Invasive Plants, Insects, and Diseases in the Forests of the Anthropocene

Alexander M. Evans

Research Director, Forest Guild, Santa Fe, NM

Abstract: *Invasive species, non-native plants, insects, and diseases can devastate forests. They outcompete native species, replace them in the ecosystem, and even drive keystone forest species to functional extinction. Invasives have negative effects on forest hydrology, carbon storage, and nutrient cycling. The damage caused by invasive species exacerbates the other forest stresses of the Anthropocene: increased human intrusion throughout natural landscapes, the fragmentation of forests, and a changing climate. Warming will open new areas for ecological invasion while the rising concentration of CO_2 (carbon dioxide) in the atmosphere gives many invasives an edge over native species. Storms and extreme climatic events are likely to become more frequent, and these events will facilitate the introduction and spread of invasive species. The cumulative effect of these stressors is impaired ecosystems that can no longer provide all the services on which humans rely. Because these changes are not possible without humans to facilitate the introduction and spread of new species, the impact of invasives is a defining element of the Anthropocene.*

INTRODUCTION

The unprecedented mixing of species from across continents and ecosystems is one of the profound changes of the Anthropocene. Species introduced into completely different ecosystems are freed from the constraints that limited their growth and expansion in their home systems (Phillips and others. 2010). For example, plants can escape the herbivores adapted to feed on them, insects can escape the pathogens that limited their population growth, and newly introduced species can find new opportunities such as hosts with little resistance to their attack (Liebhold and others. 1995). The combination of fewer constraints and new opportunities allow some introduced species to flourish in their new environments to the detriment of native species; in short, to be become invasive species (Torchin and others. 2003). Executive Order 13112 (1999) defines invasive species as alien species whose introduction causes economic or environmental harm or harm to human health. In many cases, the introduction of species into new ecosystems is an unintended consequence of human movement and trade

(Bradley and others. 2011). Some invasives were introduced intentionally to bring useful plants and animals to new places for the benefit of humans (Reichard and White 2001). However, once introduced into a new ecosystem, invasive species are able expand in that ecosystem without human assistance (e.g., Gibbs and Wainhouse 1986). As invasive species expand their range, they can create novel ecosystem interactions and unforeseen outcomes (Hobbs and others. 2006; Mascaro and others. 2011).

In addition to their ecological costs, exotic forest invaders have a large economic impact on both forest products and ecosystems services (Pimentel and others. 2005; Holmes and others. 2009) For instance, a mere three invasive insects cause approximately $1.7 billion dollars in damages in the United States annually (Aukema and others. 2011). By one estimate, the United States spends about $1.3 million dollars a year on surveillance to keep just one pest, the Asian gypsy moth (*Lymantria dispar*), from invading (Work and others. 2005).

The negative impact of invasive species is likely to expand during the Anthropocene. Their effect is exacerbated by the warming climate (Bradley and others. 2010), more frequent extreme climatic events (Diez and others. 2012), large and severe fires (Ziska and others. 2005), and forest fragmentation (Dewhirst and Lutscher 2009). Moreover, it is not just the invasive species already in our forests that will thrive as the climate changes as the introduction of new species is almost inevitable. As global trade continues to move vast cargos across the world, the chance of new introductions is high. Work and colleagues (2005) estimate that about seven species are introduced to the United States each year via refrigerated maritime cargo alone. Even native insects, plants, and diseases may act more like invasive species in the Anthropocene under new climate conditions (Weed and others. 2013).

Invasive species will help define the forests of the Anthropocene, hence it is vital to understand the types of invaders we face, their impacts, and how they interact in natural ecosystems. While all ecosystems have been altered by invasive species, this discussion is limited to plants, insects, and diseases affecting forested ecosystems. Though animals such as the brown tree snake (*Boiga irregularis*) or feral pigs (*Sus scrofa*) have detrimental impacts on forested ecosystems, they are excluded from this paper in an effort to limit an already expansive topic. For the same reason, this paper also excludes invasion of wetland and coastal communities. While all the examples and most of the research cited is drawn from the United States, the issue of invasives in the Anthropocene is, of course, international (e.g., Yan and others. 2001).

OVERVIEW

Plants

Humans are enthusiastic about importing new species of plants for economic benefit or aesthetic appeal, but these introductions frequently go wrong and result in exotic plants invading native forests (e.g., Forseth and Innis 2004). By one estimate, the horticultural trade is responsible for over 80 percent of invasive plants in the United States (Reichard and Hamilton 1997). Other common pathways include accidental introduction with crop seeds and purposeful introductions for soil erosion control (Reichard and White 2001). Many of the invasive plants in the United States are agricultural weeds; in other words, plants that interfere with crop production or grazing, but these are generally outside of the scope of this paper. Though the focus of this paper is on forests, the list of invasive plants is still long. In the northern forests of the United States, the major invasive plants of concern include the following species among many others (Shifley and others. 2012):

- spotted knapweed (*Centaurea biebersteinii*),
- tree-of-heaven (*Ailanthus altissima*),
- Russian olive (*Elaeagnus angustifolia*),
- multiflora rose (*Rosa multiflora*),
- garlic mustard (*Alliaria petiolata*),
- Japanese knotweed (*Fallopia japonica*), and
- bush honeysuckle (*Lonicera* spp.).

In the forest of the Southeast, the list includes (Hanson and others 2010):

- mimosa trees (*Albizia julibrissin*),
- kudzu (*Pueraria lobata*),
- Asian bittersweet (*Celastrus orbiculatus*),
- cogon grass (*Imperata cylindrica*), and
- Japanese stiltgrass (*Microstegium vimineum*).

In western forests, invasive species of concern would include (Cal-IPC 2006; Gray and others 2011):

- cheat grass (*Bromus tectorum*),
- salt cedar (*Tamarix* spp.),
- toadflax (*Linaria* spp.),
- spotted knapweed (*Centaurea maculosa*),
- Scotch broom (*Cytisus scoparius*),
- leafy spurge (*Euphorbia esula*), and
- knapweeds (*Centaurea* spp.).

Unfortunately, these 19 species are just a small sample of all the invasive species in the United States Forests and readers are encouraged to refer to publications specific to each region or state to identify invasive plants (e.g., Olson and Cholewa 2009; Miller and others. 2010; Gray and others. 2011). Mapping from programs such as the Early Detection and Distribution Mapping System (www.eddmaps.org/distribution/) shows that invasive plants cover the entire United States. Though not every forested acre has been invaded by non-native plants, at the county scale, invasive plants are ubiquitous in the coterminous United States. For example, a study of 24 northeastern and mid-western states found 66 percent of all plots had at least one invasive plant (Schulz and Gray 2013). Disturbed areas, particularly roadsides, accumulate invasive plants because many invasives are adept at colonizing open growing space (Aikio and others. 2012).

Invasive plants disturb ecosystems in a number of ways. Out of the 1,055 threatened plant species in the United States, about 57 percent are affected by invasive plants (though often in combination with other stressors) (Gurevitch and Padilla 2004). Invasive species outcompete and overwhelm native plant species. For example, kudzu covers some 7.4 million acres in the United States, where it shades out and crushes other plants (Forseth and Innis 2004). Similarly, stiltgrass outcompetes native plants, reduces herbaceous diversity, impedes native woody species regeneration, and creates extensive stiltgrass monocultures (Oswalt and others 2007; Adams and Engelhardt 2009). Invasive plants can disrupt plant reproductive mutualism such as pollination or seed dispersal, causing population reductions (Traveset and Richardson 2006). An example of a less visible influence of the presence of invasive plants is the allelopathic effect of tree of-of heaven, which has a detrimental impact on red oak regeneration (*Quercus rubra*), an important tree both economically and ecologically in the eastern United States (Gómez-Aparicio and Canham 2008). Another example is melaleuca (*Melaleuca quinquenervia*) which has converted wetlands to uplands through increased litter inputs over many years (Strayer and others 2006).

Invasive plants often negatively impact water quantity because they tend to grow fast and use more water than native species (Brauman and others 2007). Invasive plants alter, usually negatively, habitat for wildlife. Some reduction in habitat quality is to be expected where animals have adapted to a plant community that is subsequently disrupted by invasives. For example, birds that nest in honeysuckle and buckthorn (*Rhamnus cathartica*) experience higher predation rates than those that nest in native plants (Schmidt and Whelan 1999). Even when invasive species like buckthorn provide fruits for animals (birds in this case), these fruits are often less nutritious than those provided by the native species displaced by the invaders (Smith and others 2013). About 28 percent of birds listed as threatened are negatively affected by invasive plants (Gurevitch and Padilla 2004).

Insects

There are some 455 invasive insects in U.S. forests, though only about 62 cause significant ecosystem damage (Aukema and others 2011). Of those insects that have a significant impact on forested ecosystems and feed on trees, about a third feed on sap, a quarter are wood borers, and the remainder feed on foliage (Aukema and others 2010). Over the last century, an average of about 2.5 non-native insects were detected in the United States per year (Aukema and others 2010) and Koch and colleagues (2011) predict new alien forest insect species establishments every 5–15 years in select urban areas. Not every foreign insect that establishes in the United States becomes a destructive invasive, but many have. Some of these insects, such as the gypsy moth, have been in this country for over a century, and many have spread through the entire range of their new hosts. Mapping tools such as the Alien Forest Pest Explorer (www.nrs.fs.fed.us/tools/afpe/) illustrate that at least one, but often many, invasive forest insects infest every forested region in the United States.

Many invasive insects are specialists that feed on, or live in, one particular tree or shrub species or genus. For instance, hemlock woolly adelgid (*Adelges tsugae*) feeds only on species of hemlock. Others, such as the gypsy moth, attack a broad range of tree species. The Northeast and Appalachian forests have a particularly high number of destructive insects, in part because of their proximity to busy eastern ports and in part because of the large number of tree species that can support a large number of species-specific invaders (Liebhold and others 2013). In contrast, western interior forests have fewer different species of invasive insects (Liebhold and others 2013), perhaps because of their distance from ports of entry and because they have fewer species of trees and shrubs.

Insect populations often expand and collapse in response to environmental conditions. For native insects, populations can be very low and individuals difficult to find until conditions are right for an outbreak. The population then crashes due to declines in the host, lack of available food, climate shifts, predator response, or pathogens that spread easily at high population densities. Invasive species can build large, outbreak-type populations as they invade new areas because of the lack of constraints in the new environment. Because these are novel outbreaks, native trees are ill equipped to resist or recover from them. For example, populations of hemlock woolly adelgid can be very high once they have established in a new area, but even though adelgid populations decline as the health of hemlock trees decline, the outbreaks result in significant hemlock mortality (McClure 1991).

Polyphagous insects can cause a reduction in tree growth through massive defoliation, but species- or genus-specific invaders can also have disastrous impacts on forested ecosystems. By 2006, some 15 million ash trees had been killed by the Emerald ash borer (*Agrilus planipennis*) (Poland and McCullough 2006). This widespread mortality has cascading effects through the ecosystems with ash trees, including the loss of native insects (Gandhi and Herms 2010b). The death of hemlocks from hemlock woolly adelgid affects herbaceous plants (Eschtruth and others 2006), nutrient cycling (Cobb and others 2006), stream temperatures, fish communities (Ross and others 2003), bird diversity (Tingley and others 2002), and habitat for deer and other mammals (DeGraaf and others 1992). More generally, by removing important trees from U.S. forests, invasive insects have the potential to affect fundamental forest composition, structure, and function (Ellison and others 2005; Gandhi and Herms 2010a). The complexity of interdependencies within ecosystems makes it difficult to traces the full impact of invasive forest insects (Kenis and others 2009).

Diseases

There are likely many more non-native disease-causing organisms in the United States than have been identified because they are often difficult to detect. As with non-native insects, those we are most aware of are those that cause serious damage. For example, an early introduction, chestnut blight (*Cryphonectria parasitica*), functionally removed American chestnut (*Castanea dentata*) from its ecological role as a dominant tree in eastern forests by the 1950s (Tindall and others 2004). Though the list of significant invasive forest diseases is shorter than that of insects, diseases cover most forested regions of the United States (Aukema and others 2010). Chestnut blight, Dutch elm disease (*Ophiostoma* spp.), and butternut canker (*Sirococcus clavigignenti-juglandacearum*) cover the entire range of their host trees (Evans and Finkral 2010). Beech bark disease (*Ophiostoma* spp.) has spread through forests where beech trees (*Fagus americana*) are most dense (Morin and others 2007). Based on past spread rates, it is likely that other significant diseases including sudden oak death (*Phytophthora ramorum*), dogwood anthracnose (*Discula destructiva*), laurel wilt (*Raffaelea lauricola*), and phytophthora root rot (*Phytophthora cinnamomi*) will likewise expand to fill their ecological niche in the United States (Evans and Finkral 2010).

A lack of coevolution between host and pathogen can result in limited resistance in the host tree and excessive aggressiveness (i.e., greater host mortality) in the pathogen, which in turn causes disease outbreaks (Brasier 2001). For example, there is very limited genetic resistance of tanoaks (*Notholithocarpus densiflorus*) to sudden oak death (Hayden and others 2011). Because genetic resistance to invasive diseases may vary in a native tree population, identifying and protecting potential resistant individuals is an important management response (Schwandt and others 2010). Selection and breeding presents a possible route to increasing resistance to beech bark disease in American beech populations (Koch and others 2010). Diseases introduced to forests have removed dominant tree species, reduced diversity, altered disturbance regimes, and affected ecosystem function (Liebhold and others 1995, Mack and others 2000). The cascading effects of the removal of important trees species are similar to the effects of invasive insects and influence forest structure as well as the animals and plants connected to the diseased trees.

Synergies

The previous sections discussed invasive plants, insects, and diseases separately, but of course they interact with each other and with other forest stressors. An invasion by one species can facilitate other invaders (Green and others 2011). For example, the tree-of-heaven's allelopathy facilitates the secondary invasion of another invasive plant, Fuller's teasel (*Dipsacus fullonum*), by suppressing native competitors (Small and others 2010). There are numerous examples of insect invaders facilitating invasion by plants. The emerald ash borer helps buckthorn and honeysuckle invade forests by opening the canopy (Hausman and others 2010). Japanese barberry (*Berberis thunbergii*), Asian bittersweet, and honeysuckle often invade forests after hemlock woolly adelgid has caused canopy mortality (Small and others 2005). Defoliation by gypsy moth helped tree-of-heaven spread through the forests of Pennsylvania (Kasson and others 2013). Though less well-documented, it is likely that invasive forest diseases have also facilitated the invasion of plants by creating canopy openings. Diseases also help insects by sapping tree defenses (e.g., Parker and others 2006). The synergy between invasives that aggravate the impact on native ecosystems has been labeled "invasional meltdown" (Simberloff and Von Holle 1999). Unfortunately, evidence is beginning to accumulate that this invasional meltdown is already occurring in some ecosystems (Simberloff 2006).

INVASIVES IN THE ANTHROPOCENE

Humans are tightly linked with invasive species. They are a key factor in the introduction of invasive species as discussed above, but they are also a key factor in their spread. For example, the transportation of firewood has been identified as an important vector for invasive insects, particularly long-distance dispersal (Bigsby and others 2011; Koch and others 2012). Human development and infrastructure also help invasive species flourish. Many invasive plants such as Asian bittersweet and multiflora rose (*Rosa multiflora*) thrive in disturbed areas and the open edge habitat created by human development (Yates and others 2004; Kelly and others 2010). The trees of these disturbed, edge habitats may also be more stressed, and hence more susceptible to insects and diseases. For example, in one Ohio study, 84 percent of new emerald ash borer infestations were within 0.6 miles (1 km) of major highways (Prasad and others 2010). Even low-density residential areas are associated with a greater density of invasive plants (Gavier-Pizarro and others 2010). The effect of human land use on invasives lasts a long time, as demonstrated by a study that links invasive plants in North Carolina with historic land use and reforestation (Kuhman and others 2010).

Human Development

Human development is expanding in the Anthropocene and with it the opportunity for invasives expands as well. About one third of the coterminous United States was human-dominated in 2001, and an additional 35,600 square miles (92,200 km^2, or roughly the size of Indiana) are likely to be converted from natural cover to development by 2030 (Theobald 2010). About 15 percent of the current acreage of southern forests could be converted to housing and other uses by 2040 (Hanson and others 2010). Although the long-term trend in the Northeast during the 20th century was one of increasing forest cover, this trend has recently reversed, and the total number of forested acres has started to decline again (Drummond and Loveland 2010). As much as 909,000 acres (368,000 hectares), or about two percent of forest land, could convert from forest to other land uses in Maine, New Hampshire, Vermont, and New York by 2050 (Sendak and others 2003). This growing human presence and increased fragmentation is a significant driver in the spread and domination of invasive species in U.S. forests (Lundgren and others 2004; Gavier-Pizarro and others 2010; Schulz and Gray 2013). An indirect effect of fragmentation and suburbanization is the population growth of animals that thrive in human environments. For instance, deer (*Odocoileus virginianus*) populations have grown significantly in many suburban/forest interface zones. The high deer populations help spread invasives and, at the same time, hamper the regeneration of native species (Evans 2008; Williams and others 2008).

Climate Change

Not only is human development making the landscape more available to invasives, but in addition, human-driven changes to the climate benefit invasives. A warming climate opens new ecosystems to invaders previously limited by cold. Warming will facilitate the spread of invasive plants such as kudzu and privet (*Ligustrum sinense*) as far north as New England by 2100 (Jarnevich and Stohlgren 2009; Bradley and others 2010). In general, invasive plants have been far better able to respond to recent climate change in New England than native species (Willis and others 2010). Warming will also facilitate the spread of invasive insects such as hemlock woolly adelgid (Evans and Gregoire 2007). Two or three times more forest in Canada will be at risk from gypsy moth by 2060 because of a changing climate (Régnière and others 2009). Similarly, climate changes will modify forest pathogen dynamics and may exacerbate some disease problems (Sturrock and others 2011). For instance, sudden oak death has potential to expand its range under a warming climate (Venette and Cohen 2006). Increasing summer temperatures appear to exacerbate outbreaks of cytospora canker (*Valsa melanodiscus*) and mortality of alders (*Alnus incana*) in the Southern Rocky Mountains (Worrall and others 2010).

A changing climate means more than just warming temperatures. Other climate changes such as increased CO_2 (carbon dioxide) concentrations and more frequent and more powerful storms will benefit invasives. Rising CO_2 concentrations commonly give invaders an extra edge in competition with native species (Manea and Leishman 2011). For example, cheatgrass is able to take advantage of increased CO_2 concentrations by increasing productivity (Smith and others 2000). Higher CO_2 levels help kudzu and honeysuckle tolerate cold temperatures and hence expand these species' capacity for invading new forests (Sasek and Strain 1990). Extreme climatic events are likely to increase as the climate changes, and these events will facilitate the introduction and spread of invasive species (Diez and others 2012). Hurricanes, ice storms, wind storms, droughts, and fire can all create forest disturbances that invasive species can capitalize on. Many invasive species grow rapidly and can take advantage of the increased sunlight in forest gaps faster than can native species. A study in Florida found that nearly 30 percent of the species regenerating after Hurricane Andrew were invasive and that invasive vines negatively affect the regeneration of native plants (Horvitz and others 1998). Similarly, tufted knotweed (*Polygonum caespitosum*) and mile-a-minute weed (*Persicaria perfoliata*) were able to expand after Hurricane Isabel hit Maryland (though garlic mustard decreased because of the increased light) (Snitzer and others 2005).

The warming and, in many regions, drying predicted for the United States will increase the area burned in the United States over the next century (Moritz and others 2012). These predictions match the trend from the last few decades of increased fire activity in the United States (Westerling and others 2006). Some invasive species contribute to the increase in fire activity. Cheatgrass provides surface fuel that spreads fire more frequently than before its invasion (Ziska and others 2005). Sudden oak death also encourages fire by killing trees and creating more heavy fuel (Valachovic and others 2011). This synergy between sudden oak death and fire has caused a fourfold increase in the mortality risk for redwood trees (*Sequoia sempervirens*) (Metz and others 2013). While many native species are adapted to fire, altered fire regimes (more frequent or more severe fires) can benefit invasives. Uncharacteristically severe fire kills dominant vegetation that would have survived more natural fire and can creates growing space for invasives.

Native species under new conditions

In addition to the effects on invasives, climate change affects native species in unforeseen ways. With a changed climate, native species may be able to expand their range to new areas and may act like invaders in these new regions. Climate change has the potential to disrupt predator-prey relationships and permit outbreak conditions (Logan and others 2003). Temperature increases will shift native species ranges northward so new areas are affected, but at the same time, some previously affected areas may no longer be suitable for certain species (Ayres and Lombardero 2000). Warmer, drier conditions have helped drive insect outbreaks in the Southwest and Alaska (Logan and others 2003). Spruce budworm outbreaks in eastern Canada are predicted to be longer and more severe because of the changing climate (Gray 2008). Not only will mountain pine beetle be able to expand its range into much of the boreal forest, but it may be able to expand eastward by infesting jack pine (*Pinus banksiana*), a new host (Carroll and others 2006). Other previously obscure native insects such as the red oak borer (*Enaphalodes rufulus*) may become serious pests under new conditions (Riggins and Londo 2009).

HOPE FOR FORESTS IN THE ANTHROPOCENE

Is there any hope for native forest ecosystems in the Anthropocene? For conservationists, ecologists, foresters, wildlife biologists, and all those who work in the woods, the answer must be yes. The first key element in any response to invasive species should be concerted effort to limit new introductions (Hayes and Ragenovich 2001; Lodge and others 2006). Increased surveillance at ports and other introduction pathways can limit the growth of the invasive problem. Improved early detection strategies directed at a quarter of U.S. agricultural and forest land would likely be able to detect 70% of invaded counties (Colunga-Garcia and others 2010). If an invasive species avoid detection, a rapid response can help limit establishment (Anderson 2005). Similarly, policy or management actions that limit fragmentation and carbon emissions will reign in the negative interactions between invasives and these other forest stressors. There are steps that forest land owners and managers can take to increase ecosystem resistance to the effects of climate change and resilience to negative impacts of invasive pests and plants (Waring and O'Hara 2005). Eradication is impossible for many invasives and management should focus on those invasives that cause the most damage or those that can be effectively removed (Ellum 2009). A cornerstone of forest management in the face of the uncertainties of the Anthropocene is maintaining species diversity (Linder 2000). Maintaining or restoring species diversity on a site can increase the likelihood that some native species will flourish in this new epoch. Intact, diverse forest ecosystems may be more resistant to invasion (Jactel and others 2005; Huebner and Tobin 2006; Mandryk and Wein 2006). For example, the impact of sirex wood wasp has been less dramatic in the diverse forests of the United States than in the single species plantations in the southern hemisphere (Dodds and others 2010).

Even in the Anthropocene invasives are not invincible. Much of their competitive advantage comes from escaping the predators, pests, and pathogens of their region of origin. When those predators, pests, and pathogens catch up with an invader in a new region, the invader is less able to cause unusual damage or disrupt ecosystems. For example, *Entomophaga maimaiga*, a fungus that attacks gypsy moth, appears to have begun to limit the extent and impact of outbreaks in the areas longest infested by gypsy moth (Andreadis and Weseloh 1990). Similarly, a leaf blight has been discovered on stiltgrass that can cause reduced seed production, wilting, and, in some cases, death of stiltgrass plants (Kleczewski and Flory 2010). In a third example, an insect pest that can significantly retard the growth of kudzu has recently been found in Georgia (Zhang and others 2012). Once predators, pests, and pathogens have caught up with a non-native species in its new region, the label 'invasive' may no longer be appropriate. As with biological control of invasive plants and insects, human intervention may be able to change the dynamics of some invasive pathogens. New transgenic techniques hold promise for engineering resistance into tree such as elm and chestnut to battle exotic diseases (Merkle and others 2007).

As climate change alters ecosystems, there is the possibility that new restoration opportunities may emerge. For example, canopy openings created by hurricanes and other storm events could provide ideal planting sites for the restoration of American chestnut (Rhoades and others 2009). In addition, climate change may render some areas unfavorable to invasives that previously seemed entrenched. Models suggest that cheatgrass will no longer be viable in some areas of the western United States as the climate warms (Bradley and Wilcove 2009). In these locations, cheatgrass could be replaced with native species. Managers should be ready to seize these novel restoration opportunities if and when they emerge during the Anthropocene.

Though it can be considered heresy, invasive species may not be all bad. Some can provide ecosystem services, while others might fill novel ecological niches created by climate change and inaccessible to native species. For example, invasive tamarisk provides habitat for the endangered willow fly catcher (*Empidonax traillii*) (Shafroth and others 2005). With the recent introduction of the tamarisk leaf beetle (*Diorhabda carinulata*), which reduces tamarisks competitive advantage (Pattison and others 2011), it is worth reconsidering tamarisk's potential positive role in riparian ecosystems. A study in Hawaii demonstrates that though invasives caused the decline of native tree species, the new species were able to maintain some ecosystem functions (Mascaro and others 2011). While protecting against new invasives and fighting the spread of existing invasives are both important, it may be time to accept some non-native species.

Protecting refugia, such as parks and preserves, where threatened native species face fewer stressors may help those native species survive through the Anthropocene. Outside of parks and preserves, management that fosters diversity at both the stand and landscape scales can help minimize the threat of invasives. Managers must be ready to embrace any opportunities for pro-active restoration that may emerge because of a warming climate, species shifts, or disturbances. For entrenched invasives, conservationists may have to move from denial to acceptance and adapt forest management to a new mix of species. Though invasives are a significant threat to forests in the Anthropocene, all is not lost.

REFERENCES

Adams, S. N.; Engelhardt, K. A. M. 2009. Diversity declines in *Microstegium vimineum* (Japanese stiltgrass) patches. Biological Conservation. 142(5): 1003-1010.

Aikio, S.; Duncan, R.P.; Hulme, P.E. 2012. The vulnerability of habitats to plant invasion: disentangling the roles of propagule pressure, time and sampling effort. Global Ecology and Biogeography. 21(8): 778-786.

Anderson, L. J. 2005. California's Reaction to *Caulerpa taxifolia*: A Model for Invasive Species Rapid Response. Biological Invasions. 7(6): 1003-1016.

Andreadis, T. G.; Weseloh, R.M. 1990. Discovery of *Entomophaga maimaiga* in North American gypsy moth, *Lymantria dispar*. Proceedings of the National Academy of Sciences. 87(7): 2461-2465.

Aukema, J. E.; Leung, B.; Kovacs, K. [and others]. 2011. Economic impacts of non-native forest insects in the Continental United States. PLoS ONE. 6(9): e24587.

Aukema, J. E.; McCullough, D.G.; Holle, B.V. [and others]. 2010. Historical accumulation of nonindigenous forest pests in the continental United States. Bioscience. 60(11): 886-897.

Ayres, M.P.; Lombardero, M.J. 2000. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. The Science of the Total Environment. 262(3): 263-286.

Bigsby, K.; Tobin, P.; Sills, E. 2011. Anthropogenic drivers of gypsy moth spread. Biological Invasions. 13(9): 2077-2090.

Bradley, B., Wilcove, D.; Oppenheimer, M. 2010. Climate change increases risk of plant invasion in the Eastern United States. Biological Invasions. 12(6): 1855-1872.

Bradley, B.A.; Blumenthal, D.M.; Early, R. [and others]. 2011. Global change, global trade, and the next wave of plant invasions. Frontiers in Ecology and the Environment. 10(1): 20-28.

Bradley, B. A.; Wilcove, D. S. 2009. When invasive plants disappear: transformative restoration possibilities in the western United States resulting from climate change. Restoration Ecology. 17(5): 715-721.

Brasier, C.M. 2001. Rapid evolution of introduced plant pathogens via interspecific hybridization. Bioscience 51(2): 123-133.

Brauman, K.A.; Daily, G.C.; Duarte, T.K.; Mooney, H.A. 2007. The nature and value of ecosystem services: an overview highlighting hydrologic services. Annual Review of Environment and Resources. 32(1): 67-98.

Cal-IPC. 2006. California Invasive Plant Inventory. California Invasive Plant Council, Berkeley, CA.

Carroll, A. L.; Régnière, J.; Logan, J.A. [and others]. 2006. Impacts of climate change on range expansion by the mountain pine beetle. Mountain Pine Beetle Initiative Working Paper 2006-14, Canadian Forest Service, Victoria, BC.

Cobb, R.C.; Orwig, D.A.; Currie, S. 2006. Decomposition of green foliage in eastern hemlock forests of southern New England impacted by hemlock woolly adelgid infestations. Canadian Journal of Forest Research. 36(5): 1331-1341.

Colunga-Garcia, M.; Magarey, R.A.; Haack, R.A. [and others]. 2010. Enhancing early detection of exotic pests in agricultural and forest ecosystems using an urban-gradient framework. Ecological Applications. 20(2): 303-310.

DeGraaf, R.M.; Yamasaki, M.; Leak, W.B.; Lanier, J.W. 1992. New England wildlife: management forested habitats. General Technical Report NE-144, USDA Forest Service, Northeastern Forest Experiment Station, Radnor, PA.

Dewhirst, S.; Lutscher, F. 2009. Dispersal in heterogeneous habitats: thresholds, spatial scales, and approximate rates of spread. Ecology. 90(5): 1338-1345.

Diez, J.M.; D'Antonio, C.M.; Dukes, J.S. [and others]. 2012. Will extreme climatic events facilitate biological invasions? Frontiers in Ecology and the Environment. 10(5): 249-257.

Dodds, K.J.; de Groot, P.; Orwig, D.A. 2010. The impact of *Sirex noctilio* in *Pinus resinosa* and *Pinus sylvestris* stands in New York and Ontario. Canadian Journal of Forest Research. 40(2): 212-223.

Drummond, M. A.; Loveland, T. R. 2010. Land-use pressure and a transition to forest-cover loss in the eastern United States. Bioscience. 60(4): 286-298.

Ellison, A.M.; Bank, M.S.; Clinton, D.B. [and others]. 2005. Loss of foundation species: consequences for the structure and dynamics of forested ecosystems. Frontiers in Ecology and the Environment. 3 (9): 479-486.

Ellum, D. 2009. Proactive coevolution: Staying ahead of invasive species in the face of climate change and uncertainty. Forest Wisdom. (13): 1-3.

Eschtruth, A.K.; Cleavitt, N.L.; Battles, J.J. [and others]. 2006. Vegetation dynamics in declining eastern hemlock stands: 9 years of forest response to hemlock woolly adelgid infestation. Canadian Journal of Forest Research. 36(6): 1435–1450.

Evans, A.M. 2008. Growth and infestation by hemlock woolly adelgid of two exotic hemlock species in a New England forest. Journal of Sustainable Forestry. 26(3): 223-240.

Evans, A.M.; Finkral, A.J. 2010. A new look at spread rates of exotic diseases in North American forests. Forest Science. 56(5): 453-459.

Evans, A.M.; Gregoire, T.G. 2007. A geographically variable model of hemlock woolly adelgid spread. Biological Invasions. 9(4): 369-382.

Executive Order 13112. 1999. Invasive species. Office of the President of the United States, Washington, DC.

Forseth, I.N.; Innis, A.F. 2004. Kudzu (*Pueraria montana*): history, physiology, and ecology combine to make a major ecosystem threat. Critical Reviews in Plant Sciences. 23(5): 401-413.

Gandhi, K.; Herms, D. 2010a. Direct and indirect effects of alien insect herbivores on ecological processes and interactions in forests of eastern North America. Biological Invasions. 12(2): 389-405.

Gandhi, K.; Herms, D. 2010b. North American arthropods at risk due to widespread *Fraxinus* mortality caused by the Alien Emerald ash borer. Biological Invasions. 12(6): 1839-1846.

Gavier-Pizarro, G. I.; Radeloff, V. C.; Stewart, S. I. [and others]. 2010. Housing is positively associated with invasive exotic plant species richness in New England, USA. Ecological Applications. 20 (7): 1913-1925.

Gibbs, J. N.; Wainhouse, D. 1986. Spread of forest pests and pathogens in the northern hemisphere. Forestry. 59(2): 141-153.

Gómez-Aparicio, L.; Canham, C.D. 2008. Neighbourhood analyses of the allelopathic effects of the invasive tree *Ailanthus altissima* in temperate forests. Journal of Ecology. 96(3): 447-458.

Gray, A. N.; Barndt, K.; Reichard, S. H. 2011. Nonnative invasive plants of pacific coast forests: a field guide for identification. PNW-GTR-817, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Gray, D.R. 2008. The relationship between climate and outbreak characteristics of the spruce budworm in eastern Canada. Climatic Change. 87(3-4): 361-383.

Green, P.T.; O'Dowd, D.J.; Abbott, K.L. [and others]. 2011. Invasional meltdown: Invader–invader mutualism facilitates a secondary invasion. Ecology. 92(9): 1758-1768.

Gurevitch, J.; Padilla, D.K. 2004. Are invasive species a major cause of extinctions? Trends in Ecology & Evolution. 19(9): 470-474.

Hanson, C.; Yonavjak, L.; Clarke, C. [and others]. 2010. Southern forests for the future. World Resources Institute, Washington, DC.

Hausman, C.; Jaeger, J.; Rocha, O. 2010. Impacts of the emerald ash borer (EAB) eradication and tree mortality: potential for a secondary spread of invasive plant species. Biological Invasions. 12(7): 2013-2023.

Hayden, K. J.; Nettel, A.; Dodd, R. S.; Garbelotto, M. 2011. Will all the trees fall? Variable resistance to an introduced forest disease in a highly susceptible host. Forest Ecology and Management. 261(11): 1781-1791.

Hayes, J.L.; Ragenovich, I. 2001. Non-native invasive forest insects of eastern Oregon and Washington. Northwest Science. 75(Spec. Iss): 77-84.

Hobbs, R.J.; Arico, S.; Aronson, J. [and others]. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. Global Ecology and Biogeography. 15(1): 1-7.

Holmes, T.P.; Aukema, J.E.; Holle, B.V. [and others]. 2009. Economic impacts of invasive species in forests. Annals of the New York Academy of Sciences. 1162: 18-38.

Horvitz, C.C.; Pascarella, J.B.; McMann, S. [and others]. 1998. Functional roles of invasive non-indigenous plants in hurricane-affected subtropical hardwood forests. Ecological Applications. 8(4): 947-974.

Huebner, C.D.; Tobin, P.C. 2006. Invasibility of mature and 15-year-old deciduous forests by exotic plants. Plant Ecology. 186: 57-68.

Jactel, H.; Brockerhoff, E.; Duelli, P. 2005. A test of the biodiversity—stability theory: meta-analysis of tree species diversity effects on insect pest infestations, and re-examination of responsible factors. Pages 235-262 in M. Scherer-Lorenzen, C. Körner, and E.-D. Schulze, editors. Forest diversity and function. Temperate and boreal systems. Springer, Berlin, Germany.

Jarnevich, C.; Stohlgren, T. 2009. Near term climate projections for invasive species distributions. Biological Invasions. 11(6): 1373-1379.

Kasson, M.T.; Davis, M.D.; Davis, D.D. 2013. The invasive *Ailanthus altissima* in Pennsylvania: a case study elucidating species introduction, migration, invasion, and growth patterns in the northeastern US. Northeastern Naturalist. 20(m10): 1-60.

Kelly, A.B.; Small, C.J.; Dreyer, G.D. 2010. Vegetation classification and invasive species distribution in natural areas of southern New England. The Journal of the Torrey Botanical Society. 136(4): 500-519.

Kenis, M.; Auger-Rozenberg, M.-A.; Roques, A. [and others]. 2009. Ecological effects of invasive alien insects. Pages 21-45 in D. Langor and J. Sweeney, editors. Ecological Impacts of Non-Native Invertebrates and Fungi on Terrestrial Ecosystems. Springer Netherlands.

Kleczewski, N.M.; Flory, S.L. 2010. Leaf blight disease on the invasive grass *Microstegium vimineum* caused by a *Bipolaris* sp. Plant Disease. 94(7): 807-811.

Koch, F.; Yemshanov, D.; Colunga-Garcia, M. [and others]. 2011. Potential establishment of alien-invasive forest insect species in the United States: where and how many? Biological Invasions. 13(4): 969-985.

Koch, F.H.; Yemshanov, D.; Magarey, R.D.; Smith, W.D. 2012. Dispersal of invasive forest insects via recreational firewood: a quantitative analysis. Journal of Economic Entomology. 105(2): 438-450.

Koch, J.L.; Carey, D.W.; Mason, M.E.; Nelson, C.D. 2010. Assessment of beech scale resistance in full- and half-sibling American beech families. Canadian Journal of Forest Research. 40(2): 265-272.

Kuhman, T.; Pearson, S.; Turner, M. 2010. Effects of land-use history and the contemporary landscape on non-native plant invasion at local and regional scales in the forest-dominated southern Appalachians. Landscape Ecology. 25(9): 1433-1445.

Liebhold, A.M.; MacDonald, W.L.; Bergdahl, D.; Mastro, V.C. 1995. Invasion by exotic forest pests: a threat to forest ecosystems. Forest Science Monograph. 30(2): 1-38.

Liebhold, A.M.; McCullough, D.G.; Blackburn, L.M. [and others]. 2013. A highly aggregated geographical distribution of forest pest invasions in the USA. Diversity and Distributions. 19(9): 1208-1216.

Linder, M. 2000. Developing adaptive forest management strategies to cope with climate change. Tree Physiology. 20(5-6): 299-307.

Lodge, D.M.; Williams, S.; MacIsaac, H.J. [and others]. 2006. Biological invasions: recommendations for U.S. policy and management. Ecological Applications. 16(6): 2035-2054.

Logan, J.A.; Régnière, J.; Powell, J.A. 2003. Assessing the impacts of global warming on forest pest dynamics. Frontiers in Ecology and the Environment. 1(3): 130-137.

Lundgren, M.R.; Small, C.J.; Dreyer, G.D. 2004. Influence of land use and site characteristics on invasive plant abundance in the Quinebaug Highlands of southern New England. Northeastern Naturalist. 11(3): 313-332.

Mack, R.N.; Simberloff, D.; Lonsdale, W.M. [and others]. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. Ecological Applications. 10(3): 689-710.

Mandryk, A.M.; Wein, R.W. 2006. Exotic vascular plant invasiveness and forest invasibility in urban boreal forest types. Biological Invasions. 8(8): 1651-1662.

Manea, A.; Leishman, M. 2011. Competitive interactions between native and invasive exotic plant species are altered under elevated carbon dioxide. Oecologia. 165(3): 735-744.

Mascaro, J.; Hughes, R.F.; Schnitzer, S.A. 2011. Novel forests maintain ecosystem processes after the decline of native tree species. Ecological Monographs. 82(2): 221-228.

McClure, M.S. 1991. Density-dependent feedback and population cycles in Adelges tsugae (Homoptera: Adelgidae) on *Tsuga canadensis*. Environmental Entomology. 20: 258-264.

Merkle, S.A.; Andrade, G.M.; Nairn, C.J. [and others]. 2007. Restoration of threatened species: a noble cause for transgenic trees. Tree Genetics & Genomes. 3(2): 111-118.

Metz, M.R.; Varner, J. M.; Frangioso, K.M. [and others]. 2013. Unexpected redwood mortality from synergies between wildfire and an emerging infectious disease. Ecology. 94(10): 2152-2159.

Miller, J.H.; Chambliss, E.B.; Loewenstein, N.J. 2010. A field guide for identification of invasive plants in southern forests. GTR-SRS-119, USDA Forest Service, Southern Research Station, Asheville, NC.

Morin, R.S.; Liebhold, A.M.; Tobin, P.C. [and others]. 2007. Spread of beech bark disease in the eastern United States and its relationship to regional forest composition. Canadian Journal of Forest Research. 37(4): 726-736.

Moritz, M.A.; Parisien, M.-A.; Batllori, E. [and others]. 2012. Climate change and disruptions to global fire activity. Ecosphere. 3(6): 49.

Olson, C.; Cholewa, A.F. 2009. A Guide to nonnative invasive plants inventoried in the north by Forest Inventory and Analysis. GTR-SRS-62, USDA Forest Service, Northern Research Station, Newtown Square, PA.

Oswalt, C.M.; Oswalt, S.N.; Clatterbuck, W.K. 2007. Effects of *Microstegium Vimineum* (Trin.) A. Camus on native woody species density and diversity in a productive mixed-hardwood forest in Tennessee. Forest Ecology and Management. 242(2-3): 727-732.

Parker, T.J.; Clancy, K.M.; Mathiasen, R.L. 2006. Interactions among fire, insects and pathogens in coniferous forests of the interior western United States and Canada. Agricultural and Forest Entomology. 8(3): 167-189.

Pattison, R.; D'Antonio, C.; Dudley, T. [and others]. 2011. Early impacts of biological control on canopy cover and water use of the invasive saltcedar tree (*Tamarix* spp.) in western Nevada, USA. Oecologia. 165(3): 605-616.

Phillips, B.L.; Kelehear, C.; Pizzatto, L. [and others]. 2010. Parasites and pathogens lag behind their host during periods of host range advance. Ecology. 91(3): 872-881.

Pimentel, D.; Zuniga, R.; Monison, D. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics. 52(3): 273-288.

Prasad, A.; Iverson, L.; Peters, M. [and others]. 2010. Modeling the invasive emerald ash borer risk of spread using a spatially explicit cellular model. Landscape Ecology. 25(3): 353-369.

Régnière, J.; Nealis, V.; Porter, K. 2009. Climate suitability and management of the gypsy moth invasion into Canada. Biological Invasions. 11(1): 135-148.

Reichard, S.H.; Hamilton, C.W. 1997. Predicting invasions of woody plants introduced into North America. Conservation Biology. 11(1): 193-203.

Reichard, S.H.; White, P. 2001. Horticulture as a pathway of invasive plant introductions in the United States. Bioscience. 51(2): 103-113.

Rhoades, C.; Loftis, D.; Lewis, J.; Clark, S. 2009. The influence of silvicultural treatments and site conditions on American chestnut (*Castanea dentata*) seedling establishment in eastern Kentucky, USA. Forest Ecology and Management. 258(7): 1211-1218.

Riggins, J.J.; Londo, A.J. 2009. Wolves in sheep's clothing: Outbreaks of previously obscure native forest insects. Forest Wisdom. (13): 6-7.

Ross, R.M.; Bennett, R.M.; Snyder, C.D. [and others]. 2003. Influence of eastern hemlock (*Tsuga canadensis* L.) on fish community structure and function in headwater streams of the Delaware River basin. Ecology of Freshwater Fish. 12(1): 60-65.

Sasek, T.; Strain, B.. 1990. Implications of atmospheric CO_2 enrichment and climatic change for the geographical distribution of two introduced vines in the U.S.A. Climatic Change. 16(1): 31-51.

Schmidt, K.A.; Whelan, C.J. 1999. Effects of exotic *Lonicera* and *Rhamnus* on songbird nest predation. Conservation Biology. 13(6): 1502-1506.

Schulz, B.; Gray, A. 2013. The new flora of northeastern USA: quantifying introduced plant species occupancy in forest ecosystems. Environmental Monitoring and Assessment. 185(5): 3931-3957.

Schwandt, J.W.; Lockman, I.B.; Kliejunas, J.T.; Muir, J.A. 2010. Current health issues and management strategies for white pines in the western United States and Canada. Forest Pathology. 40(3-4): 226-250.

Sendak, P.E.; Abt, R.C.; Turner, R.J. 2003. Timber supply projections for northern New England and New York: integrating a market perspective. Northern Journal of Applied Forestry. 20(4): 175-185.

Shafroth, P.; Cleverly, J.; Dudley, T. [and others]. 2005. Control of Tamarix in the western United States: implications for water salvage, wildlife use, and riparian restoration. Environmental Management. 35(3): 231-246.

Shifley, S.R.; Aguilar, F.X.; Song, N. [and others]. 2012. Forests of the northern United States. GTR-NRS-90, USDA Forest Service, Northern Research Station, Newtown Square, PA.

Simberloff, D. 2006. Invasional meltdown 6 years later: important phenomenon, unfortunate metaphor, or both? Ecology Letters. 9(8): 912-919.

Simberloff, D.; Von Holle, B. 1999. Positive interactions of nonindigenous species: Invasional meltdown? Biological Invasions. 1(1): 21-32.

Small, C.J.; White, D.C.; Hargbol, B. 2010. Allelopathic influences of the invasive *Ailanthus altissima* on a native and a non-native herb. The Journal of the Torrey Botanical Society. 137(4): 366-372.

Small, M. J.; Small, C. J.; Dreyer, G.D. 2005. Changes in a hemlock-dominated forest following woolly adelgid infestation in southern New England. Journal of the Torrey Botanical Society. 132(3): 458-470.

Smith, S.B.; DeSando, S.A.; Pagano, T. 2013. The value of native and invasive fruit-bearing shrubs for migrating songbirds. Northeastern Naturalist. 20(1): 171-184.

Smith, S.D.; Huxman, T.E.; Zitzer, S.F. [and others]. 2000. Elevated CO_2 increases productivity and invasive species success in an arid ecosystem. Nature. 408(6808): 79-82.

Snitzer, J.; Boucher, D.; Kyde, K. 2005. Response of exotic invasive plant species to forest damage caused by Hurricane Isabel. CRC Publication 05-160, Chesapeake Research Consortium, Edgewater, MD.

Strayer, D.L.; Eviner, V. T.; Jeschke, J.M.; Pace, M.L. 2006. Understanding the long-term effects of species invasions. Trends in Ecology & Evolution. 21(11): 645-651.

Sturrock, R.N.; Frankel, S.J.; Brown, A.V. [and others]. Climate change and forest diseases. Plant Pathology. 60(1): 133-149.

Theobald, D. 2010. Estimating natural landscape changes from 1992 to 2030 in the conterminous US. Landscape Ecology. 25 (7): 999-1011.

Tindall, J.R.; Gerrath, J.A.; Melzer, M. [and others]. 2004. Ecological status of American chestnut (*Castanea dentata*) in its native range in Canada. Canadian Journal of Forest Research. 34(12): 2554-2563.

Tingley, M.W.; Orwig, D.A.; Field, R.; Motzkin, G. 2002. Avian response to removal of a forest dominant: consequences of hemlock woolly adelgid infestations. Journal of Biogeography. 29(10-11): 1505-1516.

Torchin, M.E.; Lafferty, K.D.; Dobson, A.P. [and others]. 2003. Introduced species and their missing parasites. Nature. 421(6923): 628-630.

Traveset, A.; Richardson, D.M. 2006. Biological invasions as disruptors of plant reproductive mutualisms. Trends in Ecology & Evolution. 21(4): 208-216.

Valachovic, Y.S.; Lee, C.A.; Scanlon, H. [and others]. 2011. Sudden oak death-caused changes to surface fuel loading and potential fire behavior in Douglas-fir-tanoak forests. Forest Ecology and Management. 261(11): 1973-1986.

Venette, R. C.; Cohen, S.D. 2006. Potential climatic suitability for establishment of *Phytophthora ramorum* within the contiguous United States. Forest Ecology and Management. 231(1-3): 18-26.

Waring, K.M.; O'Hara, K.L. 2005. Silvicultural strategies in forest ecosystems affected by introduced pests. Forest Ecology and Management. 209: 27-41.

Weed, A.S.; Ayres, M.P; Hicke, J.A. 2013. Consequences of climate change for biotic disturbances in North American forests. Ecological Monographs. 83(4): 441-470.

Williams, S.C.; Ward, J.S.; Ramakrishnan, U. 2008. Endozoochory by white-tailed deer (*Odocoileus virginianus*) across a suburban/woodland interface. Forest Ecology and Management. 255(3-4): 940-947.

Willis, C.G.; Ruhfel, B.R.; Primack, R.B. [and others]. 2010. Favorable climate change response explains non-native species' success in Thoreau's woods. PLoS ONE. 5(1): e8878.

Work, T. T.; McCullough, D.G.; Cavey, J. F.; Komsa, R. 2005. Arrival rate of non-indigenous insect species into the United States through foreign trade. Biological Invasions. 7(2): 323-332.

Worrall, J. J.; Adams, G. C.; Tharp, S. C. 2010. Summer heat and an epidemic of *cytospora* canker of *Alnus*. Canadian Journal of Plant Pathology. 32(3): 376-386.

Yan, X.; Zhenyu, L.; Gregg,W.; Dianmo, L. 2001. Invasive species in China—an overview. Biodiversity & Conservation. 10(8): 1317-1341.

Yates, E.D.; Levia Jr., D.F.; Williams, C.L. 2004. Recruitment of three non-native invasive plants into a fragmented forest in southern Illinois. Forest Ecology and Management. 190(2-3): 119-130.

Zhang, Y.; Hanula, J.L.; Horn, S. 2012. The biology and preliminary host range of *Megacopta cribraria* (Heteroptera: Plataspidae) and its impact on kudzu growth. Environmental Entomology. 41(1): 40-50.

Ziska, L.H.; Reeves, J. B.; Blank, B. 2005. The impact of recent increases in atmospheric CO_2 on biomass production and vegetative retention of Cheatgrass (*Bromus tectorum*): implications for fire disturbance. Global Change Biology. 11(8): 1325-1332.

This paper received peer technical review. The content of the paper reflects the views of the authors, who are responsible for the facts and accuracy of the information herein.