## Criterion 3: Maintenance of Forest Ecosystem Health and Vitality

The maintenance of forest health and vitality is dependent upon the ability of the ecosystem's functions and processes to recover from or adapt to disturbances. While many disturbances and stress events are natural components of forest ecosystems, some may overwhelm ecosystem functions, fundamentally altering their patterns and processes and reducing ecological function.

Decline in forest ecosystem health and vitality may have significant economic and ecological consequences for society including a loss of forest benefits and the degradation of environmental quality. Information gained on the impacts of biotic and abiotic processes and agents may inform management strategies to minimize and mitigate risk. The maintenance of forest ecosystem health and vitality is the foundation of sustainable forest management.

### *INDICATOR 7*

**Area of forestland affected by potentially damaging agents**

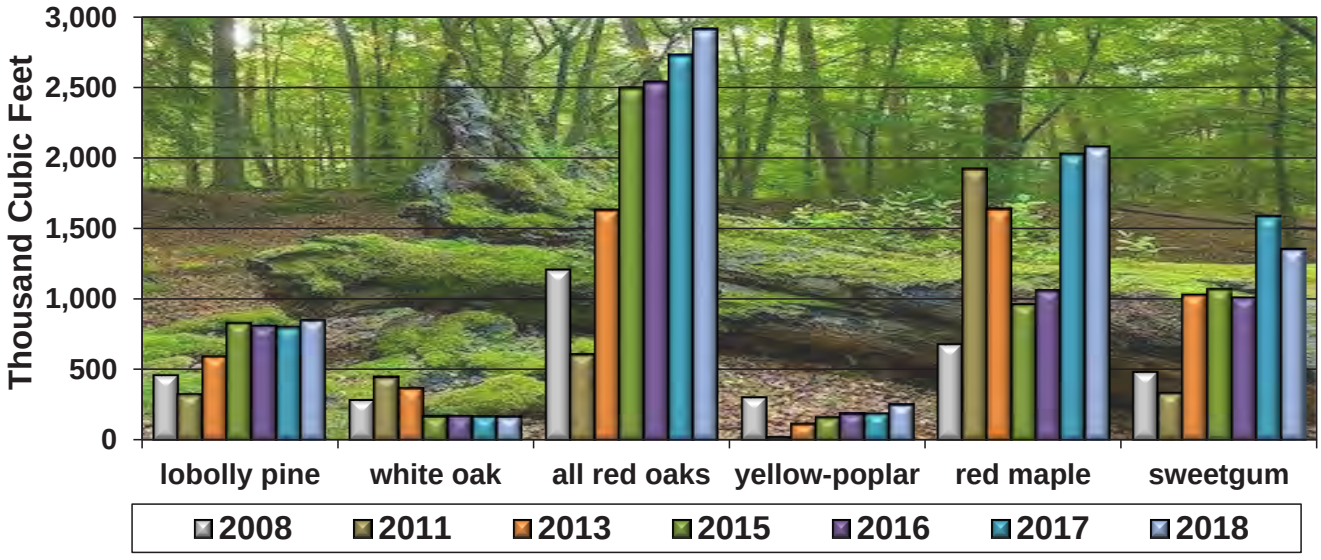
*Damaging agents include insects, diseases, and invasive species that have a significant impact on forests as well as wildfires, drought, ice storms, and other natural forces. Damaging agents can alter species composition, reduce growth rates, and disrupt normal forest management activities. While many forces of nature cannot be prevented, it is important to anticipate problems whenever possible and to develop vigilant early detection programs when new insect and disease threats become apparent.*

**Emerald ash borer**

### Tree mortality

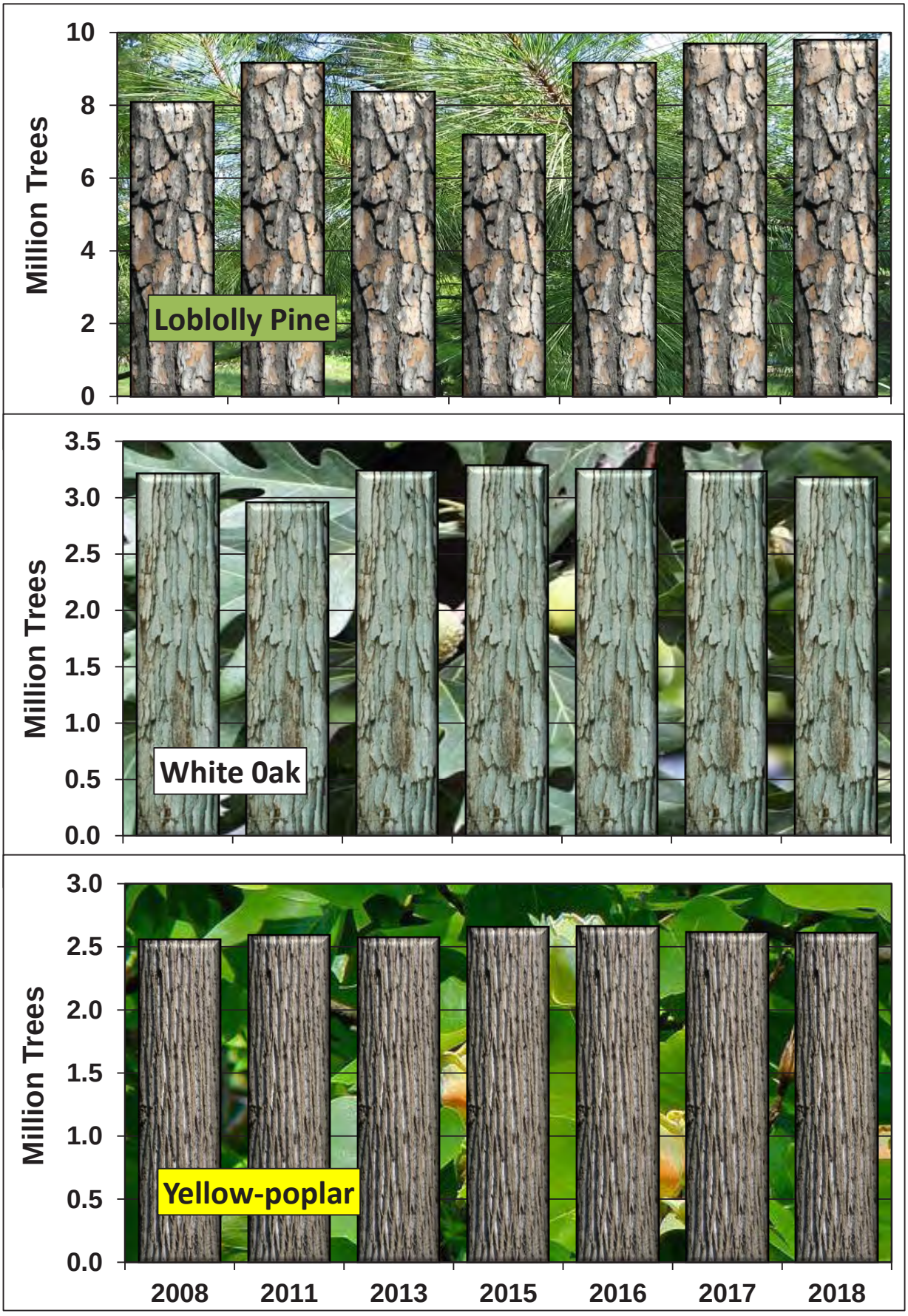
Over the last ten years, tree mortality rates have been low and relatively consistent for the three most valuable commercial tree species in Delaware: loblolly pine (*Pinus taeda*), white oak (*Quercus alba*), and yellow-poplar (*Liriodendron tulipifera*) (Figure 23). The higher loblolly pine mortality rate is mostly due to natural thinning as a pine forest matures. This natural process is not of much concern because pine acreage has increased during this time period and volume increased too, especially in the diameter classes 13 inches and greater. This point is further supported by growing-stock tree numbers—loblolly pine trees have actually increased by 1.7 million since 2008. During that same time period, white oak and yellow-poplar numbers have remained virtually constant (Figure 24).

**Figure 23. Annual mortality of growing-stock trees (at least 5 inches dbh), 2008–2018.**



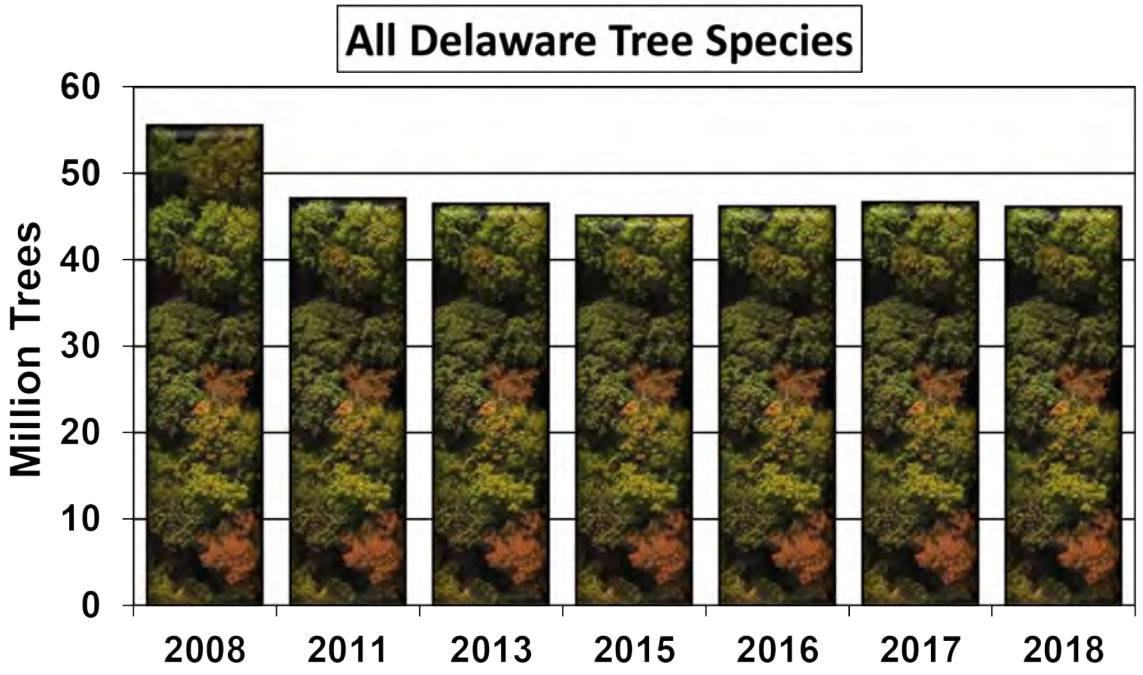

Source: U.S. Forest Service Forest Inventory and Analysis

Figure 24. Number of high-value growing-stock trees (at least 5 inches dbh), 2008–2018.




Source: U.S. Forest Service Forest Inventory and Analysis

Figure 25. Estimated total number of growing-stock trees (at least 5 inches dbh), 2008–2018.




Source: U.S. Forest Service Forest Inventory and Analysis

Looking at the total number of growing-stock trees over the last decade, there was a precipitous drop between 2008 and 2018 of 8.5 million trees (Figure 25). But since 2008, the total number of growing-stock trees in Delaware has remained constant. About half of the decrease (3.9 million) is attributable to the decline in the number of red oaks (*Quercus* spp.), red maple (*Acer rubrum*), and sweetgum (*Liquidambar styraciflua*) trees (Figure 26). The other half is due to loss of forested acres and because there are more larger trees now than ten years ago. Red oaks (all species) declined by 10% (0.54 million trees) but nearly two-thirds of the decline was for northern red oak (*Quercus rubra*) mortality (0.34 million trees). Red maple, although still the most common tree species in Delaware, declined by 26.5% (3.37 million trees). Likewise, sweetgum declined by 12.5% (0.92 million trees). The cause(s) of red maple and sweetgum mortality are not well understood. These common low-value trees can be used for paper production and heating pellets and large-diameter sweetgums are frequently used to construct crane mats in Delaware.

## Wildfire

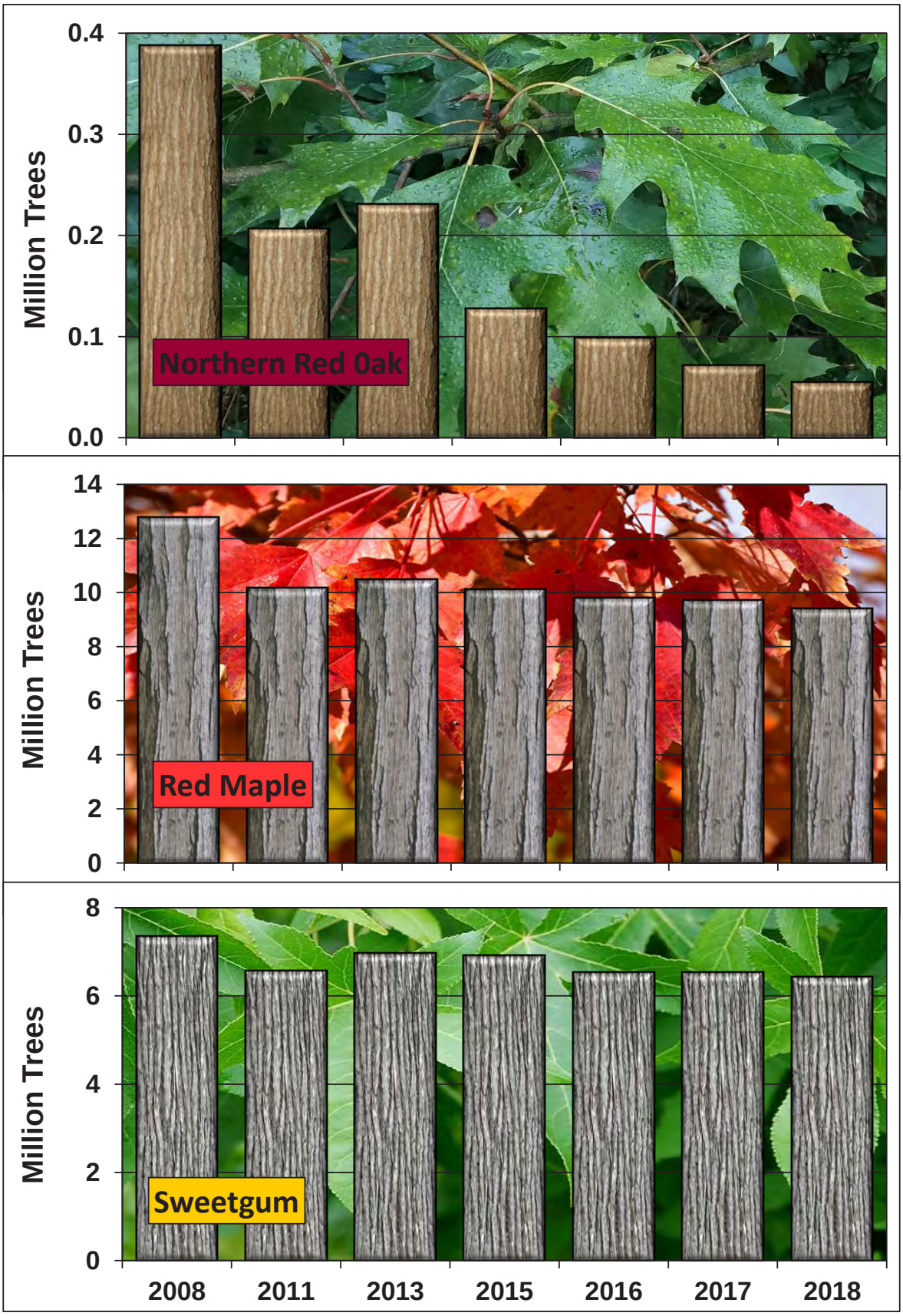
Overall, wildland fire is not a significant threat to Delaware's forests. In recent history, most of the largest wildfires occurred in marshes along the state's coastline. Occasionally, a wildfire within a forest will exceed 100 acres—typically in a young loblolly pine plantation—but these are rare and usually occur during a drought. Delaware's 60 volunteer fire companies (VFC) are nearly always the first responders to wildland fires and are very well equipped to control and contain them. Virtually every Delaware VFC operates a fully-equipped wildland fire brush truck.

The occurrences of wildland fires in Delaware was greatly reduced by the formation of the Delaware Forest Service in 1927. Fire towers were installed in strategic locations throughout the state to catch wildfires early, before they had a chance to spread over wide areas. This new feature in the fire prevention arsenal, along with quick responses from VFCs, greatly improved response times. Delaware also has relatively flat terrain interspersed with numerous ditches, other waterways, roads, and crop fields making it much less likely for a fire to spread and damage extensive acreage.

However, near catastrophic fires can occur in Delaware but only when specific environmental conditions overlap. In 2005 a plume-dominated fire near Millsboro scorched 168 acres. Temperatures were in the high 80s with relative humidity at 11%. Gusting winds pushed a road-side ignition into a young loblolly pine plantation that then spread into the tree crowns and ran through the plantation. The fire settled down in the early evening when winds calmed, relative humidity increased, and the temperature dropped.

A Community Wildfire Protection Plan (CWPP) identifies and prioritizes areas for hazardous fuel reduction and recommends treatment methods. CWPPs address wildfire response, hazard mitigation, community preparedness, and structure protection. Currently, the City of Newark in New Castle County and the City of Lewes in Sussex County have active CWPPs but there are other Delaware communities that would benefit greatly from such a plan.

Figure 26. Number of growing-stock trees (at least 5 inches dbh) for declining species, 2008–2018.




Source: U.S. Forest Service Forest Inventory and Analysis

## Drought

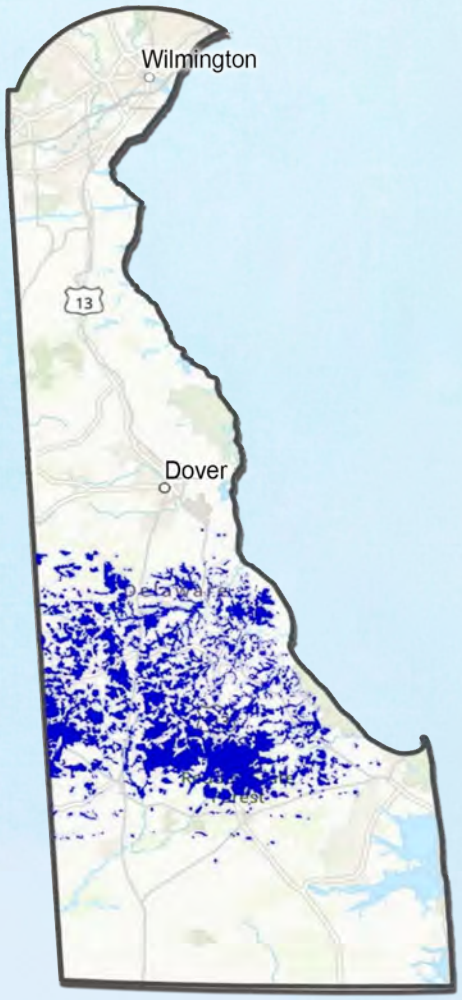
Historically, Delaware has experienced about two months of drought per year since 1895. A drought month is defined as a month in which the Palmer Drought Severity Index indicates moderate, severe, or extreme drought conditions (NOAA National Climatic Data Center). In 2000, NOAA started the U.S. Drought Monitor (USDM) to show the location and intensity of drought across the country. The USDM uses a five-category system labeled from abnormally dry to exceptional drought. Since 2000, the longest duration of drought in Delaware lasted 55 weeks beginning in late October 2001 and ending in mid-November 2002—the most intense period of this drought occurred in August where exceptional drought affected 74% of all of Delaware. However, since the end of 2013, Delaware has only experienced brief periods of abnormally dry or moderate drought conditions.

Extended periods of extreme drought can kill trees outright but is of more concern as an inducer of stress in trees. Stress predisposes trees to insect and disease problems, which do not normally affect healthy trees. In 2009, tree mortality resulted in an estimated loss of 5.0 million cubic feet of growing-stock. In 2018 losses were estimated at 9.1 million cubic feet. This equates to just less than 1% of all growing-stock in Delaware. Such a low rate is a completely acceptable level of mortality in a healthy forest. Every year some trees in any given forest die as a result of competition for light and other resources, as well as events such as severe drought, wind damage, lightning, and insect and disease attacks.

## Other climatic events (hurricanes, ice storms, etc.)

Hurricanes occasionally occur in Delaware, although forests have not experienced significant damage since Hurricane Hazel in 1954. Delaware is typically impacted by tropical storms every few years, but these events do not cause substantial forest damage. However, a large portion (30%) of Delaware's forests were significantly impacted by an ice storm in February 1994 (Figure 27). The 117,047 acres of damaged forest were contained in a swath of land in southern Kent and northern Sussex Counties. While 26 years have passed since this rare Delaware event, its long-term effects on forest health continues. Trees severely and even moderately damaged (97,980 acres or 84% of the total damaged area) incurred significant amounts of breakage and twisting thus downgrading their health in the long run and exposing them to attacks by secondary stress agents, mainly insects and diseases.

**Figure 27. Ice storm damage in 1994.**




Source: Delaware Forest Service

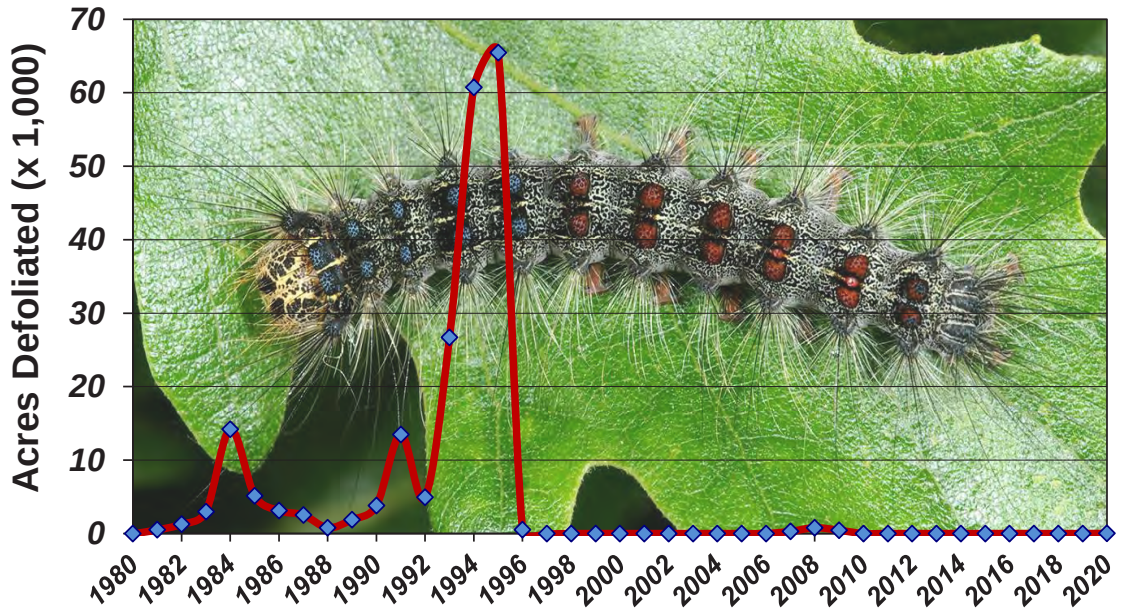
## Climate change and sea level rise

There is growing concern among forestland managers about the potential impacts of climate change in Delaware, particularly sea level rise. Delaware's entire eastern border (and its longest border) is the Atlantic Ocean and Delaware River and Bay and 95% of the state lies within the Coastal Plain. While considerable research is still needed, several potential issues relating to forests and forested habitat include:

- Migration of maritime forests/riparian areas inland,
- Shifts in species range (migration),
- Changes in species composition or disappearance of species, and
- Increases in invasive/nuisance species and diseases.

Additionally, there is a need to establish baseline risk assessment for species and habitats. Consideration can then be given to methods to move low-lying riparian forest buffers inland as sea level slowly rises to ensure these buffers are not lost. It is important that assessments also account for possible rate changes in the future. However, nearly 100 years of data from the Lewes, Delaware, tidal gauge show a trending (linear) annual increase of 3.53 mm (=1.39 inches/decade)—about half of this rise is due to land subsidence, the other half to actual sea level rise.

**Figure 28. Gypsy moth defoliation in Delaware, 1980–2020.**




Sources: Delaware Forest Service and U.S. Forest Service, Forest Health Protection, Gypsy Moth Digest

## Forest pests (insects, diseases, deer browse)

One native and three exotic pests have historically affected Delaware's rural and urban forests to varying degrees. degree. Two tree species—American chestnut (*Castanea dentata*) and American elm (*Ulmus americana*)—are now reduced to very low population levels because of exotic disease. Chestnut trees once dominated the eastern forests of Appalachia including Delaware's Piedmont region, but now are reduced to stump sprouts that eventually succumb to the chestnut blight (*Cryphonectria parasitica*) and die, never reaching significant size (>8 inches dbh). This tree species is still found throughout Delaware hardwood forests.

American elms were virtually eliminated by the Dutch elm disease (*Ophiostoma novo-ulmi*) and at one time were quite abundant in Delaware, especially along tree-lined streets as their umbrella-shaped crowns and height (>100 feet) provided shade and beauty to communities. With aggressive protection measures, some mature trees still exist in Delaware. Smaller elm trees are still found in the natural environment, but their once significant ecological role in the forest has been dramatically reduced.

The southern pine beetle (*Dendroctonus frontalis*) is a native insect that can cause localized mortality in loblolly pine stands. An outbreak occurred in 1994 in the Great Cypress Swamp affecting nearly 1,500 acres of loblolly pine stands causing extensive pine mortality. If detected early, small outbreaks can be controlled by the complete elimination of the beetle population through clearcutting and removal of the brood-infested trees.

The gypsy moth (*Lymantria dispar*) is a European species whose caterpillars feed on an extremely wide range (>500 species) of hosts but mostly favor hardwood species such as oak. First detected in Delaware in 1979, gypsy moth populations peaked in the mid-1990s with over 60,000 acres of forests defoliated in 1994 and 1995 (Figure 28). The precipitous drop in population numbers resulted from mortality due to a naturally-occurring virus and a newly introduced fungus (*Entomophaga maimaiga*) from Japan. For 25 years Delaware has not had any significant gypsy moth defoliation although residual populations still exist, especially in southern Sussex County.

There are five relatively new pest species that have the potential to seriously impact Delaware forests, both urban and rural: sirex woodwasp (*Sirex noctilio*), Asian longhorned beetle (*Anoplophora glabripennis*), emerald ash borer (*Agrilus planipennis*), sudden oak death (*Phytophthora ramorum*), and thousand cankers disease.

Sirex woodwasp was first detected in northern Pennsylvania and New York but now is found in Vermont, Connecticut, Ohio, and Michigan. In these states the wasp causes considerable damage to red pine (*Pinus resinosa*) stands. Loblolly pine is a mainstay of Delaware's forest industry but has never been infested in its natural setting. Since 2006, the Delaware Forest Service has conducted annual surveys for this potentially deadly pest by using traps baited with a special chemical formulation and trap trees deliberately stressed to attract sirex adults in the area. To date, no sirex woodwasps have been detected in Delaware through these monitoring surveys.

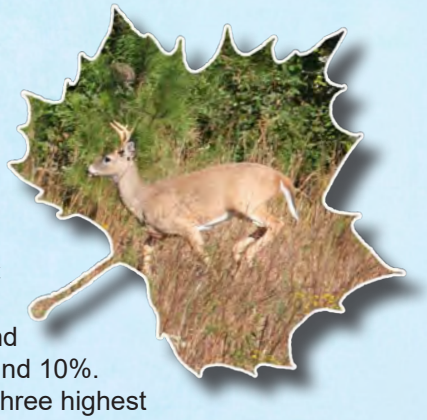
An established population of the exotic Asian longhorned beetle (ALB) was first detected in New York City in 1996. It spread quickly to neighboring New Jersey and isolated populations can now be found in Massachusetts, Ohio, and Illinois. ALB feeds on a variety of tree species but prefers maples (*Acer* spp.). Red maple is still the most abundant tree species in Delaware and is susceptible to an ALB infestation. The Delaware Forest Services monitors for the presence of this tree pest through trapping and it has not been found in the state as of early 2020.

Emerald ash borer (EAB) is an exotic pest imported from China that feeds nearly exclusively on ash, *Fraxinus* spp. (it also feeds on fringetrees, *Chionanthus* spp.). Ten years ago, populations of EAB were only known to be found in areas 100 miles away from Delaware. However, in 2016 a single specimen was collected on a purple sticky trap in northern New Castle County and in 2018 infested trees were detected in the Seaford area. In 2019 more specimens were trapped along the western edge of New Castle County and through a biomonitoring technique using a wasp (*Cerceris fumipennis*), it was positively detected in Stanton. While ash represents only about 1% of Delaware's rural forests, it has been planted widely in urban areas and some communities have nearly a 100% ash street-tree component. Now that this pest is established in Delaware, it is only a matter of time before virtually all ash trees are attacked. EAB is established in 35 states now and to date has killed tens of millions of ash trees.

Sudden oak death (SOD) represents a significant threat to Delaware's oak trees, prized for both wildlife and commercial value. SOD has caused widespread destruction of tanoaks and other species in coastal California and southwestern Oregon. Landscape plants infected with spores of this virulent pathogen have been shipped from western nurseries to the mid-Atlantic region and not all infected plants were located. SOD surveys were conducted in Delaware from 2004 to 2008 but evidence of the disease was not found. SOD is still not known to occur in the natural environment outside of its present known western distribution.

Three of the four relatively new pests have not yet been detected in Delaware through survey efforts. Monitoring surveys will continue in the future and as new threats emerge, forest health staff will continue to respond with appropriate surveying and outreach efforts.

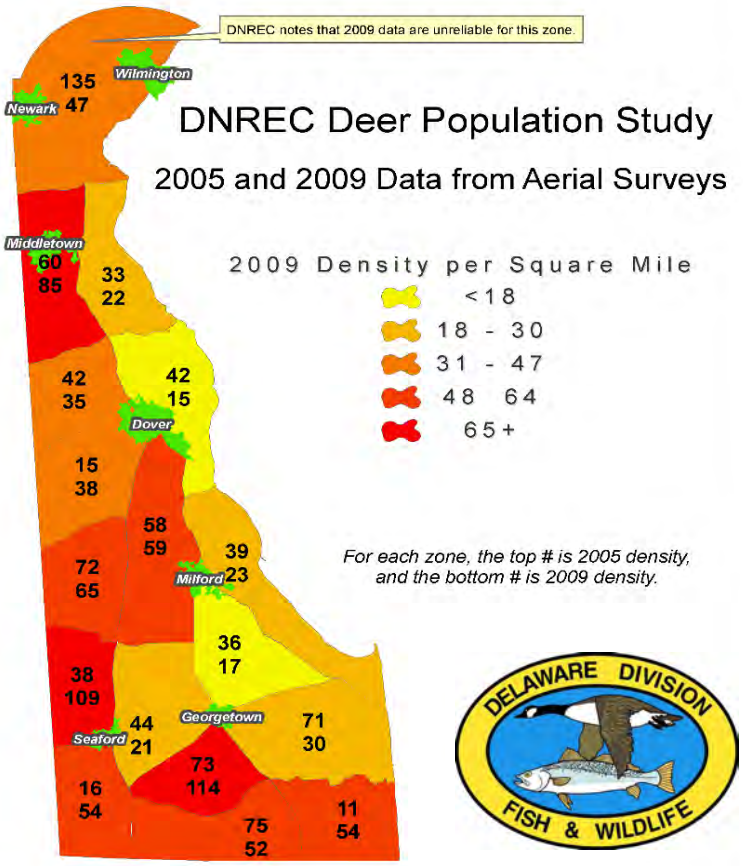
Mortality has risen significantly for red oak species, red maple, and sweetgum recently. About two-thirds of the mortality for the red oaks is related to one particular commercially valuable species—northern red oak (*Quercus rubra*). Red oaks are very susceptible to a disease called bacterial leaf scorch (*Xylella fastidiosa*), which was first detected in an urban setting in northern Delaware in the mid-1990s. This virulent disease has since spread throughout the entire state and is now common in the natural environment and there are no known cures for this disease. To make matters worse, once a red oak is weakened by this pathogen, a second disease, hypoxylon canker (*Hypoxylon atropunctatum*) attacks the tree. This secondary pathogen does not normally attack and kill healthy red oak trees. The combined attack by these two diseases has had a devastating effect on Delaware's red oak resource, particularly northern red oak.



White-tailed deer (*Odocoileus virginianus*) are extremely common in Delaware due to optimal habitat that occurs throughout the state. As a result, in some areas overall deer populations reached densities exceeding 100/square mile in 2009 (Figure 29). Delaware's Department of Natural Resources and Environmental Control (DNREC), Division of Fish & Wildlife has not performed additional deer density estimates since the 2009 study, but updated population surveys are slated for the spring of 2020. Field observations and reports of fairly widespread, and sometimes extreme, crop damage by deer indicates that populations in many areas of the state are still very high. DNREC biologists compared harvests between the five-year average of 2011–2015 and the three-year average of 2016–2018. Only two zones (1A – extreme northern Delaware and 5 – eastern portion of Dover to the Delaware Bay) showed a harvest decline, each around 10%. All other zones showed an increase in harvest numbers with 12 zones above 5%. The three highest increases were in zones 1B (+24.4%) in northern Delaware, 8 (+26.9%) in the central part of the state south of Dover, and 13 (+19.4%) in the southwest corner of the state. Harvest number changes often reflect total population numbers, assuming that hunter numbers and effort remain relatively constant.

Over the last 20 years, Delaware hunting regulations have been adjusted to allow the harvesting of more deer by encouraging the taking of does. This is the most efficient means at reducing deer densities. Since 1989 the annual statewide deer harvest has more than tripled (Figure 30). The harvest on State Forest lands averaged just over 400 deer over the last ten years. This is almost double for the average of the prior ten years (231 dear/year between 1999–2009). According to the Quality Deer Management Association's (QDMA) Whitetail Report 2019, Delaware had the highest antlerless deer per antlered buck harvested ratio in 2017 (2.0) among the lower 48 states. Additionally, Delaware ranked second in antlerless harvest/square mile (5.2), with Maryland having the top spot at 5.7. But the fact still remains that deer populations in the state remain high.

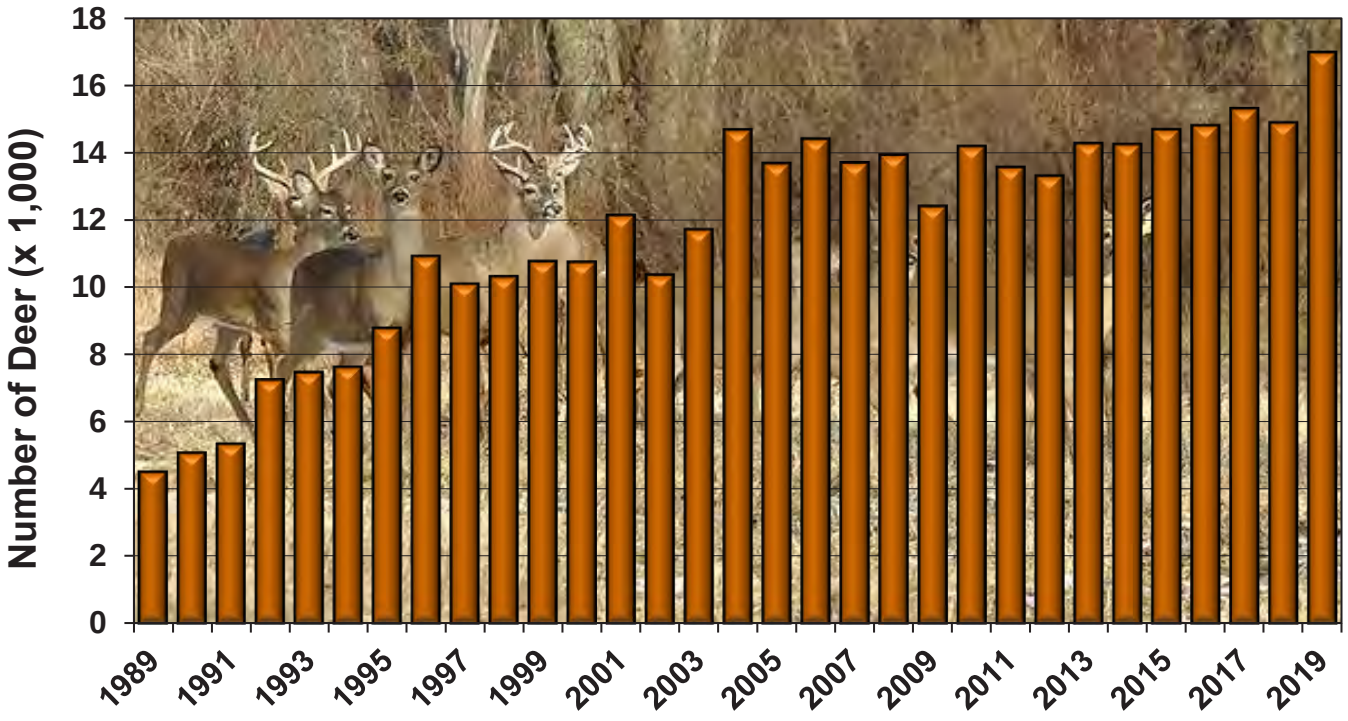
**Figure 29. Delaware deer population estimates, 2005 and 2009.**




Source: DNREC Division of Fish & Wildlife

**White-tailed deer**

**Figure 30. Delaware white-tailed deer harvest, 1989–2019.**




Source: DNREC Division of Fish & Wildlife

**Oriental bittersweet**

**Japanese stiltgrass**

**Norway maple**

**Table 8. Delaware interior forest invasive plant species.**

| *Scientific Name* | *Common Name* | *Life Form* |
|---|---|---|
| *Acer palmatum* | Japanese maple | deciduous tree |
| *Acer platanoides* | Norway maple | deciduous tree |
| *Ailanthus altissima* | tree-of-heaven | deciduous tree |
| *Akebia quinata* | five-leaf akebia | woody vine |
| *Alliaria petiolata* | garlic mustard | herb |
| *Allium vineale* | field garlic | herb |
| *Ampelopsis glandulosa* | porcelain-berry | woody vine |
| *Aralia elata* | Japanese angelica-tree | deciduous tree |
| *Berberis thunbergii* | Japanese barberry | deciduous shrub |
| *Cardamine impatiens* | touch-me-not bittercress | herb |
| *Celastrus orbiculatus* | Oriental bittersweet | woody vine |
| *Elaeagnus umbellata* | autumn olive | deciduous shrub |
| *Euonymus alatus* | winged euonymus | deciduous shrub |
| *Euonymus fortunei* | winter creeper | woody vine |
| *Ficaria verna* | lesser celandine | herb |
| *Galanthus nivalis* | snowdrops | herb |
| *Glechoma hederacea* | ground-ivy | herb |
| *Hedera helix* | English ivy | woody vine |
| *Hedera hibernica* | Atlantic ivy | woody vine |
| *Hemerocallis fulva* | orange daylily | herb |
| *Hosta ventricosa* | blue plantain-lily | herb |
| *Ilex crenata* | Japanese holly | evergreen shrub |
| *Leucojum aestivum* | summer snowflake | herb |
| *Ligustrum sinense* | Chinese privet | deciduous shrub |
| *Ligustrum vulgare* | European privet | deciduous shrub |
| *Lonicera japonica* | Japanese honeysuckle | woody vine |
| *Lonicera maackii* | Amur honeysuckle | deciduous shrub |
| *Lonicera morrowii* | Morrow's honeysuckle | deciduous shrub |
| *Lonicera standishii* | Standish's honeysuckle | deciduous shrub |
| *Lonicera tatarica* | Tartarian honeysuckle | deciduous shrub |
| *Lysimachia nummularia* | creeping Jenny | herb |
| *Magnolia kobus* | Kobus magnolia | deciduous tree |
| *Magnolia tripetala* | umbrella tree | deciduous tree |
| *Mahonia bealei* | leatherleaf mahonia | evergreen shrub |
| *Mahonia repens* | creeping hollygrape | evergreen shrub |
| *Malus baccata* | Siberian crabapple | deciduous tree |
| *Microstegium vimineum* | Japanese stilt grass | grass |
| *Morus alba* | white mulberry | deciduous tree |
| *Narcissus pseudonarcissus* | daffodil | herb |
| *Oplismenus undulatifolius* | wavyleaf basketgrass | grass |
| *Pachysandra terminalis* | pachysandra | herb |
| *Paulownia tomentosa* | royal paulownia | deciduous tree |
| *Perilla frutescens* | beefsteak plant | herb |
| *Persicaria longiseta* | longbristle smartweed | herb |
| *Persicaria perfoliata* | mile-a-minute | herb |
| *Poa compressa* | Canada bluegrass | grass |
| *Poa trivialis* | rough bluegrass | grass |
| *Prunus avium* | sweet cherry | deciduous tree |
| *Prunus subhirtella* | weeping Higan cherry | deciduous tree |
| *Rhodotypos scandens* | jetbead | deciduous shrub |
| *Rosa multiflora* | multiflora rose | deciduous shrub |
| *Rubus laciniatus* | evergreen blackberry | deciduous shrub |
| *Rubus parvifolius* | three-leaf blackberry | deciduous shrub |
| *Rubus phoenicolasius* | wineberry | deciduous shrub |
| *Urtica dioica* | stinging nettle | herb |
| *Viburnum dilatatum* | exotic arrow-wood | deciduous shrub |
| *Viburnum plicatum* | Japanese snowball | deciduous shrub |
| *Viburnum setigerum* | tea viburnum | deciduous shrub |
| *Viburnum sieboldii* | Siebold's viburnum | deciduous shrub |
| *Vinca minor* | lesser periwinkle | herb |

Source: DNREC Wildlife Species Conservation & Research Program

Elevated deer densities often result in browse damage to understory plants in the forest, especially seedlings of favored tree species such as oak. Studies in other states have shown that deer populations of more than 20 or 25/square mile can significantly impair seedling growth and negatively influence species composition in a developing stand. Understory nesting habitat for some birds, particularly neotropical migratory species, can also be reduced dramatically. A deer exclosure study initiated by the Delaware Forest Service showed conclusively that areas with high deer densities suffer substantial damage to the forest understory.

## Invasive plants

Non-native, invasive plants often go unnoticed to the untrained eye. However, their presence continues to grow, negatively impacting Delaware forests particularly in highly fragmented areas such as urban settings and the edges of expanding suburbs. While there is no estimate of the number of native plants displaced by invasive species, DNREC's Wildlife Species Conservation & Research Program identifies 60 species of non-native, invasive plants that are detrimental to forest interior habitat (Table 8). Many of them are out-competing native trees in urban forests and open areas reverting to forestland.

## Conclusions

Certain living (biotic) and non-living (abiotic) agents damage forests in Delaware. Abiotic stressors are uncontrollable (e.g., drought, storms, sea level rise) but can be mitigated to a degree. Many biotic stressors also fall into this category of uncontrollable. Once established in the environment free from their natural regulating forces, invasive exotic organisms spread rapidly and have the potential to decimate a host species (e.g., Dutch elm disease, chestnut blight, emerald ash borer). Some forest pests can be controlled through silvicultural prescriptions (e.g., southern pine beetle). And many invasive exotic plant species simply out-compete native vegetation putting those more desirable species at a disadvantage. Steps should be taken wherever and whenever possible to reduce the impact of all forest-damaging agents.

## Summary – Criterion 3

Delaware's forests face a variety of health concerns—including threats that are present and threats that could potentially arrive in the near or distant future. Weather events, such as the 1994 ice storm, pose sporadic threats to forest health and can significantly impact the long-term well-being of our forests. Neither the normal "background" tree mortality rate nor the occurrence of wildfires present a major threat to Delaware's forest resources. Constant browse damage to seedlings by a large deer herd has likely begun altering species composition in hardwood forests throughout the state. Non-native, invasive plants also negatively and significantly impact Delaware's forests, particularly in the northern part of the state and within urban/suburban areas. Several exotic insects and diseases present potential threats to rural and urban forests as well. Therefore, surveys to assess current threats and detect new pests are essential for continued forest health. Addressing all of these concerns is important to ensure that Delaware maintains healthy forest ecosystems. Thankfully, none of these threats are considered a current forest health catastrophe. However, each has the potential to produce substantial impact, and in combination over time, could be devastating. The emerald ash borer seems likely to fall into this category in the near future. Taking steps to minimize damaging threats and developing plans to respond to their future occurrences is vital and ties directly into one of the U.S. Forest Service's S&PF national priorities—*Protect forests from threats.*