avoid and diminish negative impacts of clearcutting and focus on how "ugly [clearcuts] grow quickly into beautiful [habitats]."

assertions, along with questions and concerns that have been raised in response.

1.2.2. Rationale for forest-clearing: Halt the decline of specific wildlife species

The primary justification cited for forest-clearing is that populations of many species needing early-successional habitats are declining (King et al., 2001; King and Schlossberg, 2014; Yamasaki et al., 2014; North American Bird Conservation Initiative, 2019; Rosenberg et al., 2019). Monitoring populations of species and preventing decline is a legitimate concern. Failure to take action in the past has allowed many species to become endangered or go extinct. Therefore, if these assertions are true, if losing species is a possibility, and if there are no plausible alternative explanations, a reasonable conclusion is that some species may need additional early-successional habitat to survive and thrive and would therefore justify habitat experiments and intensive habitat management programs to protect these species.

It is important to recognize that documentation of the decline of early-successional species is almost invariably based on a very recent baseline, generally dating to the 1960s or later (DeGraaf and Yamasaki, 2003; Massachusetts Audubon Society, 2013; North American Bird Conservation Initiative, 2014; Rosenberg et al., 2016, 2017, 2019; Connecticut Department of Energy and Environmental Protection, 2019; Sauer et al., 2020; Littlefield and D'Amato, 2022). This time period is a convenient benchmark because it falls within the lived experience of many of today's wildlife and forest managers and the landowners and public that they are trying to reach. It also coincides with the first annual North American Breeding Bird Survey (BBS), which took place in 1966 (Sauer et al., 2013). Prior to this time there was little reliable quantitative information on most bird populations (Foster, 1995; Foster et al., 2002; Dunn et al., 2005).

Although useful in many ways, the BBS is flawed as a truly long-term baseline for bird population trends. An ongoing deficiency is that the BBS is not a representative sampling of the broader landscape: it surveys habitats primarily near secondary roads and leaves out a wide range of habitats (Dunn et al., 2000; Dunn et al., 2005; Sauer et al., 2017). Furthermore, the quality of the data is inconsistent because volunteer observers have varying abilities (Dunn et al., 2000), including age-related declines in bird detection abilities and mobility (Farmer et al., 2014).

Beyond these problems, using a mid–1960s baseline for wildlife populations is fundamentally misguided. Every history of the region shows that at the time of the first BBS the Northeast and Upper Great Lakes regions were (and still are) in transition—with unnaturally high amounts of early-successional habitat such as abandoned farmland and forests recovering from intensive clearing and historically anomalous levels of fire, grazing and other human disturbances (Whitney, 1994; Foster et al., 2002; Mladenoff et al., 2008; Mladenoff and Forrester, 2018). As a result, the 1960s populations of wildlife species that occupied and thrived on such habitats

were likely inflated well beyond what they would be in natural forests before European settlement (Litvaitis, 1993). This set the stage for a decades-long dramatic downward population trend due to recovering landscapes that are not yet within their true ecological trajectories (Massachusetts Audubon Society, 2013; Connecticut Department of Energy and Environmental Protection, 2019; Rosenberg et al., 2019).

Wildlife population trends since the 1960s need to be viewed in the context of a much longer timeframe (Schulte et al., 2005a,b), as has been provided by many superb studies of changes in major tree species for the region (Mladenoff et al., 2008; Thompson et al., 2016). For examples, **Figure 1** spans the period from 1600 to today, displaying dual juxtaposed bell curves—one with forests (and some forest-associated species) steadily declining until the mid–1800s and then recovering through present day, and the other an inverse curve showing early-successional species populations increasing and then declining during that period (Foster et al., 2002). The recovery of the forested landscape may be causing previously inflated early-successional populations to restabilize closer to their natural baseline prior to the arrival of Europeans and under the conditions in which these species evolved.

Despite these caveats, State Wildlife Action Plans (SWAPs) rely heavily on the erroneous 1960s baseline for gauging the status of early-successional species. A SWAP must be filed with the U.S. Fish and Wildlife Service by each state to qualify for a number of major federal grants (The Wildlife Society, 2017). SWAPs include a list of Species of Greatest Conservation Need (SGCN), encompassing species that appear on federal or state lists as threatened or endangered, as well as those which are deemed rare, declining, or vulnerable to decline within that state (Minnesota Department of Natural Resources, 2016). SWAPs are useful sources of information for wildlife managers, but they are limited in scope, focusing on individual species within one state, rather than regional and national biodiversity (Pellerito and Wisch, 2002; Paskus et al., 2015).

With their mid–1900s baseline, SWAPs skew state-level biodiversity policies and programs toward management for conditions of that era. As noted, this is comfortable for wildlife and land managers who grew up during and recently after that time and appeals to many members of the public. However, this has created a false sense of endangerment for early-successional species that: (1) are common and of "least concern" based on International Union for the Conservation of Nature (IUCN) criteria (IUCN, 2012); (2) were historically uncommon (i.e., naturally rare, and at a natural population level); or (3) are non-native (i.e., did not occur in that state prior to European settlement and contribute to under-estimating populations of mature and old-growth forest species). The supposedly grave state of these species is reinforced further by the YFI. For example, its handbook for wildlife managers includes a list of "89 species of wildlife classified as [SGCN] that require young forest habitat to survive and breed" (Oehler et al., 2013).

Although these species use early-successional habitats, only a small number of them are listed under the federal Endangered Species Act (U.S. Fish and Wildlife Service, 2022b), and many of them fall into the following categories:

- They are at the edge of their range in a particular state and were temporarily increased in numbers by past forest-clearing, but are now abundant and widely distributed across their range, such as the Yellow-breasted Chat (*Icteria virens*) in Connecticut or the Prairie Warbler in Massachusetts (Nolan, 1978; Southwell, 2001);
- They were probably rare in, or not native to, a particular state before the arrival of Europeans and moved in as a result of the widespread forest clearing in the 19th century, such as Golden-winged Warbler (Askins, 2011) and Chestnut-sided Warbler (Litvaitis, 1993; Foster et al., 2002) in New England;
- They have declined in population and distribution since the 1960s, but had a limited distribution in the landscape before European settlement, such as the New England Cottontail (*Sylvilagus transitionalis*) (Figure 3; U.S. Fish and Wildlife Service, 2015a);
- They have declined from past unnaturally high mid–20th century populations, but continue to be abundant and widely distributed, such as the American Woodcock (Seamans and Rau, 2018), Northern Bobwhite (*Colinus virginianus*) (Giocomo et al., 2017), Whip-poor-will (*Caprimulgus vociferus*), Bobcat (*Lynx rufus*), Smooth Green Snake *Opheodrys vernalis*), Eastern Buck Moth (*Hemileuca maia*), and Wild Lupine (*Lupinus perennis*) (NatureServe, 2022);
- Their declines can be attributed to other causes besides lack of habitat, such as the impact of West Nile virus on Ruffed Grouse populations (Stauffer et al., 2018);
- They benefit from limited, scientifically-backed habitat management, not forest-clearing, as with restoration of Wild Lupine (*Lupinus perennis*) for the protection of specialist butterflies (Pavlovic and Grundel, 2009; Plenzler and Michaels, 2015).

Including species of questionable "conservation need" on state SGCN lists has helped to validate and encourage forest-clearing and other intensive management to expand early-successional habitats. For instance, a major goal of the Connecticut SWAP is to "keep common species common" (Connecticut Department of Energy and Environmental Protection, 2015), which has been translated into an intensive focus on forest-clearing (Neff, 2017) and is promulgated in agency publications such as "The Clear Cut Advantage" (Connecticut Department of Energy and Environmental Protection, 2013). Many federal and state agencies have goals for significantly expanding early-successional habitats from current levels (USDA Forest Service, 2018; Massachusetts Division of Fisheries and Wildlife, 2022b) without clear plans for monitoring and maintaining the habitat they are creating.

A further problem is that forest-clearing advocates exaggerate the number of species that "require" or "need" early-successional habitat. For instance, the YFI website asserts, without evidence, that, "if we fail to actively create and renew young forest...[m]any songbirds will rarely be seen or heard [and] the New England Cottontail and Appalachian Cottontail could...go extinct (Young Forest Project, 2022c). Another YFI publication claims that, "more than 40...kinds of birds need young forest..." (Fergus, 2014), yet only 12 species of birds in the Northeast are actually considered early-successional forest specialists (Askins, 1993).

Among the species most commonly cited to justify large-scale forest-clearing are the American Woodcock, Ruffed Grouse, Golden-winged Warbler, and New England Cottontail. As discussed in detail in **Supplementary 3**, whether this strategy is necessary or desirable is open to question for each of these species. For example, the woodcock (Seamans and Rau, 2018), grouse (Wiggins, 2006), and cottontail (Fuller and Tur, 2012) are game species subject to being killed by hunters while the cause and potential solutions to warbler declines are uncertain (Streby et al., 2016).

There is a contention that forest-clearing not only "restores" early-successional species, but also benefits many interior species (Chandler et al., 2012; Stoleson, 2013; King and Schlossberg, 2014; Yamasaki et al., 2014; Schlossberg et al., 2018; New Jersey Department of Environmental Protection, 2018). Yet, these claims are based on a few studies that are limited in their targeted species, timeframe, and geographic scope, and rarely examine alternative hypotheses. For instance, although interior forest bird species may use available early-successional habitats to some extent, there is little evidence that such habitats are favored or necessary for their survival (Vega Rivera et al., 1998; Marshall et al., 2003; Dorazio et al., 2015).

Aside from questions regarding its necessity, long-term effectiveness, and unintended consequences, the intense focus on creating and restoring early-successional habitats diverts resources from exploring strategies to address other factors that are known to impact wildlife populations. These factors include food availability, over-hunting, disease, climate change, environmental toxins, and myriad other reasons that are not connected simply to the areal extent of early-successional habitat.

1.2.3. Rationale for forest-clearing: Halt decline of early-successional habitats

Before European settlement, countless small patches of early-successional habitats were created in the forests of the Northeast and Upper Great Lakes regions on a continuing basis, including by wind and ice storms, insect infestations and disease, drought, floods, fire, and to a lesser extent grazing by large mammals (Runkle, 1982; Peterken, 1996). Contemporary
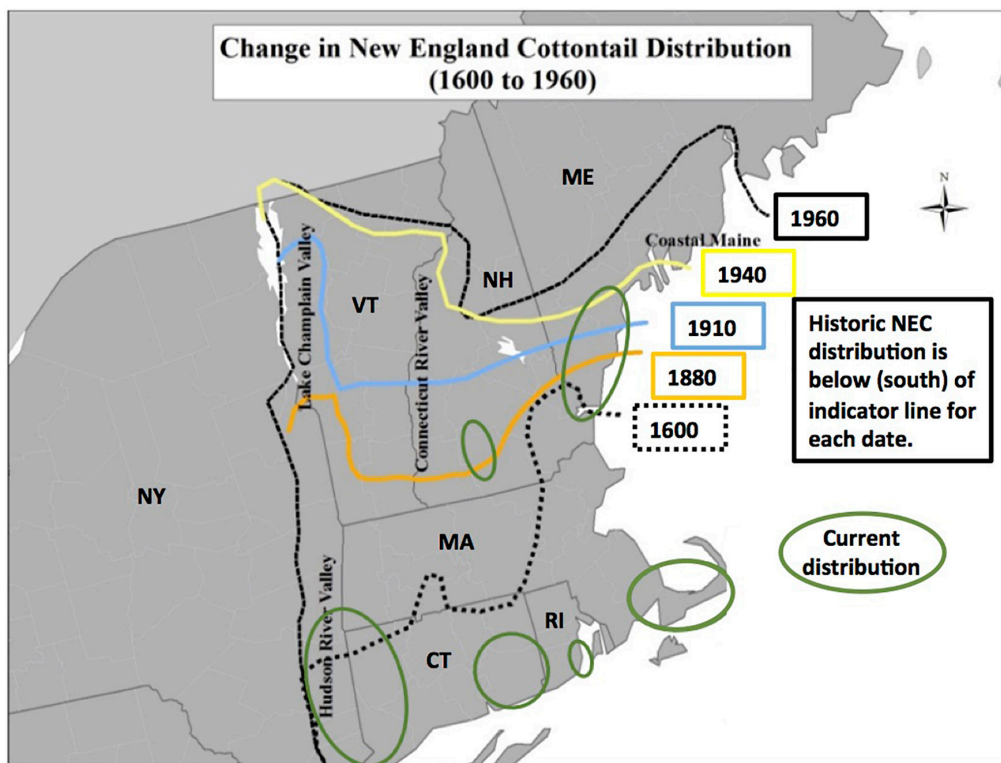
FIGURE 3

Changes in New England Cottontail (NEC) distribution over time. The estimated range of New England Cottontails (NEC) documented circa ~1600 (below the dashed line) included primarily Connecticut (CT) and Rhode Island (RI), and part of Massachusetts (MA). The distribution expanded dramatically northward following European settlement and land use (~1620–1960) to include Vermont (VT), Maine (ME), New Hampshire (NH), and into New York (NY; Hudson River Valley and Lake Champlain Valley). This dramatic expansion was followed by range contraction (~1960–2022) with forest regrowth and urban and suburban development. Green ovals represent the current documented distribution of NEC. Note that parts of current range still extend outside of pre-European settlement bounds, particularly in ME. NEC distribution map adapted from U.S. Fish and Wildlife Service (2015a,b).

studies of old-growth forests in the eastern U.S. suggest such small gaps are less than 0.1 acre in size. Larger openings were created by beaver impoundments and at intervals of hundreds of years by catastrophic windstorms and tornados. While uncommon in the Northeast outside of coastal pine barren communities, fire occurred every few decades and sometimes created large openings in the Upper Great Lakes region (Frelich, 1995; Lorimer and White, 2003). Native people generally caused minimal forest disturbances except around settlements scattered along coasts and river corridors (Motzkin and Foster, 2002; Parshall and Foster, 2002; Munoz and Gajewski, 2010; Oswald et al., 2020b; Frelich et al., 2021).

Advocates of clearing forests for early-successional habitats assert that natural and pre-European disturbances have been greatly attenuated and, therefore, managers must step in to create them (DeGraaf and Yamasaki, 2003; Oehler et al., 2006; Fergus, 2014; King and Schlossberg, 2014; Littlefield and D'Amato, 2022). While these habitats are reduced from their zenith in the 1800s and early 1900s (Foster et al., 2002; Litvaitis, 2003; Lorimer and White, 2003), extensive early-successional

habitats still exist and are continuously produced, naturally and by widespread human activity. Natural disturbances such as storms, insect infestations and disease (including many novel non-native types that were not present when Europeans arrived), floods, and beaver impoundments, continue to create forest openings (Whitney, 1994; Askins, 2000; Frelich, 2002; Zlonis and Niemi, 2014; Wilson et al., 2019). Many types of human disturbances including farming, forest harvesting, and the expansion of electrical transmission lines provide additional extensive areas of early-successional habitats.

About 13% of forest area in the Northeastern United States is currently in the smallest (seedling-sapling) size class (Oswalt et al., 2019), a decline of more than 50% over the past 40 years, but several times higher than estimated presettlement values (Lorimer and White, 2003; Figure 2). Early-successional habitats in the Upper Great Lakes regions today are more difficult to quantify, because much of the southern and western portions of the three states are covered by savannas, prairies, and agricultural land. However, a study found that 4.4% of the area of Michigan north of the prairie-hardwood transition

is characterized by forests less than 20 years old (Tavernia et al., 2016), and forests less than 20 years old are estimated to cover 12% of all forested lands in Wisconsin and Minnesota, respectively (Kilgore and Ek, 2013; Wisconsin Department of Natural Resources, 2020; USDA Forest Service, 2022b).

Approximately 65% of timber removals in the Northeast detected in U.S. Forest Service Inventory Data (FIA) are commercial clearcuts, shelterwood, high-grade, group selection, or pre-commercial thinning treatments (Belair and Ducey, 2018)—all major sources of early-successional habitats. In the Northeast and Upper Great Lakes, tens of thousands of acres of these habitats are created each year by the clearcutting of public and private timberlands—more than 10,000 acres in the national forests alone (USDA Forest Service, 2003; USDA Forest Service, 2017). Among the nine Northeast states, almost 19 million acres (16%) are farmland, most of which was formerly forested (U.S. Department of Agriculture, 2020), and about one-third of agricultural lands provide a mosaic of early-successional habitats such as grassland, woodland, wetland, and other open habitats (Brady, 2007; Jeswiet and Hermsen, 2015).

Expansive early-successional habitats are also the byproduct of urban and industrial developments. Examples include pipeline and powerline corridors (King et al., 2009; Askins et al., 2012), highway rights of way (Huijser and Clevenger, 2006; Amaral et al., 2016), golf courses (Tanner and Gange, 2005), greenways (Mason et al., 2007), wind and solar power arrays (South Carolina Department of Natural Resources, 2020; Zaplata and Dullau, 2022), military bases (Young Forest Project, 2022d), airports (Cousineau, 2017), and reclaimed strip mines (Bulluck and Buehler, 2006). Most of these development categories are not included in current inventories of early-successional habitats.

Additional factors are expected to increase the inventory of early-successional habitats. The forests of New England, for example, are rated as "above average" in health, but climate change is projected to have widespread impacts that will expand early-successional habitats (Janowiak et al., 2018; USGCRP, 2018). These impacts include major disturbances from storms (Miller-Weeks et al., 1999; Koches, 2019; Seitz, 2019), increased precipitation and flooding (National Wildlife Federation, 2009; Connecticut Department of Energy and Environmental Protection, 2020; Moustakis et al., 2021), periods of extreme heat and drought (Baca et al., 2018), insect and disease outbreaks (Paradis et al., 2008; Massachusetts Department of Conservation and Recreation, 2018), the introduction of new invasive species (Seidl et al., 2017), and shifts of vegetation and habitats northward (Chen et al., 2011; Toot et al., 2020). SWAPs and the YFI do not take into account such climate impacts.

Another potential source of early-successional habitats is the use of intensive forest management to increase climate "adaptation" and "resilience" of forests, which includes clearcutting, thinning, prescribed burning, and "assisted migration" through tree plantings (Foster and Orwig, 2006;

USDA Forest Service, 2021a, 2022c; Climate Change Response Network, 2022a,b, Massachusetts Department of Conservation and Recreation, 2022; Northern Institute of Applied Climate Science, 2022; USDA Forest Service, 2022c). Such intensive forest interventions are, to date, mostly conceptual and experimental (Millar et al., 2007; D'Amato et al., 2011; Sheikh, 2011; Schwartz et al., 2012; Park and Talbot, 2018; Aquilué et al., 2020; Palik et al., 2022). Many questions remain regarding their economic, ecological, and legal and administrative feasibility (Handler et al., 2018). A prudent course would be to move cautiously with such novel strategies while expanding protection for mature and old-growth forests, which have a high degree of ecosystem integrity, genetic diversity, and adaptive capacity (Mosseler et al., 2003a; Thompson et al., 2009; Rogers et al., 2022).

An increasingly common rationale for forest-clearing is that it is necessary to recreate the way that Native people lived in relationship with the land. This is based on the extensively criticized hypothesis that long before European settlement, humans were deliberately managing most of the Northeast and Upper Great Lakes landscape using forest burning and clearing to improve habitat for favored plants and animals (Day, 1953; Mann, 2005; Abrams and Nowacki, 2008; Poulos and Roy, 2015). Some accounts take the idea even further, contending that by 1600, North America was "a humanized landscape almost everywhere" (Denevan, 1992), managed by Native people as a "garden" (Pyne, 2000), with virtually no "natural" plant communities (Williams, 2002). According to this view, the cessation of widespread and frequent pre-European burning and the reforestation of large parts of the region (which had been cleared after European settlement) have resulted in a massive loss of early-successional habitats and species, seriously threatened major plant communities, and reduced native biodiversity (Brose et al., 2001; Poulos and Roy, 2015; Abrams and Nowacki, 2020). The assumed loss of management by Native people is also cited as a major cause of the transition now underway of many oak forests to forests dominated by shade-tolerant species (Abrams, 1992; Brose et al., 2001; Abrams, 2005; Nowacki and Abrams, 2008).

Native burning and other subsistence practices, such as hunting, fishing, plant gathering, and small-scale farming had notable ecological impacts in the immediate vicinity of native encampments and settlements in the Northeast and Upper Great Lakes regions (Whitney, 1994; Lorimer and White, 2003; Oswald et al., 2020b; Frelich et al., 2021; Tulowiecki et al., 2022). However, modern land managers seem to be inappropriately misinterpreting a set of novel landscape conditions created by European land use over the last few centuries as having pre-European origins (Chilton, 2002; Oswald et al., 2020b; Cachat-Schilling, 2021). Extrapolating this misinterpretation to a regional scale has led to claims of widespread and intensive Native manipulation for millennia before European settlement. Unfortunately, these sweeping assumptions are

being used to justify large-scale clearing and prescribed burning of established and recovering forests (Pyne, 2000; Brose et al., 2001; Williams, 2002; Oehler et al., 2006; Poulos and Roy, 2015; Abrams and Nowacki, 2020). In 2019 alone, 365,306 acres of forest—an area larger than Rocky Mountain National Park—were burned through prescribed fire in the Northeast and Upper Great Lakes, according to state forestry agencies (Melvin, 2020). Examples of major prescribed fire projects are found in Connecticut (Connecticut Department of Energy and Environmental Protection, 2021a), Massachusetts (Clark and Patterson, 2003), Michigan (Michigan Department of Natural Resources, 2022), and Vermont (USDA Forest Service, 2022d). This is in addition to the significant expanses of forest that are cleared under the premise of creating early-successional habitat.

Beyond the greater risks from mechanized modern forest management, there is significant controversy regarding the hypothesis of intensive and extensive management of the pre-European landscape by Native people (cf., Cachat-Schilling, 2021). For example:

- The presumption that the presettlement landscape was dominated by agriculturally based Native people who regularly burned large areas relies primarily on written or oral accounts by European explorers, travelers, and colonists. The vast majority of these narratives were not objective descriptions, but were vague, subjective, biased, or even meant to promote profit-making enterprises (Russell, 1981; Forman and Russell, 1983; Russell, 1983; Vale, 1998; Vale, 2002; Barrett et al., 2005; Munoz et al., 2014; Foster, 2017).

- Maintenance of the envisioned anthropocentric landscape would have required Native communities to move every 10–20 years, thereby creating extensive early-successional habitat and a wide variety of even-aged forest patches. This scenario is not supported by archeological studies of pollen and charcoal (Chilton, 2002; Oswald et al., 2020b).

- Localized burning and other land use did commonly occur in some population centers along the New England coast where maize agriculture had developed, the estuaries of New York, New Jersey, Delaware, and Maryland, around the eastern Great Lakes, and along major rivers (Russell, 1981; Motzkin and Foster, 2002; Milner and Chaplin, 2010; Munoz and Gajewski, 2010). However, throughout much of the rest of the Northeast and Upper Great Lakes regions, there is no evidence of significant land clearing or agriculture (Chilton, 2002; Parshall and Foster, 2002; Lorimer and White, 2003; Faison et al., 2006; Matlack, 2013; Oswald et al., 2020b). Rather, pollen and charcoal studies show that the vast interior of these regions had a dispersed, low-density population that was seasonally mobile and utilized native resources, not agriculture (Milner and Chaplin, 2010; Foster, 2017; Oswald et al., 2020b; Frelich et al., 2021). Archeological evidence indicates that many

Native settlements in these regions are a relatively recent phenomenon—for example, Iroquois settlement began during the last millennium (Warrick, 2000; Bruchac, 2004; Jordan, 2013) and New England coastal settlement was likely encouraged by trade with Europeans (Foster, 2017).

- Pollen and charcoal studies as well as fire records indicate that fire activity before the arrival of Europeans tracked climate and vegetation at broad scales, rather than changes in the size of Native populations (Oswald et al., 2020b; Frelich et al., 2021). Indeed, the period of greatest Native population, shortly before the time of European colonization, was one of relatively low fire activity. At smaller spatial scales, particularly near the coast, some pollen records do show relatively high fire activity just prior to European settlement in areas of higher human population densities (Stevens, 1996; Lorimer and White, 2003; Parshall et al., 2003). Sites on steep slopes in the Appalachians have both a pre-history and a historic pattern of frequent crown and ground fires (Delcourt and Delcourt, 1998; Shumway et al., 2001; Buckley, 2010). Overall fire activity spiked after forest-clearing by European settlers created dry and flammable early-successional habitats, spiked again in the late 19th and early 20th centuries with the expansion of fire-prone abandoned farmlands and cutover forests, and has dramatically declined in the last century (Irland, 2013, 2014; Frelich et al., 2021).

- Long before the first colonization of North America 15,000–18,000 years ago, Northeast and Upper Great Lakes ecosystems had evolved and were maintained by climate and natural disturbances (Foster et al., 2002; McEwan et al., 2011; Noss et al., 2014; Pederson et al., 2014; Oswald et al., 2020b). Historical data and pollen studies indicate that before European settlement, forests were mainly characterized by long-lived shade tolerant and moderately shade tolerant species, not fast growing, early-successional and weedy species that would indicate widespread Native burning (Russell, 1983; Foster et al., 2002; Motzkin and Foster, 2002; Parshall and Foster, 2002; Parshall et al., 2003; Faison et al., 2006; Shuman et al., 2019; Oswald et al., 2020b). Oak savannahs along the prairie-forest border in the Upper Great Lakes region were far more widespread than today and likely maintained at least in part by greater frequencies of fire, including burning by Native people (Whitney, 1994; Frelich et al., 2021; Paciorek et al., 2021). However, the current shift of some forests from disturbance-tolerant species to shade-tolerant species can be explained by changes in climate and other factors rather than a lack of human-caused fires (Foster et al., 2002; McEwan et al., 2011; Noss et al., 2014; Pederson et al., 2014; Oswald et al., 2020b).

- Fire-prone ecosystems occupy about 25% of the forested landscapes of northern Minnesota, Wisconsin, and Michigan (Heinselman, 1973; Frelich, 1995;

Frelich and Reich, 1995). However, even with the high occurrence of fires, there was still a much higher proportion of old-growth prior to European settlement than today (Frelich, 1995). Approximately 55% of forests were old growth within the 25% of the landscape that is fire prone (pine and oak forests with some aspen birch and spruce). These areas had 100–250 year return times for severe fires, so that only 55% of the stands would reach an age of 120 years or more. There were both natural and human understory burns, which helped maintain the old multi-aged condition in some stands. Elsewhere, for example in northern hardwood forests, where fires were much less common, the proportion of old-growth was much higher and wind storms were the primary disturbance. Severe fires that set succession back to birch and aspen were quite rare in these areas and were confined largely to blowdown areas. Only small proportions of fire-prone forest landscapes in the Boundary Waters Canoe Area Wilderness and Voyageurs National Park had a long history of regular understory burns (Johnson and Kipfmueller, 2016; Kipfmueller et al., 2017).

- In the Northeast, only limited areas are susceptible to fire, such as coastal pine barrens of Massachusetts, New York, and New Jersey, as well as scattered pavement barrens and sandplain communities in upstate New York and the Connecticut Valley (Forman and Boerner, 1981; Motzkin et al., 1999). Climate change and European land use have been the most important agents of change on these landscapes (Motzkin et al., 1999; Parshall et al., 2003).

In summary, current understanding of the role of fire and other disturbances in the Northeast and Upper Great Lakes regions before the arrival of Europeans is based on uneven, area-specific, and often-inconclusive information (Oswald et al., 2020a; Frelich et al., 2021). Available evidence does not support the hypothesis of widespread, intensive, ongoing burning and other land management over millennia by Native people (Cachat-Schilling, 2021). Instead, the evidence points to human use before European colonization limited to areas near settlements and ultimately constrained by a regional human population that is estimated to be less than 1% of the present population (Milner and Chaplin, 2010).

1.2.4. Rationale for forest-clearing: Reduce the prevalence of "mature" forests

Forest-clearing advocates assert that, in parallel with the presumed lack of "young" forests, there is an overabundance of "mature," and "even-aged" forests across the landscape. They contend that these forests do not provide an adequate diversity of habitats, and that "active management" can "restore" forest diversity and resiliency by "mimicking" natural forest disturbances and conditions (National Commission on Science for Sustainable Forestry, 2007; Fergus, 2014; King and

Schlossberg, 2014; New Jersey Department of Environmental Protection, 2018; Rohrbaugh et al., 2020; Littlefield and D'Amato, 2022). Prior to evaluating this rationale it is important to note that a forest termed "even-aged" can include ages that vary by about 20% of the dominant age, and may also include young trees/advance regeneration, dead trees, and a mosaic of habitats (for example, due to insect damage or storms). "Even-aged" does not mean "even-sized" and tree growth is highly influenced by local site conditions for that species. The term "even-aged" can evoke images of a tree farm or a plantation, but natural forests do not have such a uniform structure, particularly those older than 60–80 years. Although 60–80 year old trees may be termed "mature," or almost "overmature," they are at far less than half their natural lifespan and likely at far less than 20% of their potential carbon accumulation (Thompson et al., 2009; Leverett et al., 2021). Most important, forests that are relatively even-aged will transition on naturally toward old-growth and uneven-aged condition if simply left alone (Gunn et al., 2014; Catanzaro and D'Amato, 2019).

With these caveats in mind, it is important to determine if and when removing mature or "even-aged" forests has net benefits. In terms of risks, there is considerable evidence that human-created or -maintained habitats do not provide the complexity, resilience, and diversity over long periods of time that are provided by natural forest ecosystems (Nitschke, 2005; North and Keeton, 2008; Thompson et al., 2009; Lindenmayer and Laurance, 2012; Belair and Ducey, 2018; Thom and Keeton, 2020). Moreover, countless interconnected and long-term ecological variables and processes are not well understood or are still simply unknown—and therefore cannot be "replicated" by human intervention with any confidence.

Taken together, long-term monitoring and further research on these issues should be a top priority. After a natural disturbance a forest can be a chaotic jumble of dead and damaged trees, downed wood, and tip-ups—many involving immense old trees and their associated biodiversity above and below ground (Lain et al., 2008; Santoro and D'Amato, 2019). In a natural forest, snags and downed logs and uproot mounds and pits are large and enduring for 100 years or more, there are no large areas of bare ground or scarified soil, and downed wood and vegetation remains on site (Foster et al., 2003). After an extreme event, such as a hurricane, there may be abundant advance regeneration, understory vegetation, and a mix of damaged and undamaged trees. These building blocks help the forest recover and resist the intrusion of invasive species (Plotkin et al., 2013, D'Amato et al., 2017). Even forests with almost no advance regeneration can regenerate rapidly after a major disturbance (Faison et al., 2016).

To summarize, current programs that create new early-successional forest habitats involve clearing established forested areas. These human-made habitats are dramatically different from the old-growth forest habitats with a mosaic of natural disturbances that dominated the landscape of the Northeast and

most of the Upper Great Lakes before European settlement. Early-successional habitats have declined since their peak in the 19th and early 20th centuries but they are still widely represented, actively created by natural and human disturbances, likely undercounted, and expected to increase in the future. In light of the concerns discussed above, there is a compelling argument for re-evaluating the assertion that creating more early-successional habitat is essential for the survival and health of ecosystems, habitats, or species.

2. Impacts of forest clearing projects

2.1. Impacts on biodiversity

Advocates contend that widespread and increased forest-clearing will not have significant negative environmental impacts and can even benefit species associated with mature and old-growth forests (Chandler et al., 2012; Schlossberg et al., 2018; Nareff et al., 2019). Yet, there is ample evidence that this will result in the loss of mature forests and future old-growth habitats, reduced connectivity, an increase in edge habitats, the spread of invasive species, and deleterious effects due to mechanical disruption and species isolation (Wilcove et al., 1986; Small and Hunter, 1988; Franklin, 1989; Askins, 1992; Faaborg et al., 1993).

Meanwhile, and perhaps most important, we have insufficient data on many classes of organisms, and vast numbers of species are still undiscovered (Mora et al., 2011). Numerous moss species need older trees with thicker moisture-holding bark to survive droughts (Zhao et al., 2020). Native snails and insects are more abundant in older forests (Jordan and Black, 2012; Maloof, 2023). These forests host vast networks of plant roots and mycorrhizae, which may link trees to each other and allow the transfer of resources between mature trees (Simard et al., 2012). There is evidence that millions of species of fungi and bacteria swap nutrients between soil and the roots of trees in an interconnected "wood-wide web" of organisms (Steidinger et al., 2019). As scientific methodology evolves, so does our ability to detect tiny organisms and new molecules, including those of critical importance for medicine. In 2018, 16 new species were discovered in a teaspoonful of soil in Massachusetts (Schulz et al., 2018). A study of enchytraeids (a type of annelid worms) in maple forests of northern Minnesota found 9 species new to science (Schlaghamerský et al., 2014). Forest maturity increases the presence of groundwater macroinvertebrates and, in particular, uncommon species (Burch et al., 2022).

Unfortunately, few forests are surveyed for all types of life-forms before clearing to create early-successional habitats. "Resetting" a forest to age "zero" by clearing it reduces ecological complexity immediately because it prevents the full expression of structural and ecological diversity as well as

myriad ecosystem services. Recovery is uncertain. Although southeastern U.S. forests are some of the most frequently logged forests in the world (Hansen et al., 2013)—resulting in ample early successional habitat—the region has experienced dramatic long-term declines in early-successional birds (Hanberry and Thompson, 2019). Even less-intensive logging activity can diminish or eliminate disturbance-sensitive and slowly dispersing plant and animal species, with recovery potentially taking many decades, if at all (Duffy and Meier, 1992; Petranka et al., 1994; Hocking et al., 2013).

It is instructive to contrast previously cleared forests that are designated as parks or preserves, where forest ecosystems have been allowed to function and develop predominantly under the influence of natural processes (i.e., GAP 1 areas) with forests subject to clearing of established forests to create early-successional habitats (i.e., some GAP 2 areas) or to commercial logging (i.e., GAP 3 or GAP 4 areas). For more detail on GAP classifications, see Table 1 and U.S. Geological Survey (2022b). Forests that are allowed to recover naturally and develop past the stem-exclusion phase steadily gain structural complexity and biodiversity, in part from ongoing low-to-moderate severity disturbances (Zlonis and Niemi, 2014; Miller et al., 2016; Hilmers et al., 2018). Indeed, the accumulated legacy of a mosaic of natural disturbances is greatest in unmanaged old-growth forests (Oliver and Larson, 1996; Askins, 2000; Lorimer and White, 2003). For instance, the 1-million-acre Boundary Waters Canoe Area Wilderness in Minnesota has taller tree canopies, greater tree species richness, and a larger number of bird species than adjacent managed national forest lands (Zlonis and Niemi, 2014). This wilderness also hosts a similar richness of bird species that favor young forests, such as the Chestnut-sided Warbler (Zlonis and Niemi, 2014). In Maine's "forever wild" Baxter State Park, natural insect outbreaks create open habitats that benefit early-successional species (Oliveri, 1993). A survey of Michigan habitats concluded that designated wilderness areas had considerable early-successional habitats, even though they were not open to logging or habitat management (Tavernia et al., 2016). As discussed below, findings were similar in New York's "forever wild" Adirondack and Catskill forest preserves (Widmann et al., 2015).

Numerous rare, threatened, and endangered wildlife species depend upon mature and old-growth forests and their ecosystem services. These species include migratory birds such as the Cerulean Warbler (*Setophaga cerulean*) (U.S. Fish and Wildlife Service, 2006; Dawson et al., 2012) and Wood Thrush (*Hylocichla mustelina*) (Bertin, 1977; Hoover et al., 1995; Rosenberg et al., 2003). They include mammals such as the Eastern Spotted Skunk (*Spilogale putorius interrupta*) (Lombardi et al., 2017; Hassler et al., 2021; Pearce et al., 2021), Appalachian Cottontail (*Sylvilagus obscurus*) (Chapman et al., 1992), Northern Long-eared Bat (*Myotis septentrionalis*) (U.S. Fish and Wildlife Service, 2022a), and Allegheny Woodrat (*Neotoma magister*) (Balcom and Yahner, 1996; Lombardi et al., 2017). They include plants such as Butternut (*Juglans cinerea*),

(Schultz, 2003), Canada Yew (*Taxus canadensis*) (Dunwiddie et al., 1996; Windels and Flaspohler, 2011), Frasier Sedge (*Cymophyllus fraserianus*) (Godt et al., 2004), and American Ginseng (*Panax quinquefolius*) (McGraw et al., 2013). Some species reach their highest densities in old-growth forests, including southern and northern flying squirrels, forest interior birds, and spring ephemeral wildflowers.

The fragmentation of forests, particularly with roads and other human intrusion, can result in the decline of forest interior species. This can have significant impacts on the abundance, species richness, and community dynamics of migratory birds (Small and Hunter, 1988; Askins, 1992; Hagan et al., 1996; Zuckerberg and Porter, 2010; Askins, 2015; Betts et al., 2022). Apex predators can be lost, leading to further biodiversity loss as well as altered dynamics of disease, carbon accumulation, invasive species, and biogeochemical cycles (Terborgh et al., 1999; Anderson et al., 2004; Estes et al., 2011; Terborgh, 2015). Even common forest species are subject to major declines due to loss of natural forest habitats. A global report shows a 69% decrease in monitored wildlife populations between 1970 and 2018, in large part due to habitat fragmentation and degradation (WWF, 2022). Fragmentation can increase prevalence of wildlife diseases including Raccoon Roundworm (*Baylisascaris procyonis*) (Wolfkill et al., 2021) and may be a factor in oak decline and loss of ecosystem services (Tallamy, 2021) as well as reduced underground biodiversity—a concern that is less explored in the Northeast and Upper Great Lakes than in western forests (Simard, 2021).

Figure 1 reflects biodiversity impacts of habitat changes and hunting over several hundred years. Habitat loss was a factor in the decline of deer, moose, beaver, turkey, wolf, mountain lion, and bear, but intensive hunting and trapping probably had the greatest impact (Foster et al., 2002). Coyotes migrated eastward following wolf extirpation, interbred with wolves, and partially filled the vacant niche left by wolf extirpation. Deer can thrive in disturbed landscapes, which explains their recovery once hunting pressure was relieved (Michigan Department of Natural Resources, 2016). Forest-clearing is widely used today to boost populations of deer and other game species (Lashley et al., 2011; Dechen Quinn et al., 2013; Michigan Department of Natural Resources, 2017). However, high deer population densities can have significant negative effects on forest regeneration, native herbaceous plants—especially charismatic floristic groups such as orchids—and songbirds and their habitats (Alverson et al., 1988; deCalesta, 1994; Rooney and Waller, 2003; Knapp and Wiegand, 2014; Jirinec et al., 2017). Clearing established forests can also introduce and spread invasive and non-native species that ultimately reduce biodiversity (McDonald et al., 2008; Eschtruth and Battles, 2009; LeDoux and Martin, 2013; Coyle et al., 2017). Managed forests have been found to have as much as three times more invasives than fully protected national parks or wilderness (Riitters et al., 2018). Invasive plants can have a negative impact on native animal populations, including birds, mammals and other vertebrates (Fletcher et al., 2019). Invasive

earthworms are a serious concern, particularly the new threat of jumping worms (*Amynthas spp.*) that destroy forest soil very rapidly (Frelich et al., 2019).

2.2. Impacts on the atmosphere

Forests influence water cycles, reduce local and global temperatures, and sequester and accumulate carbon. While carbon receives the most attention, multiple biophysical processes are crucial and interactive (Makarieva et al., 2020; Lawrence et al., 2022). Proponents of forest-clearing assert that carbon emissions are offset by increased sequestration rates of younger forests, by converting trees to wood products, by burning logging "waste" for bioenergy, and by forest carbon accumulation elsewhere—or that the amount of forest removal is so small as to be inconsequential (Hawthorne, 2020; Jenkins and Kroeger, 2020; USDA Forest Service, 2021a). On the contrary, these activities have significant climate costs, including the release of greenhouse gases from the cutting, processing, and transporting of trees for wood products; the disposal of waste and wood products; the release of methane from each log landing; the release of carbon from disturbed soils; and the loss of carbon uptake and accumulation by standing trees (Smith et al., 2006; Nunery and Keeton, 2010; Ingerson, 2011; Mika and Keeton, 2013; Catanzaro and D'Amato, 2019; Cook-Patton et al., 2020; Leturcq, 2020; Vantellingen and Thomas, 2021).

Some studies suggest that younger forests between 30 and 70 years (Catanzaro and D'Amato, 2019) or 40–80 years (Leverett et al., 2021) can sequester carbon at a faster rate than mature or old-growth forests. Other analyses indicate that lands reserved from logging in the Northeast have net carbon sequestration rates that are roughly 33% higher than in logged forests and are projected to sequester more carbon over the next 150 years (Brown et al., 2018). Nevertheless, the climate mitigation value of forest carbon lies not in the sequestration rate but in the total amount that is accumulated and kept out of the atmosphere (Mackey et al., 2013). The power of forests in this process is unparalleled and far greater in old forests than in young forests, both above and below ground; carbon continues to accumulate for centuries (Zhou et al., 2006; Luyssaert et al., 2008; Keeton et al., 2011; Curtis and Gough, 2018; Leverett et al., 2021; Law et al., 2022).

The amount of carbon lost when cutting a mature or old-growth forest is not recovered by fast-growing young forests for many decades to well over a century (Harmon et al., 1990; Aalde et al., 2006; Krebs et al., 2017). One study found almost no net carbon accumulation for 15 years after clearcutting—currently a critical time window for reining in global greenhouse gas emissions (Hamburg et al., 2019). In some cases, older forests are accumulating more carbon as the climate warms (Finzi et al., 2020), they are better able to withstand physiological stress, and they are also more resistant to the stress of climate change than younger forests, particularly regarding carbon storage,

timber growth rate, and species richness (Thom et al., 2019). Soil accounts for approximately 50% of total ecosystem carbon storage in the Northeast, with mineral soils comprising the majority (Fahey et al., 2005; Petrenko and Friedland, 2015). Forest-clearing can mobilize and release soil carbon for decades (Nave et al., 2010; Petrenko and Friedland, 2015; Lacroix et al., 2016). It can take from 60 to 100 years for soils on a site to recover from clearcut logging (James and Harrison, 2016).

It is crucial to note that forest carbon stocks in the U.S. are already depleted by about 60% due to past logging and clearing (McKinley et al., 2011) and ongoing timber removals (Gunn et al., 2019). Logging accounts for about 86% of the carbon emitted by U.S. forests each year—far greater than insects, storm damage, fire, development and other uses combined (Harris et al., 2016; Duveneck and Thompson, 2019). Although a small percentage of the carbon in trees that are cut is stored in durable wood products, in the U.S. about 76% of carbon in trees cut for timber is released into the atmosphere each year (Domke et al., 2018), with most of it emitted quickly in processing, waste, and short-lived products (Harmon et al., 1996; Ingerson, 2011; Harmon, 2019; Leturcq, 2020). A logged mature forest stores less than half of the carbon of an uncut mature forest, even if carbon stored in wood products is included in the carbon storage total of the logged areas (Nunery and Keeton, 2010; Law et al., 2022). Impacts are similar for forest-clearing to produce wood bioenergy, which advocates claim is "carbon neutral" (Collins et al., 2015). However, cutting and burning trees releases large amounts of carbon immediately that would take many decades to be recover–if the forest grows back. In addition to other disrupted biophysical processes, this is time we cannot afford in light of the urgent climate crisis (Schulze et al., 2012; Law et al., 2018; Sterman et al., 2022). In short, clearing forests—whether for early-successional habitat or bioenergy—results in serious impacts to the atmosphere. In terms of maximizing carbon accumulation, allowing forests to regrow and remain standing—termed proforestation—is demonstrably preferable to cutting them (Buotte et al., 2019; Moomaw et al., 2019; Mackey et al., 2020; Rogers et al., 2022).

Despite widespread past clearing, the forests of the Northeast and Upper Great Lakes have recovered to the point that they are among the most intact and carbon-dense in the eastern U.S. (Zheng et al., 2008; Zheng et al., 2010; Foster et al., 2017). In addition, because these forests grow vigorously, decay slowly, and are, on average, less than 100 years old, they have centuries of growth ahead and enormous capacity for additional carbon storage (Pan et al., 2011; Williams et al., 2012) and climate stabilization. If allowed to continue growing, these forests can potentially increase *in situ* carbon storage by a factor of 2.3 to 4.2 (Keeton et al., 2011) and perform crucial ecosystem services (Meyer et al., 2022). For these reasons, the New England Acadian region was identified as a Tier 1 stabilization area in the Global Safety Net (Dinerstein et al., 2020). The potential in the Upper Great Lakes region is also significant, where continued

forest recovery in existing forests could add substantial amounts of carbon storage (Rhemtulla et al., 2009).

2.3. Impacts on human health and well-being

With more than 50 million acres of U.S. forests projected to be developed over the next 50 years (Thompson, 2006), forest-clearing for early-successional habitats risks further loss of vital natural green space and threatens the stability of regional temperature and water cycles. All of these have impacts on communities. There is an increasing recognition that natural ecosystems offer the public numerous benefits to physical, mental, and spiritual health, as well as social well-being (Karjalainen et al., 2010; Berman et al., 2012; Buttke et al., 2014; Newman and Cragg, 2016; Hansen et al., 2017; Watson et al., 2018; Connecticut Department of Energy and Environmental Protection, 2020). Adolescents may benefit more from natural woodlands than other types of green space in terms of cognitive development and reduced emotional and behavioral problems (Maes et al., 2021). Natural areas are important places to avoid human-related noise and listen to sounds of the natural world, which can decrease pain, lower stress, improve mood, and enhance cognitive performance (Bratman et al., 2015; Buxton et al., 2021).

Protecting intact habitats as refuges for people—even small areas—aligns with the principles of "harm reduction"—practical strategies and ideas aimed at reducing negative consequences. Increasing the well-being of a community, and avoiding or minimizing negative consequences of heat stress, acute physical and mental stress, and a long-term sense of loss can prevent a more serious or chronic condition, particularly in vulnerable populations such as adolescents, pregnant women, seniors, veterans, and those in recovery (Wang et al., 2019; Tiako et al., 2021). The positive impacts of nature on the promotion of mental health has enormous economic benefits (Bratman et al., 2019) and as does preventing mental illness (The Lancet Global Health, 2020).

In addition to social well-being, nature-based outdoor recreation can be an important factor in diversifying and stabilizing local economies (Power, 1996; Power, 2001; Haefele et al., 2016). Studies have shown that recreationists prefer spending time in forests and other landscapes that are natural and free of human manipulation (Vining and Tyler, 1999; Dwyer, 2003; Eriksson et al., 2012). The positive economic effects of robust ecotourism and increased property values can benefit an entire community (Morton, 1998; Lorah and Southwick, 2003; Holmes and Hecox, 2004; Phillips, 2004; Rasker et al., 2013; Fernandez et al., 2018; Cullinane et al., 2022).

In contrast, clearing forests to expand early-successional habitat can threaten human health. For example, it provides optimal habitat for White-tailed Deer and White-footed Mouse

(*Peromyscus leucopus*)—the most competent hosts for the vector of Lyme disease, the Eastern Blacklegged Tick (*Ixodes scapularis*) (Allan et al., 2003; LoGiudice et al., 2003; Levi et al., 2012; Telford, 2017; DellaSala et al., 2018; Robertson et al., 2019). There were 185 deaths from auto collisions with animals in 2019 and an estimated 2.1 million animal collision insurance claims in 2020–21, up 7.2 percent from the previous year, with most collisions involving deer (Insurance Information Institute, 2021).

3. Options and alternatives

As discussed above, forest-clearing projects across the Northeast and Upper Great Lakes are proceeding without well-founded consideration of conditions before European settlement, long-term plans for experimental controls and monitoring, or baseline ecological inventories. Assessments made of potential harm to non-target species are cursory, incomplete, or outdated. Quantifiable negative impacts—such as the spread of invasive species, elevated temperatures, increased fire and flood risk, destabilized and decreased climate mitigation and adaptation, degradation of healthy public green spaces, and ongoing expenditures of time and resources—are frequently overlooked. Meanwhile, potentially imperiled interior and old-growth forest species often do not receive adequate attention. Such chronic knowledge gaps render scientific assessment of the impacts of early-successional habitat projects difficult or impossible. Major interdisciplinary reports (Connecticut Department of Energy and Environmental Protection, 2020) offer a strong rationale for addressing these gaps by devoting significant funding to balancing these priorities, to monitoring, comprehensive ecological inventories, and to strengthening management standards and guidelines.

Reassessing the current forest-clearing campaign is an urgent priority: negative impacts are immediate, and once a forest has been cleared or fragmented it takes a century or more to begin to recover a mature or old-growth condition. This is far too late to address the biodiversity, climate, and public health crises that we face in the next critical decades. There are multiple compelling arguments for a new approach that greatly expands wildland preserves while maintaining needed amounts of early-successional habitats and timber production.

3.1. The importance of parks and preserves

There is growing international recognition that the preservation of mature and old-growth forests is essential to address the dual global crises of biodiversity loss and climate change, as well as to promote public health and well-being (Zhou et al., 2006; Luyssaert et al., 2008; Gilhen-Baker et al.,

2022; Law et al., 2022). However, in their drive to expand early-successional habitats, land managers have relegated the recovery and protection of old-growth forests to a tiny fraction of their pre-European extent (New Jersey Department of Environmental Protection, 2017; Massachusetts Division of Fisheries and Wildlife, 2022b). The U.S. Forest Service and Bureau of Land Management together administer the largest remaining tracts of mature and old-growth forests in the U.S., yet they are only now beginning a process to inventory these forests (The White House, 2022). Nationally, only about 24% of these forests are protected from logging (DellaSala et al., 2022a).

An extensive system of large, diverse, and connected parks and preserves can help address this challenge (Noss, 1983; Noss et al., 1999; Wuerthner et al., 2015). Studies show that eastern national parks tend to have larger trees, older forests, and more standing deadwood than surrounding managed forests (Miller et al., 2016). They also have greater tree species richness and a higher percentage of rare tree species (Miller et al., 2018). Cool interior forests such as those in parks and other preserves provide shelter for species that are most sensitive to temperature increases (Betts et al., 2017; Betts et al., 2022; Kim et al., 2022; Xu et al., 2022). Protected forests provide important climate benefits in accumulated carbon and avoided greenhouse gas emissions, and the potential to significantly increase carbon storage (Depro et al., 2008; Keeton et al., 2011; Zheng et al., 2013; McGarvey et al., 2015; Brown et al., 2018; Williams et al., 2021; Law et al., 2022). In addition, parks and preserves directly benefit people by producing clean air and water, reducing flooding, preventing soil erosion, cooling surrounding areas, and buffering damage from sea level rise (Luedke, 2019).

Climate scientists and conservation biologists around the world agree that a major expansion of nature preserves is necessary to address the threats of species extinctions and climate change (Di Marco et al., 2019; Yeo et al., 2019; Barber et al., 2020; FAO and UNEP, 2020; Bradshaw et al., 2021). There is a broad consensus that this requires the permanent protection of at least 30% of the Earth by 2030 (Noss et al., 2012; Dinerstein et al., 2019; Rosa and Malcom, 2020; Thompson and Walls, 2021). The U.S. falls far short of meeting this goal. Only about 8% of the U.S. land base now has protection from resource extraction and development equivalent to the U.S. Geological Survey's GAP 1 level and less than 5% meets GAP 2 standards; the vast majority of these lands are in Alaska and the West (Scott et al., 2001; Aycrigg et al., 2013; Jenkins et al., 2015; Lee-Ashley, 2019; Rosa and Malcom, 2020; Thompson and Walls, 2021; U.S. Geological Survey, 2022a,b). As noted previously, most old-growth forests in the U.S. have no formal protection, even on many GAP 2 public lands, leaving their future uncertain (DellaSala et al., 2022b).

The Northeast and Upper Great Lakes regions are deficient in natural area protection (Scott et al., 2001; Anderson and Olivero Sheldon, 2011; Foster et al., 2023). There are a few

notable exceptions, such as the Boundary Waters Canoe Area Wilderness, Isle Royale National Park, Adirondack Forest Preserve, and Baxter State Park, which meet GAP 1 standards (U.S. Geological Survey, 2022a,b). However, less than 1% of the Northeast and Upper Great Lakes regions is estimated to meet this strict level of protection U.S. Geological Survey (2022a). This percentage could be greatly increased through an expanded network of parks and preserves on large tracts of federal and state public lands, and could include key undeveloped private lands acquired from willing sellers (Foster et al., 2017; Meyer et al., 2022; Office of Senator Angus King, 2022). This would have numerous outsized benefits; for example, one study estimated that protected forests cover about 5% of the Northeast (including Virginia) yet store 30% of the aboveground carbon in the region (Lu et al., 2013). New wildland preserves would promote the recovery of mature and old-growth forest ecosystems and provide habitats for wide-ranging imperiled wildlife such as the Gray Wolf (*Canis lupus*) and Canada Lynx (*Lynx Canadensis*). They would also offer natural green space to tens of millions of people in major urban communities, reducing pressure on the few existing protected areas (Rhode Island Division of Statewide Planning and Rhode Island Department of Environmental Management, 2019; Reynolds, 2021).

There is ample evidence that expanded wildland preserves governed by natural disturbance regimes would provide early-successional habitats at least equivalent to the natural conditions in which native species evolved. For example, "On reserved forest land in New York [i.e., primarily the "forever wild" Adirondack and Catskill Preserves]… 3 percent [of forest area is] in seedling/sapling and non-stocked stands" (Widmann et al., 2015). Consistent with this, it is estimated that the proportion of the landscape before European settlement "in seedling–sapling forest habitat ranged from 1 to 3% in northern hardwood forests [i.e., beech–birch–maple–hemlock] of the interior upland" (Lorimer and White, 2003).

3.2. Protecting and restoring natural forest ecosystems

The most common strategy for creating early-successional habitats is to clear established forest tracts, purportedly to simulate the continually "shifting mosaic" of patches across a natural landscape (Schlossberg and King, 2007; Smith, 2017; Massachusetts Division of Fisheries and Wildlife, 2022a). However, as discussed above, forest-clearing is not equivalent to natural disturbances; it has significant costs in biodiversity, carbon accumulation, and other ecosystem services; and reduces the possibility of recovering old-growth forest ecosystems dramatically. Moreover, unlike the conservation of mature and old-growth forests, creating and/or maintaining (every 10–12 years) early-successional habitats requires a permanent,

resource-consuming commitment of intensive management to replace openings lost to forest succession (DeGraaf and Yamasaki, 2003; Askins, 2011; Bakermans et al., 2011; Yamasaki et al., 2014). This does not take into consideration the mitigation and remediation of unintended environmental side effects: such artificially created "restoration" areas are expensive to maintain (Oehler, 2003; Schlossberg and King, 2007) and there is no assurance that adequate funding will continue to be available. These are serious disadvantages that argue against the current forest-clearing of established natural forest ecosystems.

Among these different perspectives, there is a more balanced alternative: protect and recover mature and old-growth forests wherever possible, quantify the true extent of early-successional habitat and focus maintenance on ecologically suitable lands, including private lands, and encourage efforts to increase protection the full range of natural ecosystems on private lands. At this time there is no indication that this approach is receiving serious consideration from land managers. Yet the likelihood of significant benefits and greatly reduced costs are a compelling argument for such consideration.

4. Discussion

We evaluated peer-reviewed papers, published research, agency reports, and other materials related to a campaign that is focused on expanding early-successional habitats in the Northeast and Upper Great Lakes regions. Each year, this campaign is clearing thousands of acres of established forests. Conversely, the protection of old-growth forests and unmanaged mature forests is currently relegated to a tiny fraction of the land base.

Overall, the forest-clearing campaign is based on two main rationales, which are both open to serious questions and alternative hypotheses:

The primary rationale is that the decline of a number of early-successional species is a pervasive and potentially existential threat. Yet, the baseline for measuring this decline almost invariably begins in the late 1960s, when populations had begun to decrease from abnormally high levels as forests recovered from past clearing. Relying on an artificial baseline that reaches back only 60 years, in an ecosystem where most tree species live for hundreds of years, and during a regional recovery from widespread and intensive land clearing, is fraught with problems. Moreover, it is questionable that any species in these regions needs artificial expansion of early-successional forest habitats to survive and thrive across its multi-state range. Other than limited surveys of birds, game species, and endangered species, there is no reliable information on wildlife populations before the arrival of Europeans, no comprehensive census of forest species even today, and no long-term analysis that

systematically estimates wildlife population trends over the last several hundred years.

A second major rationale is that early-successional habitats have dwindled dangerously, have already fallen below the levels that existed before European settlement, and are not being adequately replenished—thereby endangering native biodiversity. However, there is ample evidence that these habitats remain plentiful across these regions (and are likely more prevalent than is accounted for currently), are considerably more abundant than presettlement, and continue to be created by natural and human disturbances—including by mounting climate change impacts. Although early-successional habitats were maintained to some extent by Native people before the arrival of Europeans, these were limited to areas of high population densities near settlements.

Despite its wide-ranging and long-term implications, the campaign for early-successional forest clearing was formulated by a small number of agency, academic, and special interest professionals, with little comprehensive research and analysis, controlled experimentation, strategic planning, monitoring and evaluation, or public involvement and accountability. This organized and aggressive campaign has confused the public and made it challenging for a range of scientists to engage in an open dialogue about an optimal and balanced approach that prioritizes climate stability, ecosystem integrity and public health. Yet, public awareness has grown regarding the evident impacts of forest-clearing projects on biodiversity, climate change, and natural green spaces and, in turn, so has public opposition to these projects (Ketcham, 2022; Potter, 2022; Whitcomb, 2022).

The Gap Analysis Project (GAP) of the U.S. Geological Survey (2022b) can provide the foundation for a balanced alternative to the current costly, intrusive and controversial approach that prioritizes protecting and sustaining natural systems and processes to the greatest extent possible. We suggest the following.

- Establish a significantly expanded system of public parks, wildland preserves, and connecting corridors across the Northeast and Upper Great Lakes with permanent protection under GAP 1 standards. This would preserve old-growth, mature, and recovering forests and allow them to reach their natural maximum ecological potential. Openlands that were deforested in the past, such as grassy areas and farm fields, would be allowed to recover unimpaired, which would provide ample young forest habitats over the next decade. In parallel, new areas of successional habitat would be created by natural disturbance regimes now, and in the future.
- End the clearing of established forests to create early-successional habitats on lands, such as wildlife refuges, under GAP 2 classification. Instead, focus on conserving grassland, shrubland, and savanna habitats where the

landform and soil naturally supports their ecological function and species. Examples include coastal landscapes of southern New England and New York, and the Upper Great Lakes prairie-forest transition zone. Re-establish natural disturbance regimes to the extent possible, but allow targeted forest management where appropriate.
- Strengthen the protection of GAP 3 "multiple-use" public lands such as national forests, to maintain natural ecosystems, carbon storage, and public access to green spaces to the extent possible. This includes avoiding intensive resource extraction that destroys or permanently impairs the integrity and productivity of natural systems.
- Regarding public and private lands with no formal protection (GAP 4), encourage the conservation of natural ecosystems and species to the extent possible. This includes agricultural lands and other open space with considerable potential to conserve early-successional habitats. These landowners would continue to determine how they manage their lands, but they would be provided with complete and accurate information on the benefits and costs of habitat management alternatives.

Implementing this "natural" alternative would be prudent, cautious, and low cost, and would permanently sustain the full range of native ecosystems. Allowing deforested lands to recover would accumulate much more carbon and avoid the steep carbon loss associated with cutting established forests (Smith et al., 2006; Cook-Patton et al., 2020).

In the face of many challenges, the people of the Northeast, Upper Great Lakes, and beyond are looking to public lands as a major solution to the loss of biodiversity, the threat of climate change, and the need for healthy public green spaces. We can realize this potential by rebalancing the vision for these lands to ensure the recovery and preservation of the full range of native habitats and the wildlife that depend on them—without ongoing intensive human intervention. There has never been a more appropriate time to make such a transition.

Author contributions

MK, JM, and SM developed the original concept and contributed research, writing, and editing of the manuscript. LF, EF, SB, and DF contributed research, writing, and editing of the manuscript. All authors contributed to its completion and approved the submitted version.

Funding

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/ffgc.2022.1073677/full#supplementary-material

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