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Michigan Department of Environmental Quality (DEQ) (2014) A guide to the control and management of invasive phragmites, 3rd edn. http://www.michigan.gov/documents/deq/deq-ogl-ais-guide-PhragBook-Email_212418_7.pdf. Accessed 11 Jan 2018

Michigan Department of Natural Resources (2012) Invasive species best control practices—Japanese barberry. https://mnfi.anr.msu.edu/invasive-species/JapaneseBarberryBCP.pdf. Accessed 11 Jan 2018

Mikulyuk A, Nault ME (2009) Curly-leaf pondweed (*Potamogeton crispus*): a technical review of distribution, ecology, impacts, and management. Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1052 2009, Madison

Natural Resources Conservation Service (NRCS) (2007) Pest management—Invasive plant control buckthorn (common and glossy) conservation practice. Job Sheet MN-797

O'Brien JG, Ostry ME, Mielke ME et al (2001) First report of beech bark disease in Michigan. Plant Dis 85:921

Ohio State University Extension (2018) Controlling non-native invasive plants in Ohio forests: bush honeysuckle factsheet F-68. https://ohioline.osu.edu/factsheet/F-68. Accessed 11 Jan 2018

Rebbeck J, Malone MA, Short DPG et al (2013) First report of Verticillium wilt caused by *Verticillium nonalfalfae* on tree-of-heaven (*Ailanthus altissima*) in Ohio. Plant Dis 97:999

Rebek EJ, Herms DA, Smitley DR (2008) Interspecific variation in resistance to emerald ash borer (Coleoptera: Buprestidae) among North American and Asian ash (*Fraxinus* spp.). Environ Entomol 37:242–246

Rothlisberger JD, Finnoff DC, Cooke RM et al (2012) Ship-borne nonindigenous species diminish Great Lakes ecosystem services. Ecosystems 15:1–15

Schultz J (2003) Conservation assessment for butternut or white walnut (*Juglans cinerea*) L: USDA Forest Service, Eastern Region. Hiawatha National Forest

Stinson K, Campbell S, Powell J et al (2006) Invasive plant suppresses the growth of native tree seedlings by disrupting belowground mutualisms. PLoS Biol 4:e140. https://doi.org/10.1371/journal.pbio.0040140

U.S. Department of Agriculture (USDA) NRCS (2018) The PLANTS database. National Plant Data Team, Greensboro. http://plants.usda.gov. Accessed 11 Jan 2018

U.S. Department of Agriculture (USDA) (2012a) Gypsy moth management in the United States: a cooperative approach. Supplemental environmental impact statement. Forest Service and Animal and Plant Health Inspection Service. NA-MB-01-12, Washington, DC

U.S. Department of Agriculture (USDA) (2012b) Asian longhorned beetle and its host trees. USDA Forest Service, Northeastern Area State and Private Forestry. NA-PR-05-12, Newtown Square

U.S. Department of Agriculture (USDA) (2017) Gypsy moth digest database. https://www.fs.usda.gov/naspf/programs/forest-health-protection/gypsy-moth-digest. USDA Forest Service, Northeastern Area State and Private Forestry, Newtown Square. Accessed 16 Jan 2018

Wisconsin Department of Natural Resources (2015) Jumping worm (*Amynthas* spp.). http://dnr.wi.gov/topic/Invasives/fact/jumpingWorm. Accessed 9 Aug 2018

Northeast Region

Jennifer Juzwik, Linda Haugen, Noel F. Schneeberger, Thomas J. Rawinski, John D. Rothlisberger, and Therese M. Poland

Introduction

The Northeast region is heavily forested with a high diversity of hardwood and conifer forest tree species. Northern hardwoods, including sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), yellow (*Betula alleghaniensis*) and paper birch (*B. papyrifera*), and aspen (*Populus tremuloides*) make up 44% of the forests, followed by the oak-hickory (*Quercus*-*Carya*) type (27%), pine (*Pinus*) types (white-red-jack pine (*P. strobus*-*P. resinosus*-*P. banksiana*), loblolly-shortleaf pine (*P. taeda*-*P. echinata*), and oak-pine) (12%), spruce-fir (*Picea*-*Abies*) type (11%), and bottomland types (elm/ash/cottonwood (*Ulmus*/*Fraxinus*/*Populus deltoides*) and oak/gum/cypress (*Quercus*/*Liquidambar*/*Taxodium*)) (5%). Topography, moisture gradient, and disturbance history highly influence where each forest type is found. The Northeast is also water rich, with over 10% of the total area covered by water. Aquatic ecosystems in the region include streams, swamps, lakes and ponds, rivers, and marine and estuarial habitats. In addition, New York has borders on two Great Lakes (Erie and Ontario), while Pennsylvania borders one (Erie).

The Northeast region comprises the New England and Mid-Atlantic States, including Maine, New Hampshire, Vermont, New York, Massachusetts, Connecticut, Delaware, Rhode Island, New Jersey, Maryland, Pennsylvania, and West Virginia (Fig. A7.1), and has a human population density greater than 330 people/mi^2. Many opportunities exist for human-mediated introductions of pests, including international shipping ports, a large urban/rural interface, highly industrialized areas, and high recreational use of forests. This region was colonized by Europeans earlier than most of the rest of the country, and coincidentally has the highest concentrations of invasive forest insects and pathogens in the country (Fig. A7.2). There are many

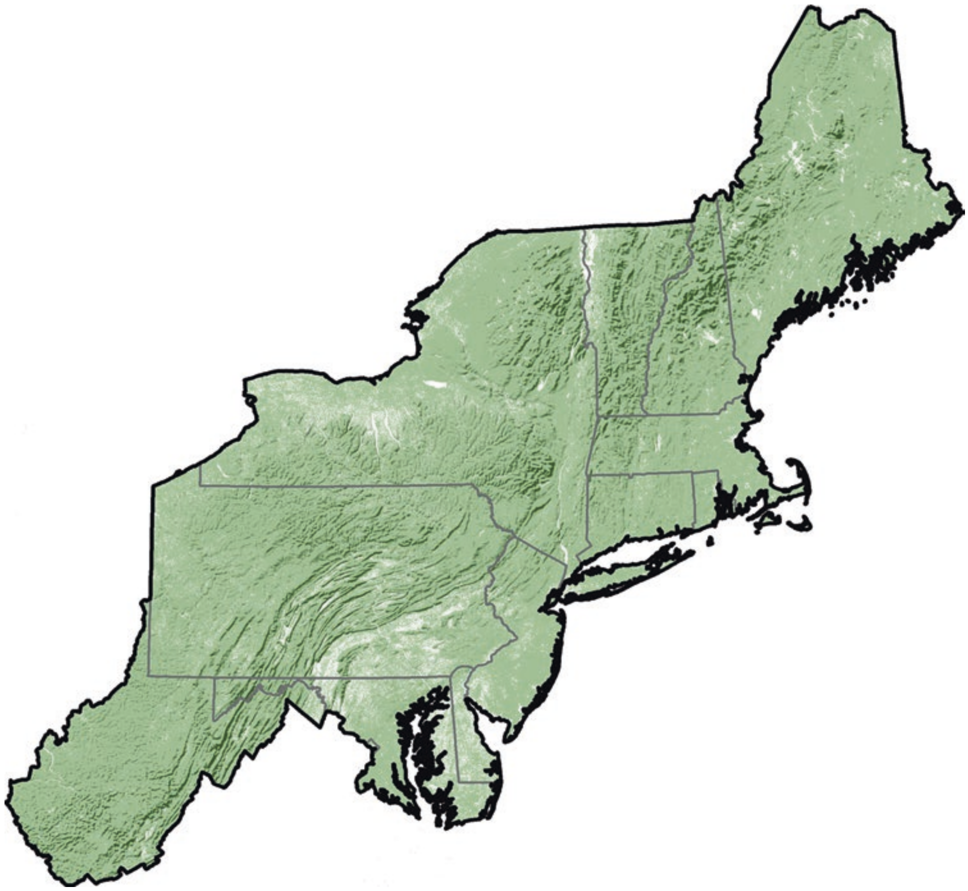

Fig. A7.1 The Northeast region. (Figure courtesy of Daniel Ryerson and Andy Graves, USDA Forest Service Southwestern Region, Forest Health Protection)

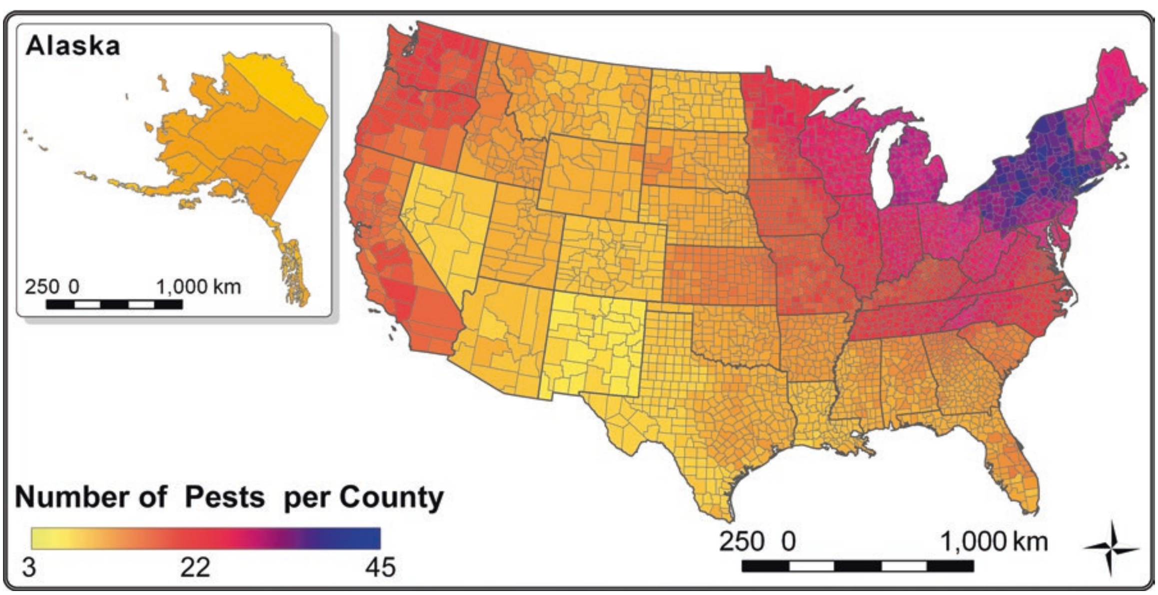

Fig. A7.2 Numbers of damaging invasive forest insects and pathogens per county in the United States. (Source: Liebhold et al. 2013)

significant invasive threats in the region encompassing insects, plant and wildlife pathogens, aquatic animals, and terrestrial and aquatic plants. Recognizing the importance of human interactions in exacerbating pest problems, collaborative organizations such as the forest health subcommittee of the Northeast-Midwest State Foresters Alliance (NMSFA) and New York's Partnerships for Regional Invasive Species Management (PRISMs) are working to identify and prioritize research needs and management/preventive actions (NAASF 2017; CUCE 2017).

Insect Pests of Trees

Gypsy moth (*Lymantria dispar*) feeds on hundreds of species of trees and shrubs and is a serious defoliator of oaks and aspen, often causing severe defoliation, as well as tree decline and mortality in the aftermath of outbreaks. Gypsy moth has caused more than 12 million ac of defoliation in the Northeast region since 2000 (USDA 2017). The insect has been the focus of government-sponsored intervention programs for more than a century, first to eradicate the insect from the United States, and then for its biological control (starting around 1900), and later to manage its adverse effects and slow its spread. Today, gypsy moth resides in all or parts of every State in the Northeast region. Gypsy moth populations are subject to regulation by a variety of biological control agents (i.e., parasitoids, predators, and entomopathogens), but these agents may not prevent periodic outbreaks and subsequent damage from occurring. At the Federal level, management of the insect consists of the integration of three distinct strategies depending on where the insect is found (USDA 2012a). Suppression is implemented to reduce adverse effects to trees caused by outbreaks of the insect. Between 2000 and 2016, State-led aerial treatment projects applied insecticides for gypsy moth control on about 2.3 million ac in Maryland, New Jersey, New York, Pennsylvania, and West Virginia (USDA 2017). With very few exceptions, the entire Northeast region is known to be generally infested by the insect. Therefore, an eradication strategy—that is, elimination of isolated colonies of the insect—is no longer pursued. The third strategy is the Slow the Spread (STS), a unique landscape-scale program in which the objective is to slow the natural and short-range human-aided spread of the insect along the leading edge of the generally infested area. STS is the first of its kind for a forest pest. The design and implementation of STS is science-based, with the overall strategy based on research that indicated this was an optimal approach for minimizing spread. Southern West Virginia is the only portion of the Northeast region located within the STS project area. Since the start of STS, more than 327,000 ac have been treated in West Virginia, mostly (> 90%) employing the application of pheromone flakes to disrupt mating by gypsy moth adults (USDA 2017).

The hemlock woolly adelgid (HWA) (*Adelges tsugae*) threatens the survival and sustainability of eastern hemlocks (*Tsuga canadensis*) in the Northeast region and wildlife species that depend on them. The insect causes tree decline and mortality. Within the region, HWA can be found throughout Connecticut, Delaware, Massachusetts, Maryland, New Jersey, and Rhode Island, with it continuing to spread into uninfested areas in Maine, New Hampshire, New York, Pennsylvania, Vermont, and West Virginia. The National HWA Initiative, a landscape-scale effort, was established by the USDA Forest Service in 2003 to develop and implement tools to manage HWA and reduce the adverse effects across the range of eastern and Carolina (*T. caroliniana*) hemlocks. Current management of HWA in the Northeast region consists of enhanced survey and monitoring of HWA spread into uninfested areas and the application of systemic insecticides to protect high-value trees in the near term complemented with the release of biological control agents (predatory beetles) to manage HWA populations in the long term. Large-scale, State-organized and implemented HWA treatment initiatives on public lands are underway particularly in New Jersey, New York, Maryland, Pennsylvania, and West Virginia. Between 2013 and 2018 more than 75,000 wild-collected and laboratory-reared HWA predatory beetles, *Laricobius nigrinus* and *L. osakensis*, have been released on public lands in nine States in the Northeast region (Massachusetts, Maryland, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Vermont, and West Virginia). Other areas of focus include region-wide collection and storage of eastern hemlock seed, investigations into plant host resistance and tolerance, and silvicultural treatments to improve hemlock health (Havill et al. 2014).

Adults of the emerald ash borer (EAB) (*Agrilus planipennis*) feed on leaves, and larvae tunnel in the phloem, killing virtually all ash trees in a stand within 5–6 years of infestation. None of the 16 species of ash in North America are immune to EAB; however, some trees do survive in infested areas. Tree losses from EAB are estimated to be in the tens of millions in the Northeast region. The first detection of EAB in the region occurred in 2003 in Maryland. Since then, the insect has been detected in all other States in the Northeast region including Pennsylvania (2007), West Virginia (2007), New York (2009), Massachusetts (2012), Connecticut (2012), New Hampshire (2013), New Jersey (2014), Delaware (2016), Vermont (2018), Maine (2018) and Rhode Island (2018). Commerce and movement of infested nursery stock and wood products such as firewood are major contributors to the spread of the insect. The current management focus is on containment of the insect, regulating the movement of potentially infested materials to areas not infested with EAB, survey and monitoring, public outreach, and management of the insect through the release and establishment of biological control agents (parasitoids).

The Asian longhorned beetle (ALB) (*Anoplophora glabripennis*) threatens urban and forest hardwood trees. At least 13 tree genera and more than 100 different tree species are known to be suitable hosts for ALB (USDA 2012b), although the insect mostly prefers maples, poplars, willows (*Salix* spp.), and elms. Native to China and Korea, ALB was first detected in the United States in New York City in 1996. Other infestations were later found in Jersey City, NJ (2002); Middlesex and Union Counties, NJ (2004); Staten Island, NY (2007); Worcester, MA (2008); Boston, MA (2010); and most recently Babylon, NY (2013). In the Northeast region, ALB has been successfully eradicated from New Jersey and several areas in New York. Current ALB management in the region includes eradication, intensive surveys, quarantines to regulate the movement of infested material, education and outreach, removal and destruction of infested and high-risk host trees, and the use of systemic insecticides to protect high-value ash in communities and protect ash seed sources in forested areas. About 70,000 trees have been removed and destroyed, and about 800,000 trees have received insecticide treatments in Massachusetts and New York eradication sites.

Pathogens of Trees

The chestnut blight pathogen, *Cryphonectria parasitica*, was introduced on plant material in the early 1900s and spread rapidly to the natural forest, with devastating impacts on the composition and ecology of the eastern deciduous forest. At the time of settlement, American chestnut (*Castanea dentata*) was a key component of the forest comprising up to 50% or more of some stands. All of the mature American chestnuts in the native range of the host have died due to this pathogen, reducing the ecological position of the species to primarily stump sprouts. Currently, there are no management tools for this disease. Genetic resistance is considered the only hope for restoring this species in the region's forests. Nearly three decades of a backcross breeding program with American chestnut and the blight-resistant Chinese chestnut (*C. mollissima*) by The American Chestnut Foundation yielded the first progeny (BC_3F_3) predicted to have stable blight resistance in 2007 (Clark et al. 2012). A series of field tests using advanced breeding materials were initiated shortly thereafter (Clark et al. 2014). Techniques used to genetically transform chestnut trees that exhibit blight resistance is anticipated to accelerate further traditional breeding work to produce stable resistance trees for restoration work (Zhang et al. 2013).

In similar fashion to chestnut blight, white pine blister rust, caused by *Cronartium ribicola*, was introduced in the early 1900s on nursery stock. Today, it is currently distributed throughout the range of eastern white pine (*Pinus strobus*). It causes mortality and top dieback to white pine, particularly on sites subject to climatic conditions suitable for infections to occur. It also influences the agricultural use of commercial varieties of the alternate *Ribes* host, on which it causes a severe leaf disease. New strains of the pathogen have recently overcome resistance of commercial *Ribes* cultivars. White pine blister rust is considered one of the most limiting factors in growing white pine in the Northeast region. The disease is currently managed by appropriate site selection, pathological pruning, and planting of putatively resistant *Pinus* nursery stock and *Ribes* cultivars (Geils et al. 2010).

The first outbreak of beech bark disease in North America, caused by the interaction of an exotic beech scale (*Cryptococcus fagisuga*) and several canker fungi (*Neonectria* spp.), was observed in Nova Scotia in 1920 and by the 1930s had invaded Maine and other parts of New England. As the disease moves through native forests, it kills a significant proportion of the important mast-producing American beech, leading to loss of wildlife food and predominant tree species. Much of the beech in the region is now part of the forest that is regenerating following beech bark disease invasion (aka the aftermath forest). The disease is currently managed on the advancing front through salvage harvesting with retention of smooth-barked and unaffected trees and preventing movement of infested materials. Management of the disease in the aftermath forest, however, may require multifactor approaches targeting the different biotic agents involved in this complex disease (Cale et al. 2015).

Dutch elm disease (DED) is a vascular wilt disease that has devastated native elms (*U. americana* and *U. rubra*) across the Northeast region since the pathogen *Ophiostoma ulmi* was introduced along with its insect vector, the smaller European elm bark beetle (*Scolytus multistriatus*), on logs before 1935. A second pathogen of unknown origin, *O. novo-ulmi*, emerged later as an even more aggressive component of the disease. The pathogen(s) are also vectored by the native elm bark beetle (*Hylurgopinus rufipes*) and the more recently introduced banded elm bark beetle (*Scolytus schevyrewi*). The disease rapidly destroyed the iconic lines of elm along city streets in the Northeast but also affected the natural floodplain forests in which these trees were a dominant species (Marks 2017). As native elms regenerate on wildland sites, DED causes mortality in temporal wave related to fluctuating populations of the vectoring bark beetles. Management of the disease in urban elms is accomplished by sanitation to control the insect vectors, chemical injections, and use of disease-tolerant cultivars (Haugen 1998). Similar management tools are not available for wildland areas; however, work has begun to enhance resistance by crossing rare, large, surviving American elms with the few DED-resistant American elms (Pinchot et al. 2017).

Butternut canker (caused by *Ophiognomonia clavigignenti-juglandacearum*) was first reported in Wisconsin in 1967 and is believed to have had several introductions to North America (Broders et al. 2014). The disease is now distributed throughout the natural range of butternut (*Juglans cinerea*). The disease kills up to 90% of butternut in affected stands and may lead to extirpation of the species (Shultz 2003). Silvicultural approaches are needed for butternut regeneration, as well as the development of resistance to ensure survival of the species (LaBonte et al. 2015). There are no existing tools for management of the disease.

Oak wilt, caused by *Bretziella fagacearum* (syn. *Ceratocystis fagacearum*), is a devastating disease, particularly of red oak species (*Quercus* subsection *Lobatae*). For decades, the disease has been known to occur within West Virginia, Pennsylvania, and Maryland. It was recently discovered at multiple locations in New York State, making this an emerging problem in the Northeast region. Oak wilt is managed in urban and wildland environments by disrupting the disease cycle to prevent new centers from becoming established and existing centers from expanding. Approaches to disease management on forest lands include preventing movement of diseased material, avoiding wounding or tree harvesting during high-risk periods, and disruption of connected root systems (Juzwik et al. 2011).

Pathogens of Wildlife

White-nose syndrome, caused by *Pseudogymnoascus destructans*, has led to a rapid decline in bat populations since the disease was first detected in New York in 2006 (Frick et al. 2010). The disease is now widespread in the Northeast region. White-nose syndrome is currently managed by restricting access to hibernacula.

Invasive Animals of Aquatic Systems

The aquatic animals that have had the greatest impacts in the Northeast region are sea lamprey (*Petromyzon marinus*) and zebra (*Dreissena polymorpha*) and quagga (*D. bugensis*) mussels. Sea lampreys, which parasitize and kill native and non-native fish sometimes leading to population crashes, are present in the Great Lakes and in several large inland lakes in New York; however, sea lamprey is only considered invasive in the Great Lakes. There are several other invasive fish that are attributed with negative impacts in the region. These include common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), northern snakehead (*Channa argus*), and oriental weatherfish (*Misgurnus anguillicaudatus*).

Zebra and quagga mussels are present in the Great Lakes as well as in large navigable rivers and many small lakes in the region. They cause economic and ecological harm by fouling infrastructure and personal property and by altering the energy flows in food webs away from pelagic species, which are often valuable sport fish. Other invasive mollusks include Asian clams (*Corbicula fluminea*) and New Zealand mud snail (*Potamopyrgus antipodarum*), which compete with native species and alter nutrient cycling.

Invasive crustaceans in the Northeast include the predatory cladocerans, spiny (*Bythotrephes longimanus*) and fishhook (*Cercopagis pengoi*) water fleas, which compete with juvenile fish for food resources. Chinese mitten crabs (*Eriocheir sinensis*) and Asian shore crabs (*Hemigrapsus sanguineus*) have also been collected in the region and have the potential to alter food webs and damage infrastructure. In the canals of New York State and the Hudson River alone, the economic losses attributable to aquatic invasive species are estimated at $500 million, with impacts affecting commercial and recreational fishing the most (Pimentel 2005). Relative to many other parts of the United States, the Northeast is highly developed and highly populated. The combination of many roads with many water access points and many people traveling those roads and visiting waterways facilitates the human-mediated spread of aquatic invasive species. Similarly, the extensive network of man-made canals in the Northeast has accelerated the spread of introduced species throughout the region.

There are no cost-effective control methods available for most aquatic invasive animals in the Northeast region. Research into more effective and less expensive control methods is ongoing. Current management efforts emphasize spread prevention through campaigns to educate the public about the importance of not intentionally or inadvertently moving species among waterways, and the best practices for avoiding these movements. Direct intervention efforts such as inspecting and pressure washing recreational boats and trailers to remove invasive species propagules and laws banning the movement of species and water among waterways are also important prevention efforts.

Invasive Plants of Aquatic and Terrestrial Systems.

State committees and working groups in the Northeast region have ranked the significance of hundreds of invasive plant species. In New York State, for example, the ranking is based on (1) ecological impact, (2) biological characteristics and dispersal ability, (3) ecological amplitude and distribution, and (4) difficulty of control (Jordan et al. 2012[1]). Of New York's 183 listed invasive plant species, 32 received an invasiveness rank of Very High (Brooklyn Botanical Garden 2013[2]). Of these 32 species, 22 occupy terrestrial habitats: Norway maple (*Acer platanoides*), garlic mustard (*Alliaria petiolata*), Japanese angelica tree (*Aralia elata*), Japanese barberry (*Berberis thunbergii*), slender false brome (*Brachypodium sylvaticum*), Oriental bittersweet (*Celastrus orbiculatus*), black swallow-wort (*Cynanchum louiseae*), pale swallow-wort (*C. rossicum*), autumn olive (*Elaeagnus umbellata*), winged euonymus (*Euonymus alatus*), Japanese knotweed (*Fallopia japonica*), Japanese honeysuckle (*Lonicera japonica*), Amur honeysuckle (*L. maackii*), Morrow's honeysuckle (*L. morrowii*), Japanese

[1] Jordan, M.J.; Moore, G.; Weldy, T.W. 2008 (2012 update). New York State ranking system for evaluating non-native plant species for invasiveness. Unpublished report. On file with: The Nature Conservancy, 250 Lawrence Hill Road, Cold Spring Harbor, NY 11724

[2] Brooklyn Botanic Garden. 2013. Invasiveness assessment scores and ranks for 183 non-native plant species in New York State. Unpublished report. On file with: Brooklyn Botanic Garden, 1000 Washington Avenue, Brooklyn NY 11225

stiltgrass (*Microstegium vimineum*), mile-a-minute weed (*Persicaria perfoliata*), kudzu (*Pueraria montana*), lesser celandine (*Ranunculus ficaria*), common buckthorn (*Rhamnus cathartica*), black locust (*Robinia pseudoacacia*), multiflora rose (*Rosa multiflora*), and wineberry (*Rubus phoenicolasius*).

The remaining 10 of the 32 highly ranked invasive species occupy wetland or aquatic sites: waterthyme (*Hydrilla verticillata*), frogbit (*Hydrocharis morsus-ranae*), Uruguayan primrose-willow (*Ludwigia grandiflora*), floating primrose-willow (*L. peploides*), purple loosestrife (*Lythrum salicaria*), broadleaf watermilfoil (*Myriophyllum heterophyllum*), Eurasian watermilfoil (*M. spicatum*), common reed grass (*Phragmites australis*), gray florist's willow (*Salix atrocinerea*), and water chestnut (*Trapa natans*).

The Federally listed noxious weed giant hogweed (*Heracleum mantegazzianum*), which received an invasiveness rank of High in New York, should also be considered a priority in the Northeast, as it poses a significant threat to human health and safety.

Because New York is somewhat geographically centered in the Northeast, most of the above-listed species occur throughout the region and are considered priority threats. Exceptions would be slender false brome, which has not yet been found in New England States, and black locust, which is actually a native species from Pennsylvania southward. Similarly, glossy buckthorn (*Frangula alnus*) and hardy kiwi (*Actinidia arguta*) are regarded as priority threats in New England States, while arthraxon (*Arthraxon hispidus*) and wavyleaf basketgrass (*Oplismenus undulatifolius*) are priority threats in Mid-Atlantic States.

Educational efforts have been extremely successful in raising awareness of the threats posed by invasive plants. Such threats are not limited to competition for space and resources. American bittersweet (*Celastrus scandens*), for example, is threatened by genetic swamping. It is hybridizing with Oriental bittersweet and no longer breeds true in certain areas (Zaya et al. 2015).

Education has led to action. Many States now have prohibited plant lists, identifying species that may no longer be bought and sold, thereby helping to prevent future spreading through cultivation. Landowners, municipalities, conservation organizations, regional partnerships, and agencies have waged countless battles on invasive plants. Over the years, control efforts have become more strategic and more effective. The emphasis has been on early detection and early control. Practitioners recognize, however, that invasive plants are here to stay. Eradication is virtually impossible. Limited resources are being directed to protect the most important and the most threatened natural resources, using control methods that are often integrated or novel. Similarly, practitioners recognize that infestations are often a symptom, and not the cause, of ecosystem degradation. Invasive plants often thrive in response to anthropogenic perturbations and in forests damaged by overabundant white-tailed deer (*Odocoileus virginianus*). Such forests have lost much of their biotic resistance to exotic plant invasion (Kalisz et al. 2014; Knight et al. 2009). After Rhode Island's largest infestation of Japanese stiltgrass was discovered, the recommendation was to enclose the four-acre area in deer fencing, which restored biotic resistance to the site and all but eliminated the stiltgrass in just 3 years, without the use of any herbicides or any mechanical control measures. Restoring biotic resistance in forest ecosystems and mitigating disturbance impacts hold promise for the effective control of invasive plants in the Northeast and elsewhere.

Literature Cited

Broders K, Boraks A, Barbison L et al (2014) Recent insights into the pandemic disease butternut canker caused by the pathogen *Ophiognomonia clavigignenti-juglandacearum*. For Pathol. https://doi.org/10.1111/efp.12161

Cale JA, Teale SA, Johnston MT et al (2015) New ecological and physiological dimensions of beech bark disease development in aftermath forests. For Ecol Manag 336:99–108

Clark SL, Schlarbaum SE, Saxton AM et al (2012) Lessons from the field: the first tests of restoration American chestnut (*Castanea dentata*) seedlings planted in the Southern Region. In: Butnor JR (ed) Proceedings of the 16th biennial southern silvicultural research conference. General Technical Report-SRS-P-156. U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, pp 69–70

Clark SL, Schlarbaum SE, Pinchot CC et al (2014) Reintroduction of American chestnut in the National Forest System. J For 112:502–512

Cornell University Cooperative Extension (CUCE) (2017) New York Invasive Species Information, Partnerships for Regional Invasive Species Management (PRISMs). http://www.nyis.info/index.php?action=prism_partners

Frick WF, Pollock JF, Hicks AC et al (2010) An emerging disease causes regional population collapse of a common North American bat species. Science 329:679–682

Geils BW, Hummer KE, Hunt RS (2010) White pine, *Ribes*, and blister rust: a review and synthesis. For Pathol 40:147–185

Haugen LM (1998) How to identify and manage Dutch elm disease. USDA Forest Service, Northeastern State & Private Forestry NA-PR-07-98

Havill NP, Viera LC, Salom SM (2014) Biology and control of hemlock woolly adelgid. USDA Forest Service, Forest Health Technology Enterprise Team. FHTET-2014-05. 21 p

Juzwik J, Appel DN, MacDonald WL, Burks S (2011) Challenges and successes in management of oak wilt in the United States. Plant Dis 95:888–900

Kalisz S, Spigler RB, Horvitz CC (2014) In a long-term experimental demography study, excluding ungulates reversed invader's explosive population growth rate and restored natives. Proc Natl Acad Sci 111:4501–4506

Knight TM, Dunn JL, Smith LA et al (2009) Deer facilitate invasive plant success in a Pennsylvania forest understory. Nat Areas J 29:110–116

LaBonte NR, Ostry ME, Ross-Davis A et al (2015) Estimating heritability of disease resistance factors that contribute to long-term survival in butternut (*Juglans cinerea* L.). Tree Genet Genomes 11:63. https://doi.org/10.1007/s11295-015-0884-8

Liebhold AM, McCullough DG, Blackburn LM (2013) A highly aggregated geographical distribution of forest pest invasions in the USA. Divers Distrib 19:1208–1216

Marks CO (2017) The ecological role of American elm (*Ulmus americana* L.) in floodplain forests of northeastern North America. In: Pinchot CC et al (eds) Proceedings of the American elm restoration workshop 2016; 2016 October 25–27; Lewis Center, OH. General Technical Report NRS-P-174. U.S. Department of Agriculture, Forest Service, Northern Research Station, Newtown Square, pp 74–98

Northeastern Area Association of State Foresters (NAASF) (2017) Northeastern Area Association of State Foresters webpage. http://www.northeasternforests.org/

Pimentel D (2005) Aquatic nuisance species in the New York State Canal and Hudson River systems and the Great Lakes Basin: an economic and environmental assessment. Environ Manag 35:692–702

Pinchot CC, Flower CE, Knight KS et al (2017) Development of new Dutch elm disease-tolerant selections for restoration of the American elm in urban and forested landscapes. In: Sniezko RA et al (tech. coords) 2017 Gene conservation of tree species—banking on the future. Proceedings of a workshop. General Technical Report PNW-GTR-963. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, pp 53–63

Shultz J (2003) Conservation assessment for butternut or white walnut (*Juglans cinerea* L.). USDA Forest Service, Eastern Region. Hiawatha National Forest. www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm91_054130.pdf

U.S. Department of Agriculture (USDA) (2012a) Gypsy moth management in the United States: a cooperative approach. Supplemental environmental impact statement. U.S. Department of Agriculture, Forest Service and Animal and Plant Health Inspection Service. NA-MB-01-12, Washington, DC

U.S. Department of Agriculture (USDA) (2012b) Asian longhorned beetle and its host trees. U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. NA-PR-05-12, New Town Square

U.S. Department of Agriculture (USDA) (2017) Gypsy moth digest database. U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry, Newtown Square. https://www.fs.usda.gov/naspf/programs/forest-health-protection/gypsy-moth-digest

Zaya DN, Leicht-Young SA, Pavlovic NB et al (2015) Genetic characterization of hybridization between native and invasive bittersweet vines (*Celastrus* spp.). Biol Invasions 17:2975–2988

Zhang B, Oakes AD, Newhouse AE et al (2013) A threshold level of oxalate oxidase transgene expression reduces *Cryphonectria parasitica*-induced necrosis in a transgenic American chestnut (*Castanea dentata*) leaf bioassay. Transgenic Res 22:973–982

Southeast and Caribbean

Albert E. Mayfield III, Humfredo Marcano-Vega, and Ariel E. Lugo

Introduction

Wide climatic variations characterize the Southeastern United States (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia) and Caribbean (Puerto Rico and the US Virgin Islands) region, including tropical, subtropical, warm-temperate, and temperate environments, as well as diverse ecosystems from coastal wetlands and dunes to piedmont savannahs and montane forests (Fig. A8.1). More than 85% of the forest land in the continental Southeast is privately owned, with the region experiencing rapid population growth (particularly around urban centers), as well as increased landscape and ownership fragmentation (Butler and Wear 2013). This population growth and urbanization, along with changing climate, are likely to put stressors on southeastern ecosystems in ways that may increase their invasion by, or decrease their resilience to, non-native invasive species (Duerr and Mistretta 2013; Miller et al. 2013a). The Atlantic, Gulf, and Caribbean Coasts in the region are home to numerous major commercial ports. The large quantity of shipments arriving from international ports daily serves as a constant potential pathway for new invasive pests and/or their propagules into the region.

Invasive species in the Southeast and Caribbean region include a wide variety of taxa and affect both terrestrial and aquatic systems. Wood-boring insect species, such as ambrosia beetles and their microbial associates and