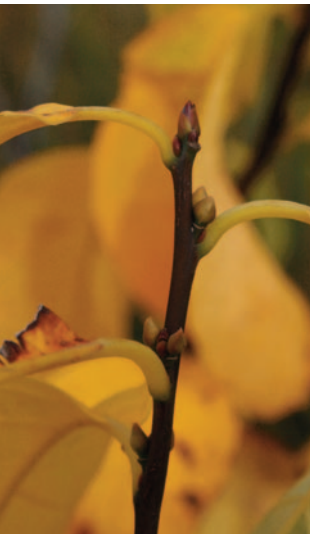




Conservation Gap Analysis of Selected Native U.S. Laurels

August 2021

Emily Beckman[1], Abby Meyer[2], David Pivorunas[3], Sean Hoban[1] and Murphy Westwood[1,4]

[1]The Morton Arboretum [2]Botanic Gardens Conservation International, U.S.
[3]USDA Forest Service [4]Botanic Gardens Conservation International

---

Lindera benzoin (L.) Blume (Northern spicebush)
Persea borbonia (L.) Spreng. (Red bay)
Persea humilis Nash (NSilk bay)
Persea palustris (Raf.) Sarg. (Swamp bay)
Sassafras albidum (Nutt.) Nees (Sassafras)

The Morton Arboretum®

BOTANIC GARDENS CONSERVATION INTERNATIONAL

INSTITUTE of Museum and Library SERVICES

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

THE MORTON ARBORETUM is an internationally recognized outdoor tree museum and tree research center located in Lisle, Illinois. As the champion of trees, the Arboretum is committed to scientifically informed action, both locally and globally, and encouraging the planting and conservation of trees for a greener, healthier, more beautiful world. The Morton Arboretum welcomes more than 1.3 million visitors annually to explore its 1,700 acres with 222,000 plant specimens representing 4,650 different kinds of plants. The Arboretum's Global Tree Conservation Program works to prevent tree extinctions around the world by generating resources, fostering cross-sector collaborations, and engaging local partners in conservation projects. The Center for Tree Science seeks to create the scientific knowledge and technical expertise necessary to sustain trees, in all their diversity, in built environments, natural landscapes, and living collections. The Arboretum also hosts and coordinates ArbNet, the interactive, collaborative, international community of arboreta and tree-focused professionals.

BOTANIC GARDENS CONSERVATION INTERNATIONAL (BGCI) is the world's largest plant conservation network, comprising more than 600 botanic gardens in over 100 countries, and provides the secretariat to the IUCN/SSC Global Tree Specialist Group. BGCI was established in 1987 and is a registered charity with offices in the UK, US, China, Singapore and Kenya.

THE INSTITUTE OF MUSEUM AND LIBRARY SERVICES is the primary source of federal support for the nation's libraries and museums. The IMLS advances, supports, and empowers America's museums, libraries, and related organizations through grantmaking, research, and policy development. Their vision is a nation where museums and libraries work together to transform the lives of individuals and communities. To learn more, visit www.imls.gov. The views, findings, conclusions or recommendations expressed in this publication do not necessarily represent those of the Institute of Museum and Library Services.

THE U.S. DEPARTMENT OF AGRICULTURE (USDA), FOREST SERVICE stewards over 193 million acres of forest and grasslands on behalf of the American people with the mission to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. Besides the management of National Forest System lands, the USDA Forest Service provides technical and financial assistance to States, universities, and other organizations to support this mission. Additionally, the Agency conducts world renowned research helping to provide answers on pressing issues facing forest managers. This institution is an equal opportunity provider and employer.

ACKNOWLEDGEMENTS

First and foremost, many thanks to the hundreds of institutions who shared their *ex situ* accessions data and/or reported conservation activities. The original analyses presented in this report are made possible through their support and participation, and we hope this synthesis is a valuable resource for advancing tree conservation goals. A special thanks to the Biota of North America Program (BONAP) and USDA PLANTS for providing valuable *in situ* occurrence data, Shannon Still for aiding in the development of methods for spatial analyses, and Christina Carrero for coordinating IUCN Red List assessments for priority species. We also thank Botanic Gardens Conservation International U.S. as well as the Science & Conservation Department and leadership team of The Morton Arboretum for their organizational support, and the Institute of Museum and Library Services (award #MA-30-18-0273-18) for aiding in the funding of spatial analysis methodologies presented here. Finally, this publication was made possible by a grant to The Morton Arboretum under a cooperative agreement with the USDA Forest Service (Cooperative Agreement 16-CA-11132546-045).

The Morton Arboretum, 4100 Illinois Route 53, Lisle, IL 60532, USA.

Recommended citation: Beckman, E., Meyer, A., Pivorunas, D., Hoban, S., & Westwood, M. (2021). *Conservation Gap Analysis of Native U.S. Laurels*. Lisle, IL: The Morton Arboretum.

INTRODUCTION

Trees are facing increasing threats globally, including habitat loss, natural systems modification, land use change, climate change, and pests and diseases. With more than 800 native tree species in the continental United States and more than 60,000 tree species globally, prioritizing species and conservation activities is vital for effectively utilizing limited resources. To facilitate this conservation planning, we developed a gap analysis methodology that examines both the accomplishments and most urgent needs for *in situ* (on-site) and *ex situ* (off-site) conservation of priority, at-risk tree groups in the U.S. This methodology was first implemented in our flagship report, *Conservation Gap Analysis of Native U.S. Oaks* (Beckman et al., 2019).

This report is one of seven that present the results of a second phase of gap analyses, which focuses on native U.S. trees within a group of priority genera that were selected due to particular economic importance, potential challenges with conventional *ex situ* conservation, and/or threats from emerging pests and diseases: *Carya, Fagus, Gymnocladus, Juglans, Pinus, Taxus,* and selected Lauraceae (*Lindera, Persea, Sassafras*). In each report, we provide a summary of ecology, distribution, and threats, and present results based on new data from a global survey of *ex situ* collections and a conservation action questionnaire that was distributed in 2019 to a wide range of conservation practitioners in the U.S. and botanical gardens globally. The aim of this report is to help prioritize conservation actions and coordinate activities between stakeholders to efficiently and effectively conserve these keystone trees in the U.S.

ECOLOGY & DISTRIBUTION

There are approximately 13 species of laurels (Lauraceae family) native to the United States, following the treatment in Flora of North America (1997). Five species were selected for analysis in this report, based on three factors – tree-like habit, susceptibility to laurel wilt, and distribution in areas currently affected by the disease – and fall into three genera: *Lindera, Persea*, and *Sassafras* (Gramling, 2010). The genus *Lindera* has three species native to the U.S., though only *L. benzoin* reaches heights higher than one or two meters and is therefore the only tree. The other two species, *L. melissifolia* and *L. subcoriacea*, are of conservation concern and should continue to be the focus of further study. *Litsea aestivalis* is also a shrub of conservation concern in the Lauraceae family. The USDA Forest Service has played a major role in providing a substantial base of research for these species, especially *Lindera melissifolia* and *Litsea aestivalis* (Best & Fraedrich, 2018; Fraedrich et al., 2011; Gordon, 2020; Hamel et al., 2007; Lockhart, 2016; USDA Forest Service, 2017). Three *Persea* species are native to the U.S., growing as evergreen shrubs to medium-sized trees with distribution in the Southeast, along the Atlantic Coastal Plain. *Sassafras* is a monotypic genus consisting of *S. albidum*, which is distributed across the eastern U.S. (Flora of North America, 1997; Figure 1).

Lindera benzoin (Northern spicebush) is a deciduous shrub with a broad, rounded habit and grows to between one and four meters in height, sometimes up to five meters in the best conditions. It thrives in moist bottomlands, woods, ravines, and valleys, often near streams, and frequently forms dense thickets. *Lindera benzoin* is widely distributed across the eastern U.S., primarily from Maine south to Georgia. There are a few small occurrences in Florida, and scattered distribution from Texas north to Missouri, Illinois, Michigan, and southeastern Canada. It spans hardiness zones four through nine (Hayden, 2006; Missouri Botanical Garden, 2018). *Lindera benzoin* has been assessed as Least Concern on the IUCN Red List (2020).

Lindera benzoin (R. A. Nonenmacher)

Persea borbonia (Red bay) is an evergreen tree reaching up to 16 meters tall, with approximately the same spread. The tree is often multi-stemmed and branches low to the ground (Gilman et al., 2018). This species is common in pocosins, forested wetlands, mixed hardwood swamps, and Mississippi pitcher-plant bogs. However, in the drier Big Thicket area of eastern Texas, it sometimes grows in upland longleaf pine (*Pinus palustris*) savannas and poorly drained sites. *Persea borbonia* is a dominant species in many of its habitats, including tree islands in the everglades, cypress dome understories, southern Florida tree islands, and coastal plain communities (Van Deelen, 1991). Its native range stretches along the Atlantic Coastal Plain from North Carolina to eastern Texas. *Persea borbonia* was assessed in 2018 as Least Concern on the IUCN Red List, but recent research regarding impacts from laurel wilt has prompted reassessment. The species will likely be assessed as Vulnerable (C. Carrero pers. comm., 2020).


Persea borbonia (Susan McDougall)

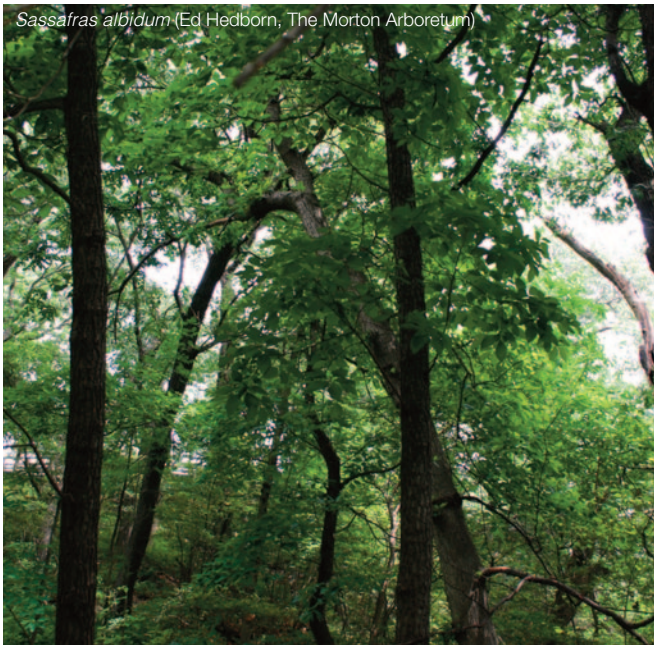
Persea humilis (Silk bay), is endemic to Florida and occurs in sand pine-scrub and shrub layers dominated by evergreen oaks. It grows as a shrub or small tree, up to ten meters, and was previously known as *Persea borbonia* var. *humilis*. Preferring sandy, well-drained to dry soil and full sun, *P. humilis* is also a good choice for coastal gardens due to its tolerance of salt spray (Flora of North America, 1997; Menges et al., 1993; N.C. Cooperative Extension, 2020). *Persea humilis* is in the process of being assessed for the IUCN Red List, and it has been recommended for the Near Threatened category, due to predicted population decline from laurel wilt impacts (C. Carrero pers. comm., 2020).


Persea humilis (Shirley Denton)

Persea palustris (Swamp bay) is a small to medium sized tree, 15 to 20 meters tall. It occurs in moist woodlands, savannas, swamps, and wetlands in the Atlantic and Gulf Coastal Plain, Eastern Mountains and Piedmont, and Great Plains, but can also grow in fairly dry, sandy soils in maritime forests. Its native distribution extends south and west from Pennsylvania, following the coast to eastern Texas (Flora of North America, 1997; N.C. Cooperative Extension, 2020). *Persea palustris* is in the process of being assessed for the IUCN Red List, and it is recommended for the Vulnerable category, based on predicted impacts from laurel wilt (C. Carrero pers. comm., 2020).


Persea palustris (Homer Edward Price)

Sassafras albidum (Sassafras) is a small to medium-sized deciduous tree reaching up to 20 or 30 meters tall in maturity. It occurs most frequently in forest edges, fence rows, fields, thickets, and roadsides, tolerating a variety of soil types but prefers moist, acidic, loamy soils. *Sassafras albidum* often spreads clonally by root suckers to form large colonies of what appear to be multi-stemmed shrubs (Missouri Botanical Garden, 2018). This species is also a common component of *Quercus ilicifolia* dry scrub habitat along the Coastal Plain, and dominates the shrub-layer of dry pine-oak forests (Sullivan, 1993). *Sassafras albidum* is widely distributed across the eastern U.S. and just into southeastern Canada, with a range similar to that of *Lindera benzoin*, and has been assessed as Least Concern on the IUCN Red List (2020).


Sassafras albidum (Ed Hedborn, The Morton Arboretum)

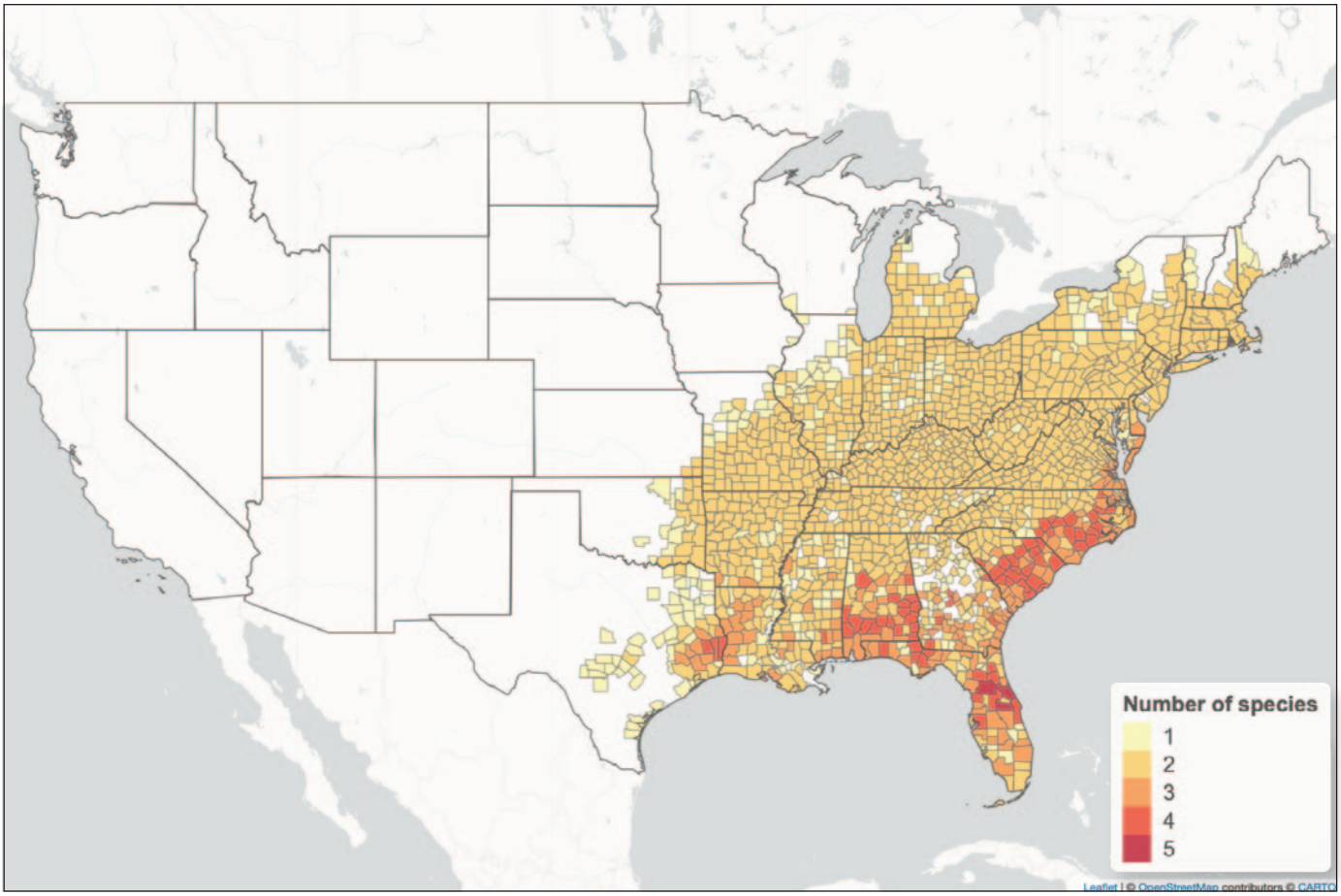


Figure 1. Species richness of selected native U.S. Lauraceae species by U.S. county, including *Lindera benzoin, Persea borbonia, P. humilis, P. palustris*, and *Sassafras albidum*. County level distribution data from USDA PLANTS and Biota of North America Program (BONAP) have been combined to estimate species presence (Kartesz, 2018; USDA NRCS, 2018).

PESTS & DISEASES

Laurel wilt, a deadly vascular disease caused by the fungal pathogen *Raffaelea lauricola*, is devastating populations of trees within the Lauraceae family across the southeastern U.S. The disease vector, the redbay ambrosia beetle (*Xyleborus glabratus*), is native to Asia and was introduced to the U.S. at a port in northeastern Georgia in the early 2000s. The beetle was first discovered in 2002 and laurel wilt disease was found one year later (Fraedrich, 2019). Since its initial detection, laurel wilt has spread throughout coastal Georgia, South Carolina and southern North Carolina, as well as the entirety of Florida, and jumped to a few locations in Alabama, Mississippi, Louisiana, Texas, Arkansas, Tennessee, and Kentucky (Bates, 2020).

A variety of studies have explored the spread of the disease, the mortality rate for different host species in the Lauraceae family, and various effects on the ecosystem as a whole. One analysis measured the boring response of female redbay ambrosia beetle (*Xyleborus glabratus*) for nine species of North American Lauraceae by exposing at least five wood bolts of each laurel species to the beetles for 24 hours in a no-choice bioassay. Final boring percentages were 97.8% for *Persea humilis*, 97.5% for *Umbellularia californica* (California bay laurel), 95.7% for *Persea palustris*, 95% for *P. borbonia*, 66.7% for *Sassafras albidum*, and 52% for *Lindera benzoin* (Kendra et al., 2014).

Because *Persea borbonia* is a dominant or co-dominant component of the forests most impacted by laurel wilt, the majority of research so far has been focused on this species. By 2017, laurel wilt had killed at least 320 million *P. borbonia* trees, which is nearly one third of the species' population size prior to the invasion of laurel wilt. Within plots across its range, *P. borbonia* experienced a mortality rate of 67.5% in Georgia, 41.6% in South Carolina, 36.5% in Florida, 9.8% in North Carolina, and 2.1% in Mississippi between 1999 and 2007 (Hughes et al., 2017). Another study of *P. borbonia* in Georgia compared multiple diseased populations two to four years after infestation to healthy, uninfested populations. Results showed high *P. borbonia* mortality, shifts in size structure, and changes in community composition, with an average mortality of 90% for *P. borbonia* trees ≥3 cm diameter at breast height (DBH), compared to 0–35% mortality in control sites. Community structure measurements revealed that *P. borbonia* "trees had the greatest mean importance value (IV) at control sites compared to the 8th mean IV at infested sites for live stems," and the normally co-dominant species *Magnolia virginiana* and *Gordonia lasianthus* were of higher importance at infested sites (Spiegel & Leege, 2013). In Etoniah Creek State Forest, Florida, "percent mortality of [*P. borbonia*] in the overstory, sapling, and seedling layers were 100%, 30.2%, and 1.8%, respectively, in the year after the first signs of infection were observed...In other forests, such reductions caused from laurel wilt will depend on how much growing space is occupied by [*P. borbonia*], which will vary by habitat type" (Shields et al., 2011). Also focused on a more specific area affected by laurel wilt, tree surveys were conducted from 2004 to 2009 on an island near the location where the disease was introduced. These surveys found 98% mortality of main stems and all remaining individuals showing signs of laurel wilt. They also noted that, "sprouting does not appear to give [*P. borbonia*] the ability to maintain genets and recruit new stems into the forest canopy" (Snyder, 2014). Evidence from these studies and others point towards the ecological extinction of *P. borbonia* from coastal forest ecosystems in the southeastern United States (Evans et al., 2014).

A study monitoring both *Persea borbonia* and *Sassafras albidum* established long-term plots in southeastern Georgia to monitor the progression of laurel wilt through four years. Laurel wilt killed 87.3% of *P. borbonia* and 79.5% of *S. albidum* trees in the plots. It took between 1.1 and 3.6 years from initial disease detection until mortality ceased in *P. borbonia* stands, depending on host-tree size and abundance. Larger trees died at a higher rate in both *P. borbonia* and *S. albidum* stands, and mortality curves were similar for both species (Cameron et al., 2015). Because the current distribution of laurel wilt spans only a small percent of the range of *S. albidum,* the disease does not pose an imminent threat to the species. But, recent cold-tolerance tests for redbay ambrosia beetle have indicated it can survive temperatures as low as -11 °F, which increases the possibility of northward spread into more of the native distribution of *S. albidum* (Randolph, 2017).

Results from the USDA Forest Service study *Important Insect and Disease Threats to United States Tree Species and Geographic Patterns of Their Potential Impacts* (Potter et al., 2019a) are provided in Table 1, to give an overview of the major pests and diseases affecting selected native U.S. *Lauraceae* species. That study performed a thorough literature review, including more than 200 sources, and consulted dozens of expert entomologists and pathologists to identify up to five of the most serious insect, disease, and parasitic plant threats facing each of 419 native U.S. tree species; priority was given to pests and diseases causing mortality of mature trees, rather than agents primarily affecting reproductive structures or seedlings. Distribution and severity maps for laurel wilt are also provided below (Figures 2-3). A second USDA Forest Service study, *Prioritizing the conservation needs of United States tree species: Evaluating vulnerability to forest insect and disease threats* (Potter et al., 2019b), combined results from Potter et al. (2019a) with species trait and vulnerability data to further categorize overall pest and disease vulnerability of the 419 target native U.S. tree species. Results from this study are provided in Table 2.

Table 1. The most serious insect, disease, and parasitic plant agents affecting selected native U.S. *Lauraceae* species, from the results of Potter et al. (2019a), which analyzed 419 native U.S. tree species. *Lindera benzoin, Persea humilis*, and *P. palustris* were not included in the study. Numbers represent the severity of the agent's impact on the host species. * = nonnative invasive agent. Table adapted, with permission, from Potter et al. (2019a).

Host species	Insect, Disease, or Parasitic Plant Agent						
	Black twig borer (*Xylosandrus compactus*)*	Ganoderma rot of hardwoods (*Ganoderma lucidum*)	Japanese beetle (*Popillia japonica*)*	Lobate lac scale (*Paratachardina pseudolobata*)*	Laurel wilt (Raffaelea lauricola)/redbay ambrosia beetle (*Xyleborus glabratus*)*	Verticillium wilt (*Verticillium albo-atrum*)	Witches'-broom (*Apiosporina collinsii*)
Persea borbonia	1			1	10		
Sassafras albidum		1	1		8	1	1

Severity of agent's impact

10 = near complete mortality of all mature host trees (>95%)
8 = significant mortality of mature host trees (25% to 95%)
5 = moderate mortality of mature host trees (10% to 25%)
3 = moderate mortality in association with other threats, such as drought stress (1% to 10%)
1 = minor mortality, generally to host trees that are already stressed (<1%)

Sassafras albidum (Susan McDougall)

Current county-level distribution

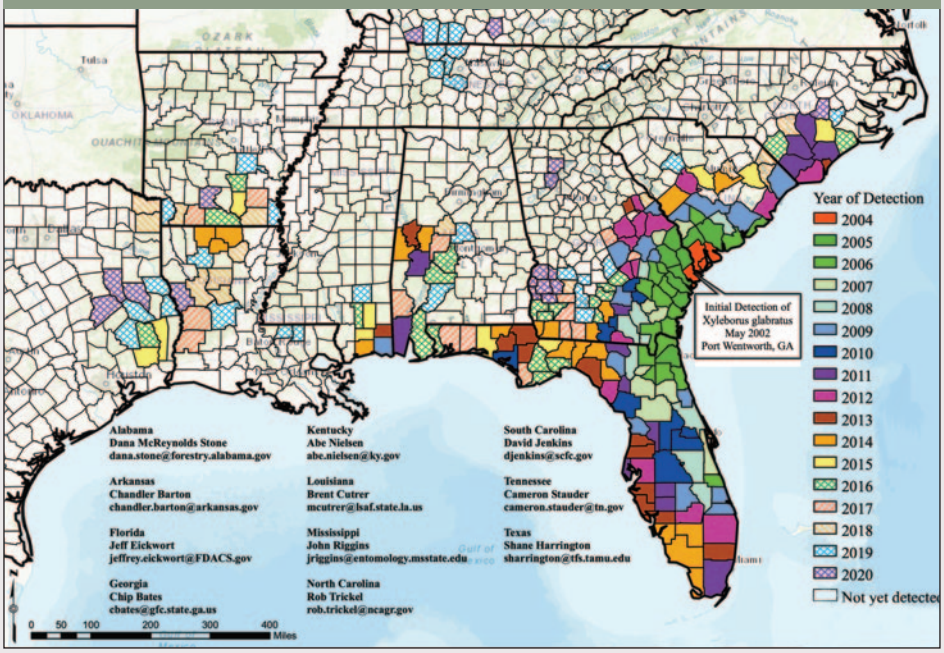


Figure 2. Distribution of laurel wilt (*Raffaelea lauricola*) by county and year of initial detection. Created by Chip Bates (Georgia Forestry Commission) and the USDA Forest Service, Forest Health Protection, The Southern Region (Bates, 2020).

Watersheds ranked by basal area loss hazard

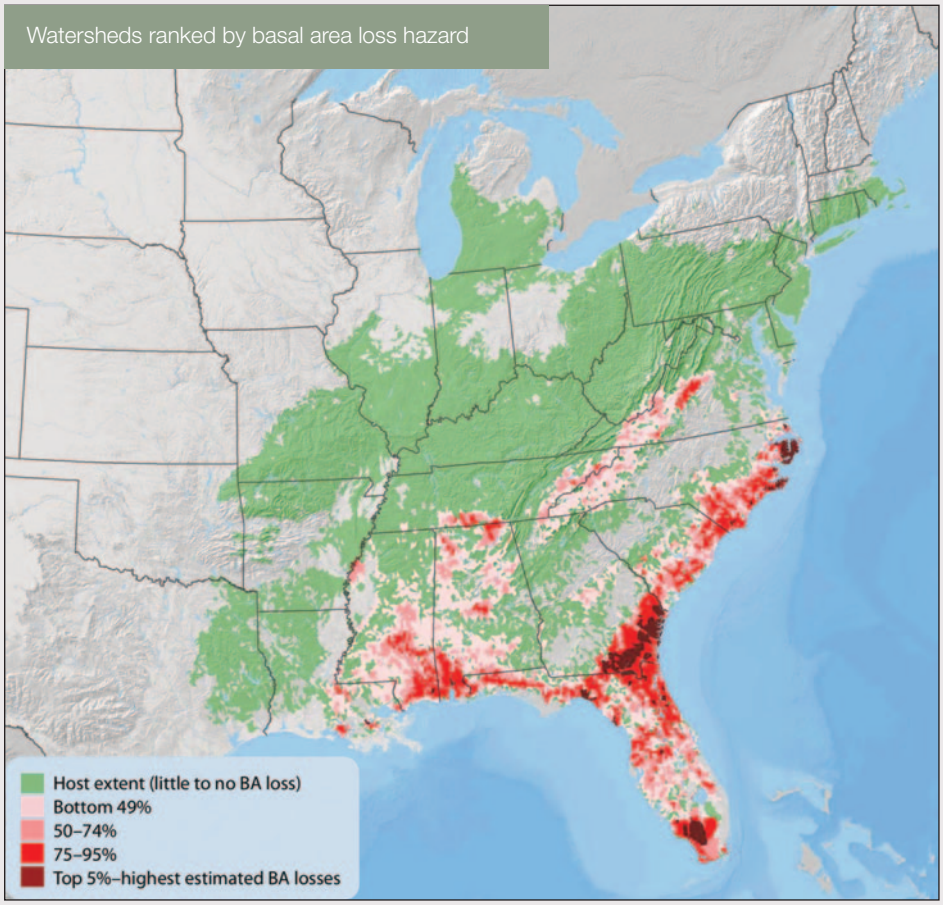
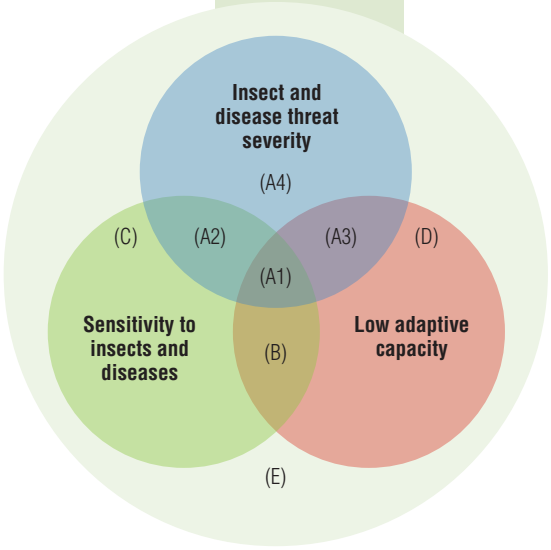


Figure 3. National Insect and Disease Risk Map quantifying the predicted impact of laurel wilt (*Raffaelea lauricola*) on *Persea borbonia* and *Sassafras albidum* by 2027. Green areas are predicted to have little to no loss, light red areas are predicted to have some loss, and dark red areas are predicted to have the most loss. These maps were created by the USDA Forest Service, Forest Health Technology Enterprise Team. Further methods information can be found in the full USDA publication (Krist et al., 2014).

Table 2. Pest and disease vulnerability of selected native U.S. Lauraceae species, from the results of a USDA Forest Service study that analyzed 419 native U.S. tree species. *Lindera benzoin, Persea humilis*, and *P. palustris* were not included in the study. Species are ordered by overall rank, from most vulnerable to least vulnerable. Figure is adapted, with permission, from Potter et al. (2019b).

Species	Vulnerability Class	Overall Rank (of 419)
Persea borbonia	A1	7
Sassafras albidum	D	292



Vulnerability Classes

A) High current severity
   1) High vulnerability
   2) Potential adaptation
   3) Potential persistence
   4) Potential persistence and adaptation

B) Potential high vulnerability to future threats

C) Potential high sensitivity to future threats

D) Potential low adaptation to future threats

E) Low current and potential vulnerability

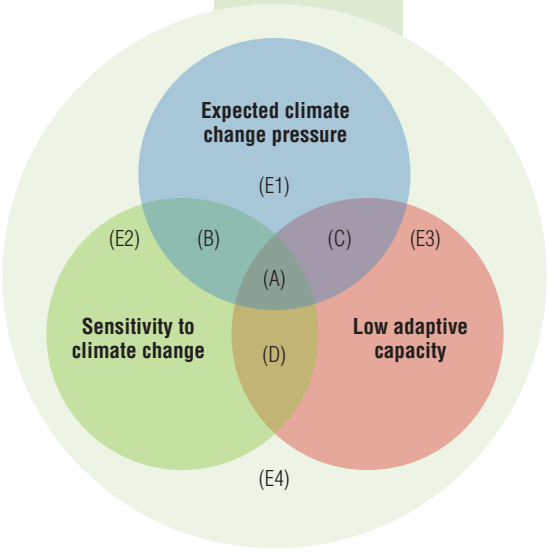

Lindera benzoin (R. A. Nonenmacher)

CLIMATE CHANGE VULNERABILITY

Native U.S. Laurels face varying impacts from climate change, though data are lacking for most species. Current analyses point to moderate or low vulnerability of native U.S. Lauraceae species, compared to other native U.S. trees. Using a similar methodology to Potter et al. (2019b), which focuses on species-specific traits in addition to vulnerability data, Potter et al. (2017) analyzed species vulnerability to climate change in the study, *A United States national prioritization framework for tree species vulnerability to climate change*. A selection of 339 native U.S. tree species were assessed through comprehensive literature review, in addition to input from 25 USDA Forest Service resource managers and scientists from across the country and varying departments within the agency. Results from that study are provided in Table 3.

Table 3. Climate change vulnerability of selected native U.S. Lauraceae species, from the results of a USDA Forest Service study that analyzed 339 native U.S. tree species. *Lindera benzoin, Persea humilis*, and *P. palustris* were not included in the study. Species are ordered by overall rank, from most vulnerable to least vulnerable. Figure is adapted, with permission, from Potter et al. (2017).

Species	Vulnerability Class	Overall Rank (of 339)
Persea borbonia	D	165
Sassafras albidum	E1	262



Vulnerability Classes

A) High vulnerability, little adaptation or persistence potential

B) High vulnerability, potential adaptation

C) High vulnerability, potential persistence

D) Potential high future vulnerability

E) Low current vulnerability

MAJOR CONSERVATION INITIATIVES

The *Recovery Plan for Laurel Wilt on Redbay and Other Forest Species Caused by Raffaelea lauricola and Disseminated by Xyleborus glabratus* was published in 2015 as one of several disease-specific reports created as part of the National Plant Disease Recovery System (NPDRS). The document is intended to ensure that the "tools, infrastructure, communication networks, and capacity [are available to] mitigate the impact of high-consequence plant disease outbreaks," and includes a brief summary of laurel wilt, assessment of recovery components, and identification of disease management research, extension, and education needs (Hughes et al., 2015). Also, educational guides such as the *Biology, Ecology, and Management of Laurel Wilt and the Redbay Ambrosia Beetle* have been produced as an important resource for professional and general audiences to build awareness regarding best practices (Hughes et al., 2016).

Studies are underway to determine if there is any laurel wilt resistance in *P. borbonia*. There are also studies to manage the spread of the disease through insecticides and fungicides, but these solutions are costly and require frequent, often yearly, maintenance. It is suggested that the best management strategy may be to allow the disease to run its course and see if regeneration happens naturally (Shearman et al., 2014). Another similar topic of research is focused on identifying semiochemicals, which are likely key components of redbay ambrosia beetle's ability to locate host trees. This research should "facilitate improvement of field lures for pest detection, and development of attract-and-kill bait stations for pest suppression" (Kendra et al., 2014).

Persea humilis (Shirley Denton)

Persea borbonia (David J. Stang)

Monitoring is also an important component of current conservation initiatives. Randolph (2017) states, "continued region-wide monitoring of sassafras by the FIA Program and the implementation of other localized studies will be important for assessing the loss of sassafras as [laurel wilt] progresses throughout the eastern United States...If and when [laurel wilt] establishes itself in the more-centrally located forests where sassafras is most abundant, the impact of [laurel wilt] on sassafras will increase" and studies similar to those conducted for *P. borbonia* should be performed. Landowners and forest managers in areas where *Sassafras albidum* or *Lindera benzoin* are most abundant "should be diligent to watch for [laurel wilt] symptoms because discontinuous jumps of the disease may continue" (Randolph, 2017).

Naples Botanical Garden is collaborating with several local partners, including Fakahatchee Strand Preserve State Park and the Florida Forest Service's Caloosahatchee Forestry Center, to preserve the genetic diversity of *Persea palustris* through wild seed collection. Germination has been successful and seedlings are being grown in the garden's nursery. The hope is that these plants may eventually be used to reintroduce the species (Naples Botanical Garden, 2018). A separate study has pursued vegetative propagation experiments for *P. borbonia*, which could also aid in the evaluation of disease resistance and to conserve germplasm. This work included the development of "a primary framework for redbay vegetative propagation to address limitations of long-term seed storage and the need to preserve and screen putatively laurel wilt-resistant redbays" (Hughes & Smith, 2014).

Aerial images have been explored as an option for identifying plants affected by laurel wilt by using a modified camera during low-altitude helicopter surveys. The methodology has only been tested on avocado farms, but has shown very good potential in that setting; other factors with symptoms similar to laurel wilt, such as fruit stress and vines covering trees, were successfully distinguished from laurel wilt (de Castro et al., 2015).

EX SITU SURVEY RESULTS

There are relatively little data regarding the seed storage behavior of native U.S. Lauraceae species, though *Persea americana* (Avocado) has been studied extensively and determined to be recalcitrant, meaning its seeds do not retain viability when dessicated (Royal Botanic Gardens Kew, 2020). Other *Persea* species are expected to show the same characteristic. Because seeds must first be desiccated before storing in a conventional seed bank, alternative methods of long-term *ex situ* preservation are necessary for conserving the genetic diversity of recalcitrant species, including living collections and new seed storage technologies such as cryopreservation (Walters & Pence, 2020). *Lindera benzoin* is known to store poorly at room temperature, but more information is needed regarding its behavior in conventional seed banks; data are available for *L. megaphylla* (native to southern China), which show the seeds to be freeze-sensitive and only partially desiccation tolerant – therefore *L. benzoin* seeds are likely short-lived in conventional storage conditions and require other means of long-term *ex situ* storage. *Sassafras albidum* is thought to be tolerant of desiccation, but still sensitive to long-term storage (Bonner & Karrfalt, 2008). More research is needed, but current evidence suggests that native U.S. Lauraceae species should be considered exceptional, or unable to be stored at low temperature and moisture for more than ten to 20 years, and should be prioritized for *ex situ* preservation in living collections and through other new seed storage technologies.

In 2018, we conducted a global accessions-level *ex situ* survey of priority native U.S. tree species within nine target genera: *Carya, Fagus, Gymnocladus, Juglans, Lindera, Persea, Pinus, Sassafras*, and *Taxus*. The request for data was emailed directly to target e*x situ* collections, including arboreta, botanical gardens, private collections, and USDA Forest Service seed orchards. We started with institutions that had reported collections of these genera to BGCI's PlantSearch database, and whose contact information was available in BGCI's GardenSearch database. The data request was also distributed via newsletters and social media through ArbNet, the American Public Gardens Association, Botanic Gardens Conservation International, the Center for Plant Conservation, the Plant Conservation Alliance, The Morton Arboretum, and the USDA Forest Service. A total of 143 collections from 25 countries provided accessions data for our target genera, including 77 collections from 16 countries reporting *Lindera benzoin*, 27 collections from three countries reporting native U.S. *Persea species*, and 71 collections from 14 countries reporting *Sassafras albidum* (Figure 4). See Appendix A for a list of participating institutions. When providing *ex situ* collections data, institutions were asked to include the number of individuals in each accession. When such data were unavailable, we assumed the accession consisted of one individual; therefore our results represent a conservative estimate. Also, because some Lauraceae species can last for short periods of time in seed banks, it is possible that the *ex situ* survey results presented here include some seed-banked individuals in addition to individuals in living collections.

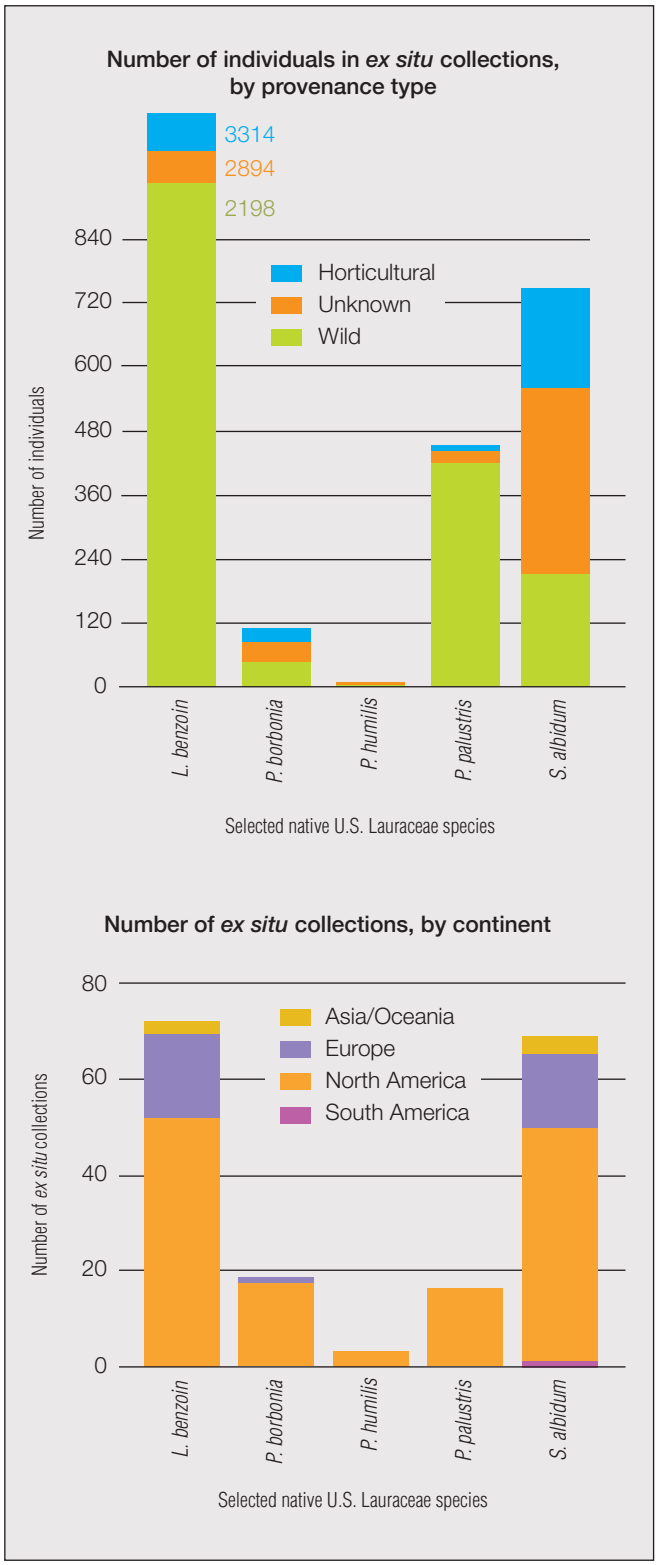


Figure 4. Results from a 2018 global accessions-level *ex situ* survey for selected native U.S. Lauraceae species. Colored numbers above a bar indicate the value exceeds the limits of the chart.

SPATIAL ANALYSIS OF *EX SITU* COLLECTIONS

Ex situ collections conserve the most genetic diversity when they represent a large percent of the target species' geographic and ecological range. Therefore, identifying under-represented populations and ecoregions is vital to improving the conservation value of *ex situ* collections. To prioritize regions and species for future *ex situ* collecting, we mapped and analyzed the estimated native distribution of each target species versus the wild provenance localities of germplasm in *ex situ* collections.

We used two proxies for estimating *ex situ* genetic diversity representation: geographic and ecological coverage. These proxies are based on the assumption that sampling across a species' full native distribution and all ecological zones it inhabits is the best way to ensure that the full spectrum of its genetic diversity is captured in *ex situ* collections (CPC, 2018; Hanson et al., 2017; Khoury et al., 2015). Using methods introduced by Khoury et al. (2019) and Beckman et al. (2019), we calculated geographic and ecological coverage by comparing two sets of geographic points: 1) known *in situ* occurrences, and 2) *ex situ* collection source localities (i.e., wild occurrences where seed was collected for *ex situ* preservation). To approximate potential suitable habitat, nearby populations, and/or gene flow, we placed a circular buffer around each *in situ* occurrence point and each *ex situ* collection source locality. When buffers around *ex situ* collection source localities overlap with buffers around *in situ* occurrence points, that area is considered 'conserved' by *ex situ* collections (Figures 5-10; Table 4). Because our calculations of geographic and ecological coverage are based on a rough estimation of the distribution of a species and only address the portion of a species distribution within the U.S., the values reported here should be viewed as estimates that can be used to compare among species for prioritization rather than values reflecting the actual capture of genetic diversity (e.g., alleles or DNA sequence differences) in *ex situ* collections.

Sassafras albidum (Deb Brown, The Morton Arboretum)

Persea palustris (Susan McDougall)

In situ occurrence points for each target species were downloaded from a variety of publicly available data sources, including Biodiversity Information Serving Our Nation (BISON; USGS, 2019), Botanical Information and Ecology Network (BIEN; bien.nceas.ucsb.edu, 2020; Maitner, 2020), Forest Inventory and Analysis (FIA) Program of the USDA Forest Service (Forest Inventory and Analysis Database, 2019), Global Biodiversity Information Facility (GBIF.org, 2020; Chamberlain & Boettiger, 2017), Integrated Digitized Biocollections (iDigBio; idigbio.org, 2020; Michonneau & Collins, 2017), and U.S. herbarium consortia (e.g., SERNEC; Data Portal, 2020). To increase their reliability, these raw data points were automatically vetted using a set of common filters for biodiversity data (Zizka et al., 2019). Points were removed if they fell within 500 meters of a state centroid or 100 meters of a biodiversity institution, or if they were not within a county of native occurrence for the target species based on county-level data from Biota of North America (BONAP; Kartesz, 2018). Points were also removed if they were recorded before 1950, were missing a record year, were recorded as a living or fossil specimen, or were recorded as introduced, managed, or invasive. For species of conservation concern (assessed as Near Threatened, Vulnerable, Endangered, or Critically Endangered on the IUCN Red List) the *in situ* distribution points were also vetted manually based on literature review.

Ex situ data were gathered during the 2018 survey described in the previous section, and records for target species with a wild source locality description were manually geolocated when latitude and longitude were missing. For selected native U.S. Lauraceae species, about 25% of records with wild or unknown provenance were manually geolocated, while 29% had latitude and longitude provided by the institution and 46% contained too little locality information to geolocate to county-level or finer. To map wild provenance localities of *ex situ* individuals, accessions collected from wild localities near each other were grouped together based on latitude and longitude rounded to one digit after the decimal. All data processing and mapping were performed in R (R Core Team, 2020; Graul, 2016).

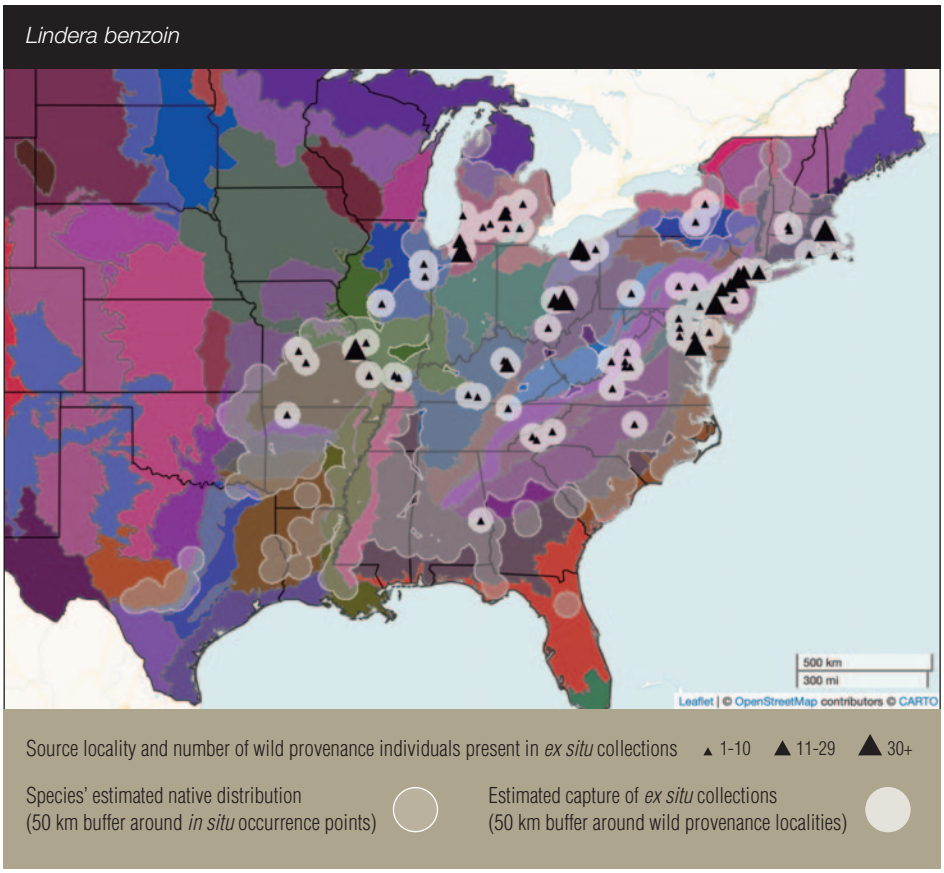


Figure 5. Native distribution and wild provenance localities of *ex situ* individuals for *Lindera benzoin* in the U.S., based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development, 2013a).

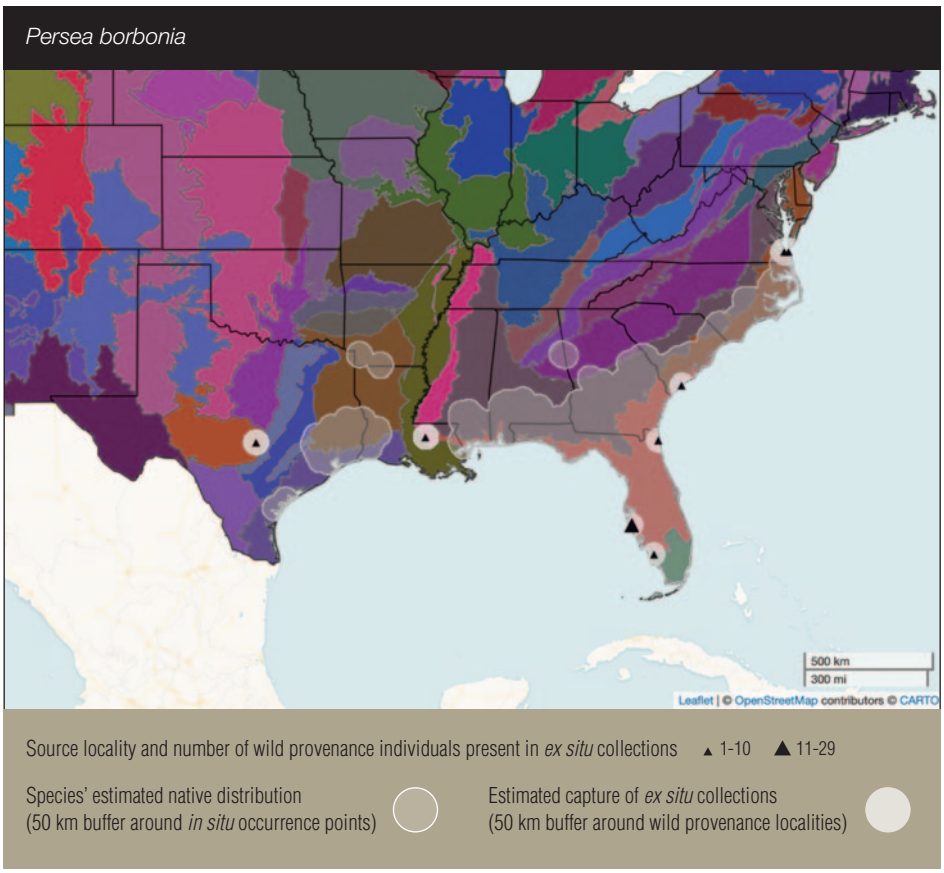


Figure 6. Native distribution and wild provenance localities of *ex situ* individuals for *Persea borbonia*, based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development, 2013a). In addition to standard *in situ* occurrence point filters applied to all target species, *P. borbonia* occurrence points were further refined by removing records more than 200 km outside native counties provided in the USDA PLANTS database (USDA NRCS, 2018).

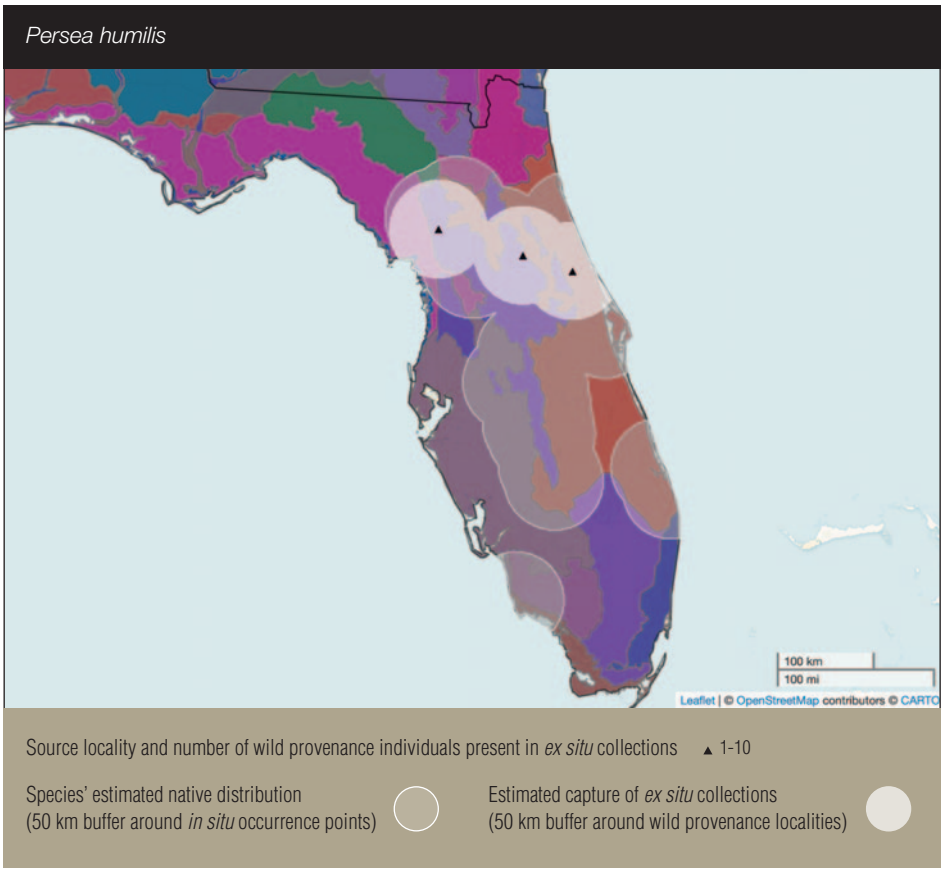


Figure 7. Native distribution and wild provenance localities of *ex situ* individuals for *Persea humilis*, based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level IV Ecoregions (U.S. EPA Office of Research & Development, 2013b). In addition to standard *in situ* occurrence point filters applied to all target species, *P. humilis* occurrence points were further refined by removing records outside native counties provided in the Atlas of Florida Plants (Wunderlin et al., 2020).

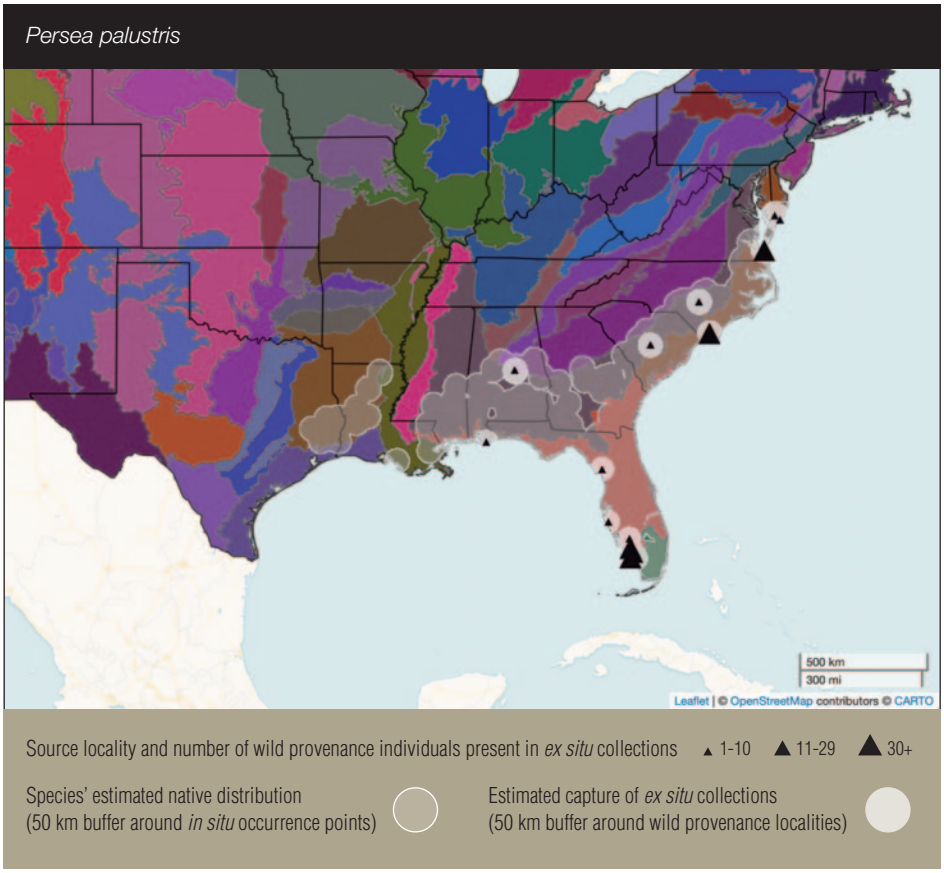


Figure 8. Native distribution and wild provenance localities of *ex situ* individuals for *Persea palustris*, based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development, 2013a). Occurrence points were not further refined after standard *in situ* occurrence point filters used for all target species, due to a lack of data; populations in central Alabama, South Carolina, and North Carolina are the furthest outside the species' generally-accepted range, and should be examined.

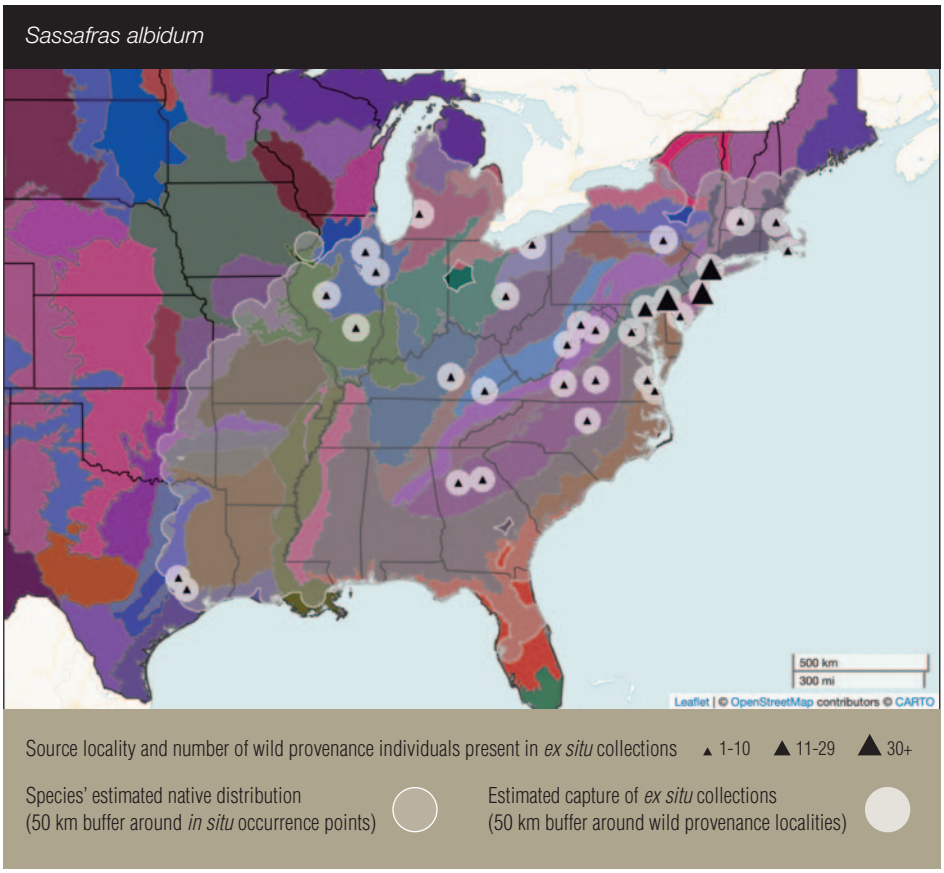


Figure 9. Native distribution and wild provenance localities of *ex situ* individuals for *Sassafras albidum* in the U.S., based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development, 2013a).

Lindera benzoin (R. A. Nonenmacher)

Table 4. Estimated geographic and ecological coverage of *ex situ* collections of selected native U.S. Lauraceae species. Geographic coverage = area covered by buffers around *ex situ* wild provenance localities / area covered by buffers around *in situ* occurrence points (values are given in km^2). Ecological coverage = number of ecoregions under buffers around *ex situ* wild provenance localities / number of ecoregions under buffers around *in situ* occurrence points. U.S. EPA Level IV Ecoregions (2013b) were used for calculating ecological coverage. Buffer area falling outside the contiguous U.S. was removed for all calculations. Three different-sized buffers (radius of 20 km, 50 km, and 100 km) were used to show the variation in estimated *ex situ* genetic representation depending on assumptions regarding population size and gene flow.

Species	20 km buffers		50 km buffers		100 km buffers		Average of all three buffer sizes	
	Geographic coverage	Ecological coverage	Geographic coverage	Ecological coverage	Geographic coverage	Ecological coverage	Geographic coverage	Ecological coverage
Lindera benzoin	75,871 / 1,018,766 **(7%)**	108 / 260 **(42%)**	345,503 / 1,965,743 **(18%)**	150 / 282 **(53%)**	891,894 / 2,404,265 **(37%)**	197 / 311 **(63%)**	**21%**	**53%**
Persea borbonia	6,649 / 365,706 **(2%)**	13 / 58 **(22%)**	38,148 / 520,042 **(7%)**	27 / 74 **(36%)**	144,811 / 780,405 **(19%)**	44 / 94 **(47%)**	**9%**	**35%**
Persea humilis	3,770 / 22,436 **(17%)**	3 / 6 **(50%)**	18,422 / 61,004 **(30%)**	6 / 12 **(50%)**	42,478 / 103,121 **(41%)**	9 / 14 **(64%)**	**29%**	**55%**
Persea palustris	14,411 / 305,872 **(5%)**	21 / 60 **(35%)**	64,100 / 577,353 **(11%)**	35 / 69 **(51%)**	207,052 / 775,772 **(27%)**	45 / 85 **(53%)**	**14%**	**46%**
Sassafras albidum	36,425 / 2,069,029 **(2%)**	75 / 283 **(27%)**	209,636 / 2,398,635 **(9%)**	109 / 290 **(38%)**	640,087 / 2,605,179 **(25%)**	153 / 308 **(50%)**	**12%**	**38%**

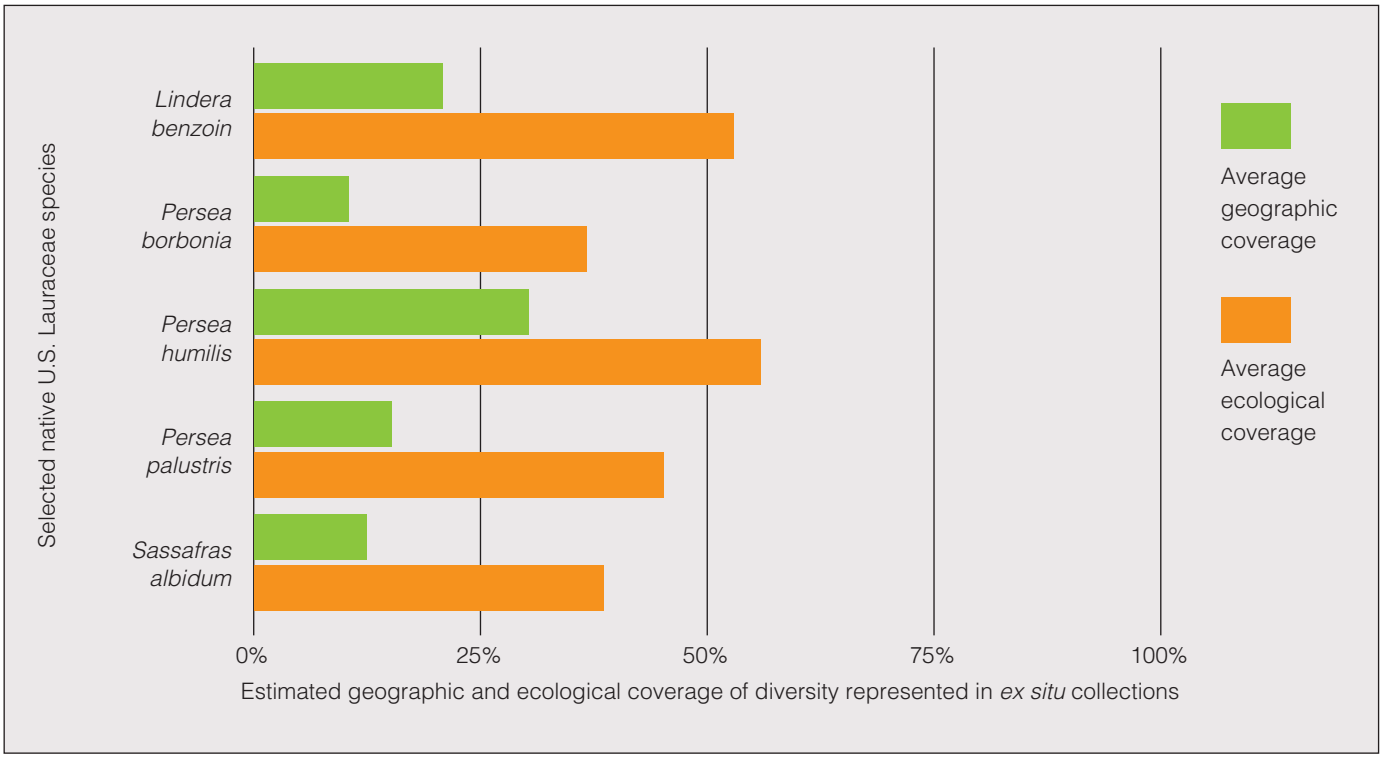


Figure 10. Average geographic and ecological coverage of *ex situ* collections for selected native U.S. Lauraceae species (See Table 4 for details).

TREE CONSERVATION QUESTIONNAIRE RESULTS

In 2019, we conducted a Tree Conservation Action Questionnaire for priority native U.S. tree species within nine target genera: *Carya, Fagus, Gymnocladus, Juglans, Lindera, Persea, Pinus, Sassafras*, and *Taxus*. The questionnaire was designed primarily to gather information regarding current or future planned conservation activities, but also to provide a platform to ask experts their opinion regarding most urgent conservation actions and most significant threats for each target species (Figure 11). A subset of target species were chosen to be included in the questionnaire based on threat rankings (IUCN Red List Category and NatureServe Global Status), climate change vulnerability, impact from pests and diseases, and representation in *ex situ* collections.

The questionnaire was emailed directly to targeted *ex situ* collections, content experts, attendees of the 2016 "Gene Conservation of Forest Trees: Banking on the Future" workshop, native plant societies and The Nature Conservancy contacts (from states with 20 or more target species), NatureServe and Natural Heritage Program contacts (from states with ten or more target species), BLM field offices, the USDA Forest Service RNGR National Nursery and Seed Directory, and USFS geneticists, botanists, and pest/disease specialists. The questionnaire was also distributed via newsletters and social media through ArbNet, the American Public Gardens Association, Botanic Gardens Conservation International, the Center for Plant Conservation, the Plant Conservation Alliance, The Morton Arboretum, and the USDA Forest Service.

More than 200 institutions completed the questionnaire, including 69 institutions that provided input on conservation activities for selected native U.S. Lauraceae species. Institutions reporting that they could "provide information regarding current conservation activities, most urgent conservation needs, and/or primary threats to wild populations" included 61 for *Lindera benzoin*, 14 for *Persea borbonia*, four for *P. humilis*, 12 for *P. palustris*, and 65 for *Sassafras albidum*. See Appendix A for a list of participants and Appendix B for a full summary of questionnaire responses, which can be used to identify potential collaborators, coordinate conservation efforts, and recognize possible gaps in current activities.

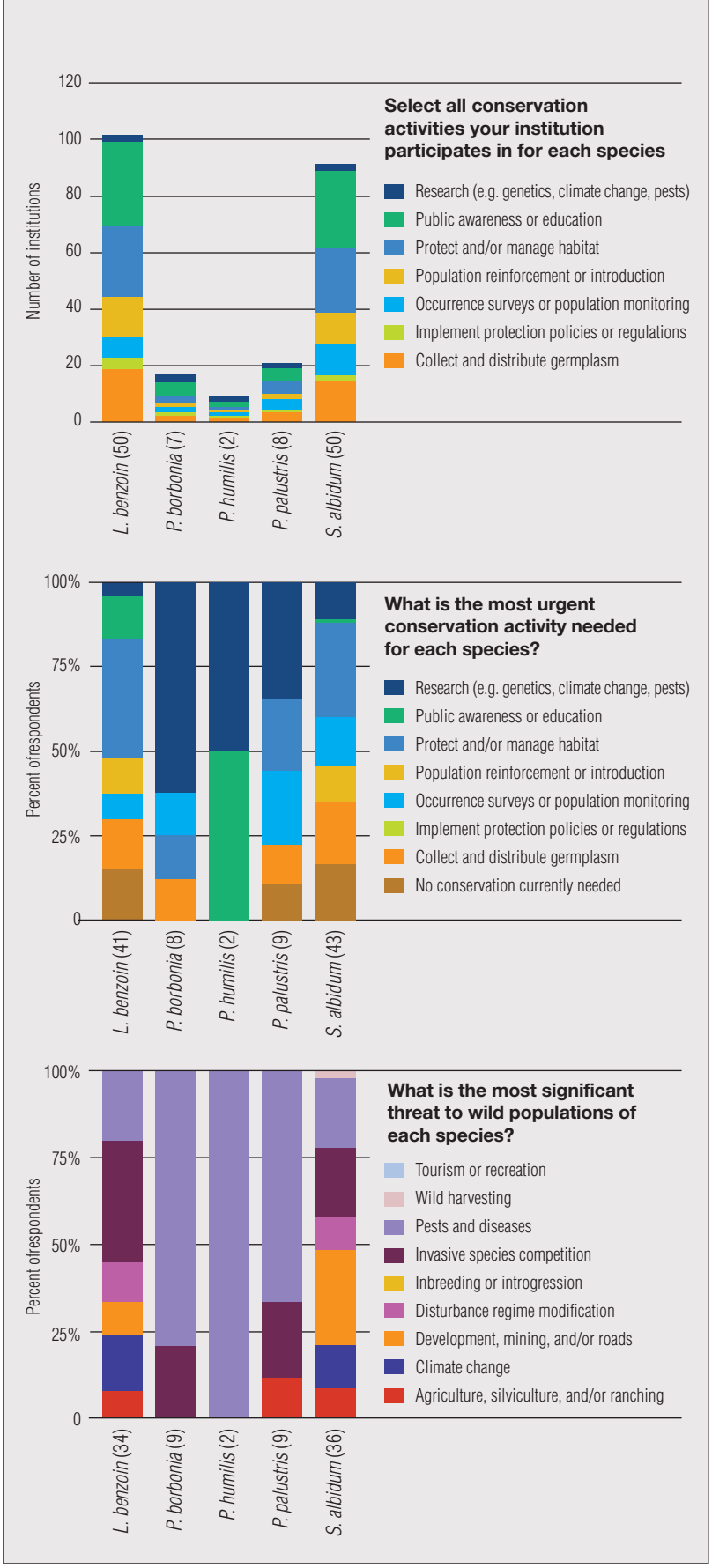


Figure 11. Results from the Tree Conservation Action Questionnaire for selected native U.S. Lauraceae species. The number of institutions or respondents participating in each question is listed in parentheses after the species' name. See Appendix B for details regarding which institutions reported each conservation activity.

CONCLUSIONS & RECOMMENDATIONS

Species' distributions and threats: This report focuses on five species in the Lauraceae family, selected based on their tree-like habit, susceptibility to laurel wilt, and distribution in areas currently affected by the disease. *Lindera benzoin* and *Sassafras albidum* are widely distributed across the eastern U.S., *Persea borbonia* and *P. palustris* are native to coastal areas from Texas to Virginia and New Jersey, and *P. humilis* is endemic to Florida (Figure 1). *Persea borbonia* and *P. palustris* are being devastated by laurel wilt disease, while the other selected native U.S. Lauraceae species have experienced minor effects from laurel wilt and should continue to be monitored (Tables 1-2; Figures 2-3). *Persea borbonia* and *S. albidum* are predicted to have relatively low vulnerability to climate change (Table 3); reliable models do not exist for the other selected native U.S. Lauraceae species. The native U.S. Lauraceae that were not examined in this report have been shown to have varying levels of susceptibility to laurel wilt and should be monitored. *Lindera melissifolia*, *L. subcoriacea*, and *Litsea aestivalis* are of special concern, due to their rarity, and should be prioritized for assessment in the IUCN Red List, in addition to further coordination of conservation actions. The USDA Forest Service has provided an excellent start to this work.

Conservation quality of *ex situ* collections: Based on data from more than 80 *ex situ* collections that submitted accessions data for selected native U.S. Lauraceae species, *Lindera benzoin* is represented by the most *ex situ* individuals (3,314), with nearly 70% of wild origin. The majority of wild origin individuals for *L. benzoin* had the spatial data necessary for mapping their wild *ex situ* source locality, resulting in relatively high geographic coverage (21%) and ecological coverage (53%) compared to the other target species. *Persea humilis* is the selected native U.S. Lauraceae species represented by the fewest individuals in *ex situ* collections (6), but the majority of these individuals were able to be mapped to their wild provenance localities and provided the highest geographic (29%) and ecological (55%) coverage of any native U.S. Lauraceae species analyzed here. The other three target species, *Persea borbonia, P. palustris*, and *Sassafras albidum*, are well-represented in *ex situ* collections (112, 453, and 745 individuals, respectively), but have lower geographic (9 to 14%) and ecological (35 to 46%) coverage. For *Lindera benzoin, Persea humilis*, and *Sassafras albidum*, the southern portion of their distribution has especially low known representation in *ex situ* collections (Figures 5-10; Table 4).


Sassafras albidum (Ed Hedborn, The Morton Arboretum)


Lindera benzoin (Ed Hedborn, The Morton Arboretum)

Conservation actions: Within the Tree Conservation Action Questionnaire, conservation activities for selected native U.S. Lauraceae species were reported by 69 of the more than 200 participating institutions. Across all five species, public awareness or education was one of the most common activities reported (tied with research for *Persea humilis*), followed by protect and/or manage habitat (tied with research for *P. borbonia* and occurrence surveys or population monitoring for *P. palustris*). Collecting and distributing germplasm was also frequently reported for all target species. For *Lindera benzoin* and *Sassafras albidum*, the conservation activity most frequently identified as most urgent was to protect and/or manage habitat, while research was the highest priority for the *Persea* species. The threats frequently identified as the most significant varied among species, but pests or pathogens and invasive species competition were identified as important for the majority of target species (Figure 11). Reported activities are all in line with the needs for selected native U.S. Lauraceae species, other than the need for increased research, especially focused on laurel wilt, species distributions, and climate impacts; it is also likely that more activities have been initiated since the survey was conducted.

Overall summary and recommendations: Native U.S. Lauraceae species face significant threat from laurel wilt disease. *Persea* species are highly susceptible and within the pathogen's current distribution, but other species in the Lauraceae family have been shown to be affected and within the potential range of laurel wilt. Time will reveal the full effect of laurel wilt toward *Lindera* and *Sassafras*, but continued monitoring of unaffected areas, research of disease resistance, and collection of wild material for *ex situ* protection could help mitigate the impact. As Kendra et al. (2014) states, "it is apparent that a holistic approach is warranted for disease management, which will require a better understanding of the complex ecological and physiological interactions that occur among the insect vector(s), its fungal symbiont, and susceptible host trees."

CONCLUSIONS & RECOMMENDATIONS

Bates, C. (2020). *Distribution of Counties with Laurel Wilt*. Georgia Forestry Commision and the USDA Forest Service. Retrieved from http://southernforesthealth.net/diseases/laurel-wilt/distribution-map

Beckman, E., Meyer, A., Denvir, A., Gill, D., Man, G., Pivorunas, D., Shaw, K., & Westwood, M. (2019). *Conservation Gap Analysis of Native U.S. Oaks*. Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/conservation-gap-analysis-of-native-US-oaks.pdf

Best, G. S., & Fraedrich, S. W. (2018). An Assessment of the Potential Impact of Laurel Wilt on Clonal Populations of *Lindera melissifolia* (Pondberry). *Southeastern Naturalist*, 17(4), 616-628. Retrieved from https://doi.org/10.1656/058.017.0409

Bonner, F. T. & Karrfalt, R. P. (Eds.) (2008). *The Woody Plant Seed Manual*. Agricultural Handbook No. 727. Washington, DC: U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.fed.us/rm/pubs_series/wo/wo_ah727.pdf

Cameron, R. A., Hanula, J., Fraedrich, S., & Bates, C. (2015). Progression and Impact of Laurel Wilt Disease within Redbay and Sassafras Populations in Southeast Georgia. *Southern Naturalist*, 14(4), 650–674. Retrieved from http://www.bioone.org/doi/full/10.1656/058.014.0408

Chamberlain, S. & Boettiger C. (2017). R Python, and Ruby clients for GBIF species occurrence data. *PeerJ PrePrints*. Retrieved from https://doi.org/10.7287/peerj.preprints.3304v1.

CPC (Center for Plant Conservation). (2018). *Best plant conservation practices to support species survival in the wild.* The Center for Plant Conservation.

Data Portal. (2020). Retrieved from http://sernecportal.org/index.php.

de Castro, A. I., Ehsani, R., Ploetz, R. C., Crane, J. H., & Buchanon, S. (2015). Detection of Laurel Wilt Disease in Avocado Using Low Altitude Aerial Imaging. *Plos One, 10*(4). doi: 10.1371/journal.pone.0124642

Evans, J. P., Scheffers, B. R. & Hess, M. (2014). Effect of laurel wilt invasion on redbay populations in a maritime forest community. *Biological Invasions*, 16(8), 1581-1588. Retrieved from https://doi.org/10.1007/s10530-013-0592-y

Forest Inventory and Analysis Database (2019). St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station. Retrieved from https://apps.fs.usda.gov/fia/datamart/datamart.html

Flora of North America Editorial Committee (Eds). (1997). *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.

Fraedrich, S. (2019). *Raffaelea lauricola* (laurel wilt). Centre for Agriculture and Bioscience International (CABI), Invasive Species Compendium. Retrieved from https://www.cabi.org/isc/datasheet/109424.

Fraedrich, S. W., Harrington, T. C., Bates, C. A., Johnson, J., Reid, L. S., Best, G. S. . . . Hawkins, T. S. (2011). Susceptibility to laurel wilt and disease incidence in two rare plant species, pondberry and pondspice. *Plant Disease*, 95(9), 1056-1062. doi:10.1094 / PDIS-11-10-0841

GBIF.org (23 September 2020). GBIF Occurrence Download. https://doi.org/10.15468/dl.hdjwfz

Gilman, E. F., Watson, D. G., Klein, R. W., Koeser, A. K., Hilbert, D. R., & McLean, D. C. (2018). *Persea borbonia: Redbay*. University of Florida, IFAS Extension, Environmental Horticulture Department. Retrieved from https://edis.ifas.ufl.edu/st436

Gordon, K. L. (2020). Plant of the Week: Bog Spicebush (*Lindera subcoriacea* B.E. Wofford). USDA Forest Service. Retrieved from https://www.fs.fed.us/wildflowers/plant-of-the-week/lindera_subcoriacea.shtml

Gramling, J. M. (2010). Potential Effects of Laurel Wilt on the Flora of North America. *Southeastern Naturalist* 9(4), 827-836. Retrieved from https://doi.org/10.1656/058.009.0417

Graul, C. (2016). leafletR: Interactive Web-Maps Based on the Leaflet JavaScript Library. R package version 0.4-0. Retrieved from http://cran.r-project.org/package=leafletR.

Hanson, J. O., Rhodes, J. R., Riginos, C., & Fuller, R. A. (2017). Environmental and geographic variables are effective surrogates for genetic variation in conservation planning. *Proceedings of the National Academy of Sciences,114*(48), 12755-12760. doi:10.1073/pnas.1711009114

Hayden, W. J. (2006). *VNPS Wildflower of the Year 2006: Spicebush, Lindera benzoin*. Virginia Native Plant Society. Retrieved from https://vnps.org/wp-content/uploads/2013/09/woy2006_lindera.pdf

Hughes, M. A., Riggins, J. J., Koch, F. H., Cognato, A. I., Anderson, C., Formby, J. P., . . . Smith, J. A. (2017). No rest for the laurels: symbiotic invaders cause unprecedented damage to southern USA forests. *Biological Invasions*. doi: 10.1007/s10530-017-1427-z

Hughes, M. C., Smith, J. A., & Coyle, D. R. (2016). *Biology, Ecology, and Management of Laurel Wilt and the Redbay Ambrosia Beetle*. Southern Regional Extension Forestry. Retrieved from https://sref.info/resources/publications/biology-ecology-and-management-of-laurel-wilt-and-the-redbay-ambrosia-beetle/at_download/file

Hughes, M. A., & Smith, J. A. (2014). Vegetative propagation of putatively laurel wilt-resistant redbay (*Persea borbonia*). *Native Plants Journal*, 15(1), 42–50. doi: 10.3368/npj.15.1.42

Hughes, M. A., Smith, J. A., Ploetz, R. C., Kendra, P. E., Mayfield III, A. E., Hanula, J. L., . . . Permas, T. (2015). Recovery Plan for Laurel Wilt on Redbay and Other Forest Species Caused by *Raffaelea lauricola* and Disseminated by *Xyleborus glabratus*. Plant Health Progress, 16(4), 173-210. doi: 10.1094/PHP-RP-15-0017.

IUCN. (2020). The IUCN Red List of Threatened Species. Version 2020-2. Retrieved July, 2020 from https://www.iucnredlist.org.

Kartesz, J. T. (2018). The Biota of North America Program (BONAP). Taxonomic Data Center, Floristic Synthesis of North America, Version 1.0. Chapel Hill, NC. Retrieved from http://www.bonap.net/tdc

Kendra, P. E., Montgomery, W. S., Niogret, J., Pruett, G. E., Mayfield, A. E., Mackenzie, M., . . . Epsky, N. D. (2014). North American Lauraceae: Terpenoid Emissions, Relative Attraction and Boring Preferences of Redbay Ambrosia Beetle, *Xyleborus glabratus* (Coleoptera: Curculionidae: Scolytinae). *PLoS ONE*, 9(7). doi: 10.1371/journal.pone.0102086

Khoury, C. K., Carver, D., Barchenger, D. W., Barboza, G. E., Van Zonneveld, M., Jarret, R., . . . Greene, S. L. (2019). Modelled distributions and conservation status of the wild relatives of chile peppers (Capsicum L.). *Diversity and Distributions*, 26(2). doi:https://doi.org/10.1111/ddi.13008

Khoury, C. K., Heider, B., Castañeda-Álvarez, N. P., Achicanoy, H. A., Sosa, C. C., Miller, R. E., . . . Struik, P. C. (2015). Distributions, *ex situ* conservation priorities, and genetic resource potential of crop wild relatives of sweetpotato [Ipomoea batatas (L.) Lam., I. series Batatas]. *Frontiers in Plant Science*, 6. doi:10.3389/fpls.2015.00251

Krist Jr., F.J., Ellenwood, J.R., Woods, M.E., McMahan, A.J., Cowardin, J.P., Ryerson, D.E., . . . Romero, S.A. (2014). 2013 – 2027 National Insect and Disease Forest Risk Assessment. USDA Forest Service, Forest Health Protection, Forest Health Technology Enterprise Team. Retrieved from https://www.fs.fed.us/foresthealth/technology/pdfs/2012_RiskMap_Report_web.pdf

Lockhart, B.R. (2016). *Silvicultural treatments to improve pondberry stem length growth*. In: Schweitzer, C. J., Clatterbuck, W. K., Oswalt, C. M. (Eds). (2016). Proceedings of the 18th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–212. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

Maitner, B. (2020). BIEN: Tools for Accessing the Botanical Information and Ecology Network Database. R package version 1.2.4. https://CRAN.R-project.org/package=BIEN.

Menges, E. S., Abrahamson, W. G., Givens, K. T., Gallo, N. P., & Layne, J. N. (1993). Twenty Years of Vegetation Change in Five Long-Unburned Florida Plant Communities. *Journal of Vegetation Science*, 4(3), 375–386. Retrieved from https://www.jstor.org/stable/3235596

Michonneau, F. & Collins, M. (2017). ridigbio: Interface to the iDigBio Data API. R package version 0.3.5. Retrieved from https://CRAN.R-project.org/package=ridigbio.

Hamel, P., McCown, D. D., Connor, K. (2007). Micropropagation of the Endangered Shrub Pondberry (Lindera melissifolia [Walt.] Blume). *HortScience*, 42(2), 407-409.

Missouri Botanical Garden. (2018). Plant Finder. Retrieved from http://www.missouribotanicalgarden.org/plantfinder/plantfindersearch.aspx

N.C. Cooperative Extension. (2020). The North Carolina Extension Gardener Plant Toolbox. Retrieved from https://plants.ces.ncsu.edu

Naples Botanical Garden. (2018). Conserving Florida's native plants. Retrieved from https://www.naplesgarden.org/education/conservation/

Potter, K. M., Crane, B. S., & Hargrove, W. W. (2017). A United States national prioritization framework for tree species vulnerability to climate change. *New Forests*, 48(2), 275–300. doi: 10.1007/s11056-017-9569-5

Potter, K. M., Escanferla, M. E., Jetton, R. M., & Man, G. (2019a). Important Insect and Disease Threats to United States Tree Species and Geographic Patterns of Their Potential Impacts. *Forests*, 10(4), 304. doi: 10.3390/f10040304

Potter, K. M., Escanferla, M. E., Jetton, R. M., Man, G., & Crane, B. S. (2019b). Prioritizing the conservation needs of United States tree species: Evaluating vulnerability to forest insect and disease threats. *Global Ecology and Conservation, 18*. doi: 10.1016/j.gecco.2019.e00622

Randolph, K. C. (2017). Status of *Sassafras albidum* (Nutt.) Nees in the Presence of Laurel Wilt Disease and Throughout the Eastern United States. *Southeastern Naturalist*, 16(1), 37–58. doi: 10.1656/058.016.0104

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from https://www.R-project.org/.

Royal Botanic Gardens Kew. (2020). Seed Information Database (SID). Version 7.1. Retrieved from http://data.kew.org/sid/

Shearman, T. M., Wang, G. G., & Bridges, W. C. (2014). Population dynamics of redbay (*Persea borbonia*) after laurel wilt disease: an assessment based on forest inventory and analysis data. *Biological Invasions*, 17(5), 1371–1382. doi: 10.1007/s10530-014-0799-6

Shields, J., Jose, S., Freeman, J., Bunyan, M., Celis, G., Hagan, D., . . . Zak, J. (2011). Short-term impacts of laurel wilt on redbay (*Persea borbonia* [L.] Spreng.) in a mixed evergreen-deciduous forest in northern Florida. *Journal of Forestry*, 109(2), 82-88.

Snyder, J. R. (2014). *Ecological implications of Laurel Wilt infestation on Everglades Tree Islands*, *southern Florida*. U.S. Geological Survey Open-File Report 2014-1225. Retrieved from http://dx.doi.org/10.3133/ofr20141225

Spiegel, K. S. & Leege, L. M. (2013). Impacts of laurel wilt disease on redbay (*Persea borbonia* (L.) Spreng.) population structure and forest communities in the coastal plain of Georgia, USA. *Biological Invasions*, 15(11), 2467-2487. Retrieved from https://doi.org/10.1007/s10530-013-0467-2

Sullivan, J. (1993). Sassafras albidum. In *Fire Effects Information System*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from https://www.fs.fed.us/database/feis/plants/tree/sasalb/all.html

U.S. EPA Office of Research & Development. (2013a). Level III Ecoregions of the conterminous United States. National Health and Environmental Effects Research Laboratory (NHEERL). Retrieved from ftp://ftp.epa.gov/wed/ecoregions/us/us_eco_l3.zip

U.S. EPA Office of Research & Development. (2013b). Level IV Ecoregions of the conterminous United States. National Health and Environmental Effects Research Laboratory (NHEERL). Retrieved from ftp://ftp.epa.gov/wed/ecoregions/us/us_eco_l4.zip

USDA Forest Service (2017). New research sheds light on fate of the imperiled pondberry plant. Retrieved from https://www.fs.fed.us/research/highlights/highlights_display.php?in_high_id=1301

USDA, NRCS. (2018). The PLANTS Database. National Plant Data Team. Greensboro, NC. Retrieved from http://plants.usda.gov

USGS. (2019). Biodiversity Information Serving Our Nation (BISON) -- Species occurrence data for the Nation. U.S. Geological Survey General Information Product 160, version 1.1., U.S. Geological Survey, 2015. Retrieved from https://doi.org/10.3133/gip160.

Van Deelen, T. R. (1991). Persea borbonia. In *Fire Effects Information System*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from https://www.fs.fed.us/database/feis/plants/tree/perbor/all.html

Walters, C, & Pence, V. C. (2020). The unique role of seed banking and cryobiotechnologies in plant conservation. *Plants, People, Planet*, 3, 83–91. Retrieved from https://doi.org/10.1002/ppp3.10121

Wunderlin, R. P., Hansen, B. F., Franck, A. R., & Essig, F. B. (2020). *Atlas of Florida Plants* [S. M. Landry and K. N. Campbell (application development), USF Water Institute.] Tampa, FL: Institute for Systematic Botany, University of South Florida. Retrieved from http://florida.plantatlas.usf.edu/

Zizka, A., Silvestro, D., Andermann, T., Azevedo, J., Duarte Ritter, C., Edler, D., . . . Antonelli, A. (2019). CoordinateCleaner: Standardized cleaning of occurrence records from biological collection databases. *Methods in Ecology and Evolution*, 10(5), 744-751. doi:https://doi.org/10.1111/2041-210X.13152

APPENDIX A. LIST OF PARTICIPANTS

Institutional participants in the 2018 *ex situ* collections survey:

Agro-Botanical Garden of USAMV Cluj-Napoca • Antony Woodland Garden • Arboretum Bramy Morawskiej w Raciborzu • Arboretum Bukovina • Arboretum Kirchberg, Musée national d'histoire naturelle • Arboretum National des Barres • Arboretum w Przelewicach • Arboretum Wespelaar, Foundation • Arboretum Wojslawice, University of Wroclaw • Arizona-Sonora Desert Museum • Arnold Arboretum of Harvard University, The • Atlanta Botanical Garden • Auckland Botanic Gardens • Bamboo Brook Outdoor Education Center • Bartlett Tree Research Laboratories Arboretum • Bayard Cutting Arboretum • Beal Botanical Gardens, W. J. • Bedgebury National Pinetum and Forest • Belmonte Arboretum • Bergius Botanic Garden, Stockholm University • Bessey Nursery, Nebraska National Forests and Grasslands • Boerner Botanical Gardens • Bok Tower Gardens • Botanic Garden Meise • Botanic garden of Le Havre, Ville du Havre • Botanic Garden of Smith College, The • Botanic Gardens of South Australia • Botanischer Garten der Philipps-Universität Marburg • Brenton Arboretum, The • Brookgreen Gardens • Brooklyn Botanic Garden • Bureau of Land Management, Prineville District • Cheryl Kearns, private garden • Chicago Botanic Garden • Cornell Botanic Gardens • Cox Arboretum • Darts Hill Garden Park • Davis Arboretum of Auburn University • Dawes Arboretum, The • Denver Botanic Gardens • Dunedin Botanic Garden • Eastwoodhill Arboretum • Eddy Arboretum, Pacific Southwest Research Station Placerville, The Institute of Forest Genetics (IFG) • Eden Project • Estancia San Miguel • Fairchild Tropical Botanic Garden • Finnish Museum of Natural History LUOMUS • Frelinghuysen Arboretum • Ghent University Botanical Garden • Green Bay Botanical Garden • Green Spring Gardens • GRIN Database, National Plant Germplasm System (NPGS) • Hackfalls Arboretum • Holden Forests & Gardens (Cleveland Botanical Garden and The Holden Arboretum) • Hollard Gardens • Honolulu Botanical Gardens System • Hørsholm Arboretum • Hoyt Arboretum • Huntington, The • Ioulia & Alexandros Diomidis Botanical Garden • Jardin Botanique de l'Université de Strasbourg • Jardin botanique de Montréal • JC Raulston Arboretum • Keith Arboretum, The Charles R. • Key West Tropical Forest and Botanical Garden • Linnaean Gardens of Uppsala, The • Longwood Gardens • Lovett Pinetum • Lyon Arboretum & Botanical Garden of the University of Hawaii • Marie Selby Botanical Gardens • Mercer Botanic Gardens • Millennium Seed Bank Partnership, Royal Botanic Gardens Kew • Missouri Botanical Garden • Montgomery Botanical Center • Morris Arboretum of the University of Pennsylvania, The • Morton Arboretum, The • Moscow State University Botanical Garden Arboretum • Mount Auburn Cemetery • Mt. Cuba Center, Inc. • Muséum national d'Histoire naturelle, Paris • Naples Botanic Garden • National Tropical Botanical Garden • NDSU Dale E. Herman Research Arboretum, Woody Plant Improvement Program • New York Botanical Garden • Norfolk Botanical Garden • North Carolina Arboretum, The • Orto Botanico dell'Università degli studi di Siena • Orto Botanico dell'Universita della Calabria • Peckerwood Garden • Pinetum Blijdenstein • Polly Hill Arboretum, The • Powell Gardens • Pukeiti • Pukekura Park • Rancho Santa Ana Botanic Garden • Real Jardín Botánico Juan Carlos I • Red Butte Garden, The University of Utah • Reiman Gardens, Iowa State University • Rogów Arboretum of Warsaw University of Life Sciences • Royal Botanic Garden Edinburgh • Royal Botanic Gardens Kew, Wakehurst Place • Royal Botanic Gardens Ontario • Royal Botanic Gardens Victoria • Royal Horticultural Society Garden, Wisley • Smale Riverfront Park • Starhill Forest Arboretum • State Botanical Garden of Georgia, University of Georgia • State Botanical Garden of Kentucky, The Arboretum • Stavanger Botanic Garden • Tasmanian Arboretum Inc., The • Timaru Botanic Garden • Tucson Botanical Gardens • Tyler Arboretum • U.S. National Arboretum • UBC Botanical Garden, The University of British Columbia • UC Davis Arboretum and Public Garden • University of California Botanical Garden at Berkeley • University of Connecticut Arboretum • University of Delaware Botanic Gardens • University of Florida/IFAS, North Florida Research and Education Center, Gardens of the Big Bend • University of Guelph Arboretum • University of Washington Botanic Gardens • USFS Brownwood Provenance Orchard • USFS western white pine, sugar pine, and whitebark pine seed orchards in OR and WA • Utrecht University Botanic Garden • Vallarta Botanical Gardens A. C. • VanDusen Botanical Garden • Village of Riverside, Illinois • Waimea Valley Botanical Garden • Wellington Botanical Gardens • Westonbirt, The National Arboretum • Willowwood Arboretum • Winona State University, The Landscape Arboretum at • Xishuangbanna Tropical Botanical Garden (XTBG) of Chinese Academy of Sciences (CAS) • Zoo and BG Plzen

Sassafras albidum (Ed Hedborn, The Morton Arboretum)

Lindera benzoin (Deb brown, The Morton Arboretum)

Institutional participants in the 2019 Tree Conservation Action Questionnaire:

Adkins Arboretum • Agnes Scott College • Aldrich Berry Farm & Nursery, Inc • Alpha Nurseries, Inc • American Chestnut Foundation, The • American University • Arboretum des Grands Murcins • Arboretum Kalmthout • Arboretum San Miguel • Arboretum Wespelaar • Arkansas Natural Heritage Commission • Atlanta Botanical Garden • Auckland Botanic Gardens • Baker Arboretum • Bartlett Tree Research Lab & Arboretum • Bayard Cutting Arboretum • Bergius Botanic Garden • Bernheim Arboretum and Research Forest • Better Forest Tree Seeds • Blue Mountains Botanic Garden, The • Boehm's Garden Center • Boerner Botanical Gardens • Bok Tower Gardens • Borderlands Restoration Network • Botanic Garden of Smith College • Botanic Garden TU Delft • Botanical Garden of the University of Turku • Bowman's Hill Wildflower Preserve • Brenton Arboretum, The • Brookgreen Gardens • Brooklyn Botanic Garden • California Department of Fish and Wildlife • California Native Plant Society • Catawba Lands Conservancy • Chatham University Arboretum • Chicago Botanic Garden • Cincinnati Zoo & Botanical Garden • City of Columbia Stephens Lake Park Arboretum • City of Hamilton • City of Kansas City, Missouri • Colonial Williamsburg Foundation • Connecticut College Arboretum • Cowichan Lake Research Station • Cox Arboretum and Gardens • David Listerman & Associates, Inc • Dawes Arboretum, The • Delaware Division of Fish and Wildlife • Denver Botanic Gardens • Donald E. Davis Arboretum at Auburn University • Downtown Lincoln Association • Draves Arboretum • Dunedin Botanic Garden • Dunn School • Earth Tones Natives • Ed Leuck Louisiana Academic Arboretum, The • Eden Project • Elmhurst College • Evergreen Burial Park and Arboretum • Excelsior Wellness Center • Fairchild Tropical Botanic Garden • Farmingdale State College • Florida Fish and Wildlife Conservation Commission • Florida Forest Service • Florida Natural Areas Inventory • Folmer Botanical Gardens • Frostburg State University • Georgia Department of Natural Resources • Green Bay Botanical Garden • Growild, Inc • Hackfalls Arboretum • Hastings College • Hazel Crest Open Lands • Holden Forests and Gardens • Huntington, The • Illinois Department of Natural Resources Mason State Nursery • Indiana Native Plant Society • Jane E. Lytle Memorial Arboretum • Jardin Botanique de Paris, Arboretum de Paris • John F. Kennedy Arboretum • Johnson's Nursery, Inc. • Keefer Ecological Services Ltd. • L.E. Cooke Co • Lauritzen Gardens • Le Jardin du Lautaret de la Station alpine Joseph Fourier • Longfellow Arboretum • Longwood Gardens • Louisiana Department of Wildlife and Fisheries • Lovell Quinta Arboretum, The • Maryland Department of Natural Resources • McKeithen Growers, Inc. • Meadow Beauty Nursery • Michigan Natural Features Inventory • Mill Creek MetroParks, Fellows Riverside Gardens • Minnesota Department of Natural Resources • Minnesota Natural Resources Commission • Missouri Arboretum • Missouri Native Plant Society • Missouri State University • Montgomery Botanical Center • Morris Arboretum • Moscow State University Botanical Garden • Mt. Cuba Center • Mt. Desert Land & Garden Preserve • Muscatine Arboretum • Naples Botanical Garden • National Botanical Garden of Georgia • Native Plant Society of Oregon • Native Plant Trust • Natural Resources Canada • Nature Conservancy, The • New College of Florida • New Jersey Audubon • New York Botanical Garden, The • New York City Department of Parks & Recreation • New York Natural Heritage Program • Norfolk Botanical Garden • North Carolina Natural Heritage Program • North Dakota State University • Parque Botânico da Tapada da Ajuda • Peaceful Heritage Nursery • Peckerwood Garden • Pennsylvania Department of Conservation & Natural Resources • Pennsylvania Natural Heritage Program • Pizzo Group • Polly Hill Arboretum, The • Powell Gardens • Pronatura Veracruz • R.L. McGregor Herbarium • Rancho Santa Ana Botanic Garden • Reeseville Ridge Nursery • Regional Parks Botanic Garden • Reveg Edge, The • Rogów Arboretum of Warsaw University of Life Sciences • Royal Botanic Garden Edinburgh • Royal Botanic Gardens Victoria • San Diego Botanic Garden • Santa Barbara Botanic Garden • Sidmouth Civic Arboretum • Sister Mary Grace Burns Arboretum at Georgian Court University • Smith Gilbert • Smithsonian • Springfield-Greene County Parks • Starhill Forest Arboretum • State Botanical Garden of Kentucky, The Arboretum • Strasbourg University Botanic Garden • Tasmanian Arboretum, The • Tennessee Division of Natural Areas • Texas A&M Forest Service • Tower Grove Park • Town of Winthrop • Tree Musketeers • Tucson Botanical Gardens • Twin Peaks Native Plant Nursery • UC Davis Arboretum and Public Garden • United States Botanic Garden • United States Fish and Wildlife Service • United States National Arboretum • University of California • University of California Botanical Garden at Berkeley • University of Florida North Florida Research and Education Center • University of Guelph Arboretum • University of Leicester Botanic Garden • University of Maribor Botanic Garden • University of Minnesota • University of Notre Dame • University of Oklahoma • University of Washington Botanic Gardens • USDA Agricultural Research Service • USDA Forest Service • USDI Bureau of Land Management • VanDusen Botanical Garden • Vietnam National University of Forestry • Village of Bensenville • Village of Riverside • West Virginia Native Plant Society • West Virginia Wesleyan College • Westonbirt, The National Arboretum • Wilson Seed Farms, Inc • Woodland Park Zoo • WRD Environmental, Inc. • Wright Nursery Alberta • Yellowstone Arboretum

Lindera benzoin (Susan McDougall)

Persea borbonia (Daderot)

APPENDIX B. RESULTS FROM THE 2019 TREE CONSERVATION ACTION QUESTIONNAIRE

To receive contact information for a specific respondent and target species, please email treeconservation@mortonarb.org.

Species	Institution reporting conservation activities	Country (U.S. state)	Collect and distribute germplasm	Implement protection policies or regulations	Occurrence surveys or population monitoring	Population reinforcement or introduction	Protect and/or manage habitat	Public awareness or education	Research (e.g., genetics, climate change, pests)
Lindera benzoin	Adkins Arboretum[1]	United States (MD)			X		X	X	
	Alpha Nurseries, Inc[8]	United States (MI)	X						
	Arkansas Natural Heritage Commission[6]	United States (AR)					X	X	
	Bayard Cutting Arboretum[1]	United States (NY)				X	X		
	Bergius Botanic Garden[1]	Sweden		X					
	Bernheim Arboretum and Research Forest[1]	United States (KY)	X				X		
	Boehm's Garden Center[8]	United States (IL)	X					X	
	Botanical Garden of the University of Turku[1]	Finland						X	
	Bowman's Hill Wildflower Preserve[1]	United States (PA)	X			X	X		
	Brooklyn Botanic Garden[1]	United States (NY)	X					X	
	Catawba Lands Conservancy[4]	United States (NC)					X		
	City of Columbia Stephens Lake Park Arboretum[2]	United States (MO)	X					X	
	Denver Botanic Gardens[1]	United States (CO)	X						
	Donald E. Davis Arboretum at Auburn University[1]	United States (AL)	X	X	X	X	X	X	
	Draves Arboretum[1]	United States (NY)				X		X	
	Elmhurst College[9]	United States (IL)					X	X	
	Folmer Botanical Gardens[1]	Canada				X			
	Growild, Inc[8]	United States (TN)	X					X	
	Holden Forests and Gardens[1]	United States (OH)	X				X		
	Indiana Native Plant Society, Southwest Chapter[5]	United States (IN)						X	
	Jane E. Lytle Memorial Arboretum[1]	United States (NY)					X	X	
	Louisiana Department of Wildlife and Fisheries[6]	United States (LA)					X		
	Michigan Natural Features Inventory[6]	United States (MI)			X		X		
	Missouri Native Plant Society, Hawthorn Chapter[5]	United States (MO)	X			X		X	
	New York Botanical Garden, The[1]	United States (NY)				X	X	X	
	New York City Department of Parks & Recreation[2]	United States (NY)	X		X	X	X	X	
	Peaceful Heritage Nursery[8]	United States (KY)	X						
	Peckerwood Garden[1]	United States (TX)	X		X			X	
	Pennsylvania Natural Heritage Program, Western Pennsylvania Conservancy[6]	United States (PA)					X		
	Pizzo Group[8]	United States (IL)	X	X		X	X	X	
	R.L. McGregor Herbarium[9]	United States (KS)			X				
	Rogów Arboretum of Warsaw University of Life Sciences[1]	Poland	X						
	Royal Botanic Garden Edinburgh[1]	United Kingdom	X					X	
	Sister Mary Grace Burns Arboretum at Georgian Court University[1]	United States (NJ)						X	
	Smithsonian[3]	United States (VA)			X		X		X
	Springfield-Greene County Parks[1]	United States (MO)						X	
	Strasbourg University Botanic Garden[1]	France						X	
	United States Fish and Wildlife Service, Clarks River National Wildlife Refuge[3]	United States (KY)					X	X	
	United States Fish and Wildlife Service[3]	United States (MO)					X		
	University of Guelph Arboretum[1]	Canada	X					X	
	University of Leicester Botanic Garden[9]	United Kingdom						X	

Species	Institution reporting conservation activities	Country (U.S. state)	Collect and distribute germplasm	Implement protection policies or regulations	Occurrence surveys or population monitoring	Population reinforcement or introduction	Protect and/or manage habitat	Public awareness or education	Research (e.g., genetics, climate change, pests)
Lindera benzoin	University of Maribor Botanic Garden[1]	Slovenia						X	
	University of Oklahoma[9]	United States (OK)			X				
	West Virginia Wesleyan College[9]	United States (WV)				X	X	X	
	Westonbirt, The National Arboretum[1]	United Kingdom						X	X
	Name not shared[1]	Ireland	X					X	
	Name not shared[2]	United States (MA)			X	X	X		
	Name not shared[7]	United States (NJ)					X	X	
	Name not shared[2]	United States (PA)		X					
	Name not shared[7]	United States (VA)				X	X	X	
Persea borbonia	Arkansas Natural Heritage Commission[6]	United States (AR)						X	
	Donald E. Davis Arboretum at Auburn University[1]	United States (AL)	X					X	
	Georgia Department of Natural Resources[6]	United States (GA)					X	X	X
	Louisiana Department of Wildlife and Fisheries[6]	United States (LA)					X		
	Peckerwood Garden[1]	United States (TX)	X	X	X	X	X	X	X
	Westonbirt, The National Arboretum[1]	United Kingdom						X	X
	Name not shared[1]	United States (LA)			X				
Persea humilis	Delaware Division of Fish and Wildlife[6]	United States (DE)			X				
	Peckerwood Garden[1]	United States (TX)	X	X	X	X	X	X	X
	Westonbirt, The National Arboretum[1]	United Kingdom						X	X
Persea palustris	Donald E. Davis Arboretum at Auburn University[1]	United States (AL)	X					X	
	Georgia Department of Natural Resources[6]	United States (GA)					X	X	
	Louisiana Department of Wildlife and Fisheries[6]	United States (LA)					X		
	Maryland Department of Natural Resources[6]	United States (MD)			X		X		
	Naples Botanical Garden[1]	United States (FL)	X		X	X		X	
	Peckerwood Garden[1]	United States (TX)	X	X	X	X	X	X	X
	Westonbirt, The National Arboretum[1]	United Kingdom						X	X
Sassafras albidum	Adkins Arboretum[1]	United States (MD)			X		X	X	
	Alpha Nurseries, Inc[8]	United States (MI)	X						
	Arboretum San Miguel[1]	Argentina					X	X	
	Arkansas Natural Heritage Commission[6]	United States (AR)					X	X	
	Baker Arboretum[1]	United States (KY)			X				
	Bayard Cutting Arboretum[1]	United States (NY)				X	X		
	Blue Mountains Botanic Garden, The[1]	Australia	X						
	Boehm's Garden Center[8]	United States (IL)	X					X	
	Brooklyn Botanic Garden[1]	United States (NY)	X					X	
	Catawba Lands Conservancy[4]	United States (NC)					X		
	City of Columbia Stephens Lake Park Arboretum[2]	United States (MO)	X					X	
	City of Kansas City, Missouri[2]	United States (MO)				X			
	Connecticut College Arboretum[1]	United States (CT)			X				
	Cox Arboretum and Gardens[1]	United States (GA)					X		
	Denver Botanic Gardens[1]	United States (CO)	X						
	Donald E. Davis Arboretum at Auburn University[1]	United States (AL)	X					X	
	Downtown Lincoln Association[1]	United States (NE)	X						

Species	Institution reporting conservation activities	Country (U.S. state)	Collect and distribute germplasm	Implement protection policies or regulations	Occurrence surveys or population monitoring	Population reinforcement or introduction	Protect and/or manage habitat	Public awareness or education	Research (e.g., genetics, climate change, pests)
Sassafras albidum	Draves Arboretum[1]	United States (NY)				X		X	
	Frostburg State University[9]	United States (MD)	X				X	X	
	Growild, Inc[8]	United States (TN)	X					X	
	Holden Forests and Gardens[1]	United States (OH)	X				X		
	Indiana Native Plant Society, Southwest Chapter[5]	United States (IN)						X	
	Louisiana Department of Wildlife and Fisheries[6]	United States (LA)					X		
	Missouri Arboretum[1]	United States (MO)			X			X	
	Morris Arboretum[1]	United States (PA)					X		
	New York Botanical Garden, The[1]	United States (NY)				X	X	X	
	New York City Department of Parks & Recreation[2]	United States (NY)	X		X	X	X	X	
	Pennsylvania Natural Heritage Program, Western Pennsylvania Conservancy[6]	United States (PA)				X	X	X	
	Pizzo Group[8]	United States (IL)	X	X		X	X	X	
	Polly Hill Arboretum, The[1]	United States (MA)			X		X		
	R.L. McGregor Herbarium[9]	United States (KS)			X				
	Rogów Arboretum of Warsaw University of Life Sciences[1]	Poland	X						
	Royal Botanic Garden Edinburgh[1]	United Kingdom	X					X	
	Sister Mary Grace Burns Arboretum at Georgian Court University[1]	United States (NJ)					X	X	
	Smithsonian[3]	United States (VA)			X		X		X
	Springfield-Greene County Parks[1]	United States (MO)						X	
	Strasbourg University Botanic Garden[1]	France						X	
	United States Fish and Wildlife Service, Clarks River National Wildlife Refuge[3]	United States (KY)					X	X	
	University of Guelph Arboretum[1]	Canada			X			X	
	University of Maribor Botanic Garden[1]	Slovenia						X	
	University of Oklahoma[9]	United States (OK)			X				
	VanDusen Botanical Garden[1]	Canada						X	
	West Virginia Wesleyan College[9]	United States (WV)				X	X	X	
	Westonbirt, The National Arboretum[1]	United Kingdom						X	X
	Yellowstone Arboretum[1]	United States (MT)				X	X	X	
	Name not shared[1]	United States (LA)				X	X		
	Name not shared[2]	United States (MA)			X	X			
	Name not shared[7]	United States (NJ)					X	X	
	Name not shared[2]	United States (PA)		X					
	Name not shared[7]	United States (VA)					X	X	

Institution types

[1] Arboretum/botanical garden
[2] Government (local) [3] Government (national)
[4] Land conservancy [5] Native plant society
[6] Natural heritage program
[7] Other non-governmental organization
[8] Private sector [9] University

List of state abbreviations used in Appendix B

U.S. State	Abbreviation	U.S. State	Abbreviation	U.S. State	Abbreviation	U.S. State	Abbreviation
Alabama	AL	Indiana	IN	Mississippi	MS	Pennsylvania	PA
Arkansas	AR	Kansas	KS	North Carolina	NC	South Carolina	SC
Arizona	AZ	Kentucky	KY	North Dakota	ND	Tennessee	TN
California	CA	Louisiana	LA	New Jersey	NJ	Texas	TX
Colorado	CO	Massachusetts	MA	New Mexico	NM	Utah	UT
Florida	FL	Maryland	MD	New York	NY	Washington	WA
Georgia	GA	Michigan	MI	Ohio	OH		
Iowa	IA	Minnesota	MN	Oklahoma	OK		
Illinois	IL	Missouri	MO	Oregon	OR		

Conservation Gap Analysis of Selected Native

U.S. Laurels

For further information please contact:

The Morton Arboretum
4100 Illinois Route 53
Lisle, IL 60532
Tel: 630-968-0074
Fax: + 44 (0) 1223 461481
Email: treeconservation@mortonarb.org
Web: www.mortonarb.org

BGCI
Descanso House
199 Kew Road, Richmond
Surrey, TW9 3BW
United Kingdom
Tel: +44 (0)20 8332 5953
Fax: +44 (0)20 8332 5956
E-mail: info@bgci.org
Web: www.bgci.org

Front cover images:
Lindera benzoin (Ed Hedborn, The Morton Arboretum)
Persea borbonia (Daderot)
Persea humilis (Shirley Denton)
Persea palustris (Susan McDougall)
Sassafras albidum (Ed Hedborn, The Morton Arboretum)

Back cover image:
Persea palustris (Susan McDougall)

Design:
John Morgan. www.seascapedesign.co.uk