Conservation Gap Analysis of American Beech

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Fagus grandifolia Ehrh. (American beech)

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ACKNOWLEDGEMENTS

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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

Fagus grandifolia, or American beech, is a dominant tree in forests throughout the northeastern U.S. and Canada, including some distribution in the midwestern U.S., southeastern U.S. and eastern Mexico, making it one of the most widely distributed hardwoods in North America. It is also the only native member of the genus *Fagus* in the Americas and an important nut-producing tree, providing a vital food source for native wildlife. Due at least in part to its extensive distribution, American beech is a native component of a wide variety of forest types. In New England it is prominent in Beech-Sugar Maple, Sugar Maple-Beech-Yellow Birch, and Red Spruce-Sugar Maple-Beech forest cover types. Other major associated trees include Balsam fir in New England, Michigan, Wisconsin and Minnesota, oak and hickory in the northern central United States, and magnolias in the southeastern United States. American beech is very shade tolerant and, at maturity, creates significant shade; the result is a distinctively shaded forest floor that inhibits the establishment of less shade tolerant saplings (Ohio State University Extension, 2018; Stephanson & Coe, 2017). On the IUCN Red List of Threatened Species, *F. grandifolia* is assessed as Least Concern due to its broad distribution and since significant threats only affect specific populations (Barstow, 2017).

Fagus grandifolia (Tim Ross)

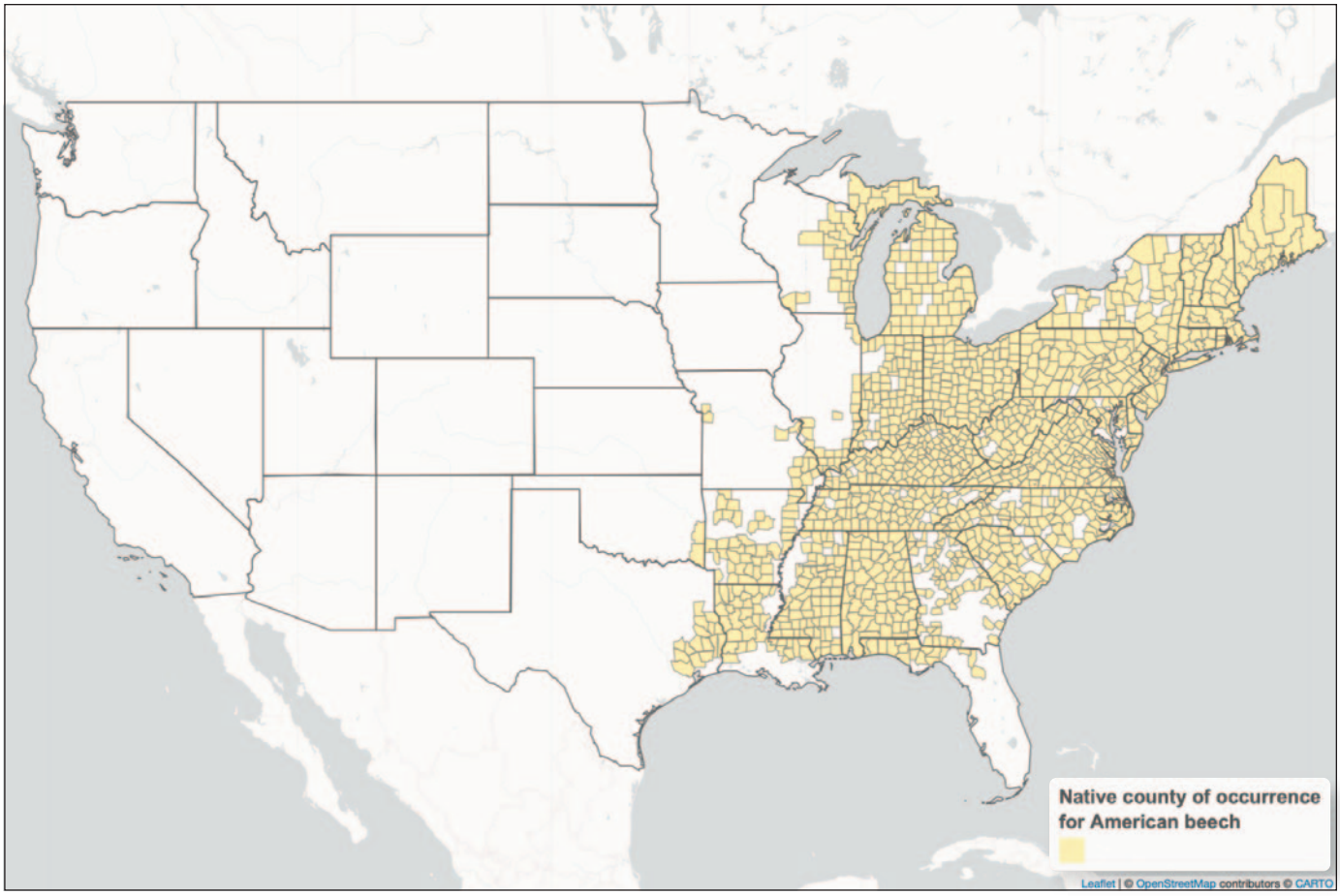

Figure 1. County level native distribution of *Fagus grandifolia* in the United States. County level distribution data from USDA PLANTS and Biota of North America Program (BONAP) have been combined to estimate species presence (Kartesz, 2018; USDA NRCS, 2018).

Fagus grandifolia (Plant Image Library)

Fagus grandifolia (Ed Hedborn, The Morton Arboretum)

PESTS & DISEASES

Beech bark disease (BBD) has devastated northeastern populations of American beech. The disease is caused by bark and tissue damage inflicted by beech scale insect (*Cryptococcus fagisuga*), followed by infection with several fungal species including *Neonectria faginata, Neonectria ditissima, and Bionectria ochroleuca*. Beech scale was unknowingly brought from Europe into Nova Scotia in the 1890s and spread from there. The disease is now well established in all beech-dominated forests in the U.S., though it occurs on less than 30% of American beech's full distribution. Within ten years, the disease kills about 50% of mature trees, sometimes more, and up to 90% of American beech trees eventually succumb. After mature *F. grandifolia* die, thickets of young, shade-tolerant American beech choke the forest floor and prevent regeneration of other tree species (Ohio State University Extension, 2018). Between one and three percent of *F. grandifolia* individuals are reported to be resistant to BBD, meaning they cannot be infected by beech scale (Stephanson & Coe, 2017). Using historical maps of the advancing presence of beech scale insects in North America, Morin et al. (2007) estimated the rate of spread to be about 15 km each year. Though, they point out that this estimate did not account for human-caused "jumps" by the beech scale insects to disjunct locations, and therefore the rate is a conservative estimate.

Over 70 species of decay fungi have been reported to infect American beech. Some of the most impactful agents include *Phellinus igniarius* (white spongy rot), *Ganoderma applanatum* (artist's conk), and *Armillaria* spp. (armillaria root disease). Other agents include *Daedalea unicolor, Fomes fomentarius, Hericium erinaceus*, *H. coralloides, Hypoxylon deustum, Steccherinum septentrionale*, and *Inonotus glomeratus* (Pijut, 2006).

Pathogenic species of *Armillaria* are located in most forested regions of North America, however their impacts vary greatly by species of *Armillaria*, host species, and site. In addition to American beech, primary hosts in the Northeast include oak, maple, beech, birch, aspen, balsam fir, spruce, and pine. Armillaria root disease infects stressed trees, often leading to declines caused by interacting agents. However, impacts to *F. grandifolia* are very rarely fatal (Lockman & Kearns, 2016).

The forest tent caterpillar, *Malacosoma disstria*, is the most widely distributed tent caterpillar native to North America and a significant defoliator of a wide variety of deciduous hardwood trees, including American beech. Its populations periodically reach outbreak levels, where huge numbers of caterpillars cause extensive defoliation. Even during outbreaks, though, trees are rarely killed. Severe and repeated defoliation can lead to dieback and/or reduced growth, which is sometimes significant (Meeker, 2001).

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., 2019) are provided in Table 1, to give an overview of the major pests and diseases affecting *Fagus grandifolia*. 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 beech bark disease are also provided below (Figures 2-3).

Table 1. The most serious insect, disease, and parasitic plant agents affecting *Fagus grandifolia*, from the results of Potter et al. (2019), which analyzed 419 native U.S. tree species. Numbers represent the severity of the agent's impact on the host species. * = nonnative invasive agent. Table adapted, with permission, from Potter et al. (2019).

Host species	Insect, Disease, or Parasitic Plant Agent				
	Armillaria root disease (*Armillaria spp.)*	Artist's conk (*Ganoderma applanatum)*	Beech bark disease (*Neonectria spp./ Cryptococcus fagisuga)**	Forest tent caterpillar (*Malacosoma disstria)*	White spongy rot (*Phellinus igniarius)*
Fagus grandifolia	1	1	8	1	3

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%)

Beech bark disease *(Nectria faginata)*

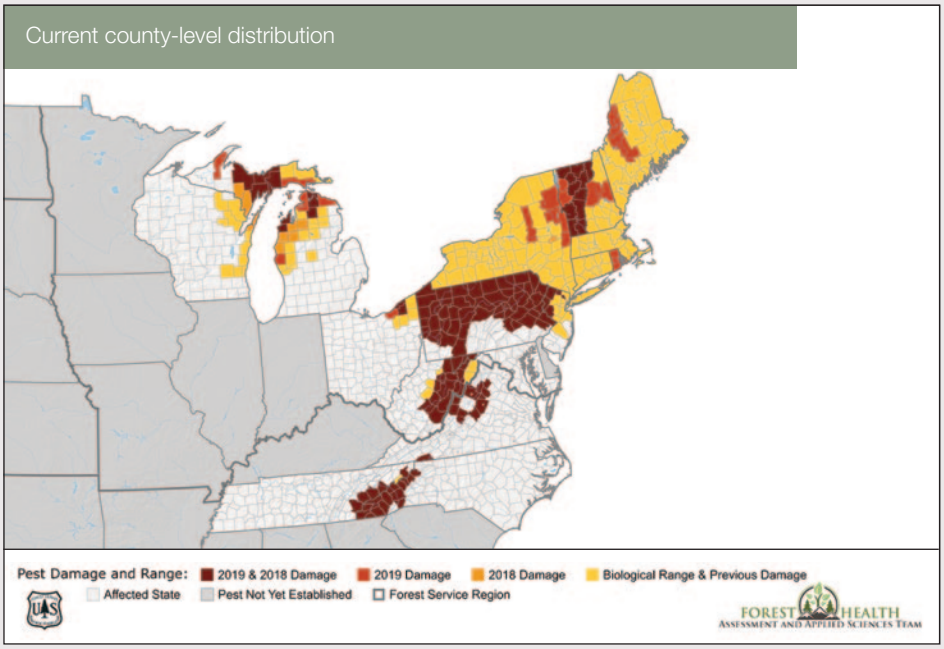

Figure 2. National Forest Damage Agent Range Map for beech bark disease (*Nectria faginata*), created by the USDA Forest Service, Forest Health Assessment and Applied Sciences Team. Data are "an integration of various sources, reviewed by regional authorities... intended to display the biological extent of major damage agents, or the range over which they have been a managerial concern" (USDA Forest Service, 2020).

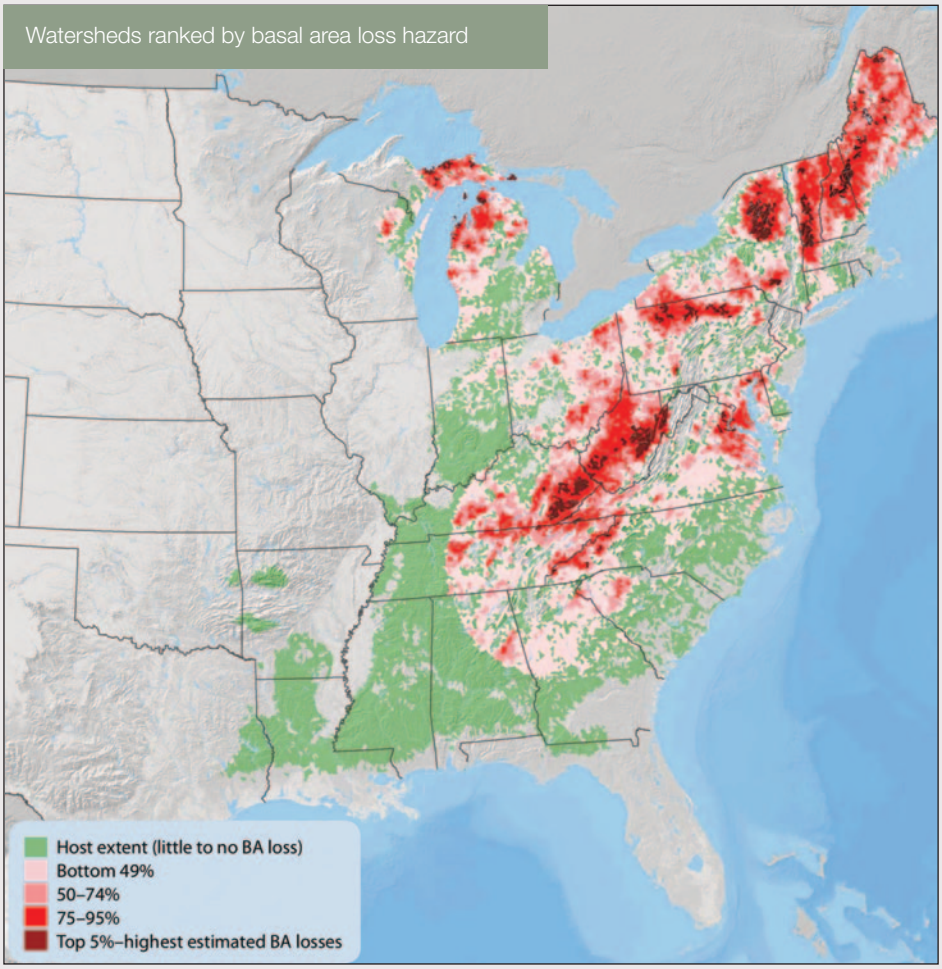

Figure 3. National Insect and Disease Risk Map quantifying the predicted impact of beech bark disease (*Nectria faginata*) on American beech by 2027. Green areas are predicted to have little to no loss, light red areas are predicted to have some loss, and dark red areas are predicted to have the most loss. This map was 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).

CLIMATE CHANGE VULNERABILITY

Climate change is another possible threat to *F. grandifolia*, due to expected fluctuations in precipitation. Compared to other broad-leaf trees, American beech is especially sensitive to both flooding and drought (Stephanson & Coe, 2017). However, a recent analysis of U.S. tree vulnerability to climate change, which factored in species-specific intrinsic traits to assess trees species' risk of negative effects from climate change, found American beech to have low current vulnerability to climate change (Potter et al., 2017). Predicted milder winters and less snowpack will also favor regeneration and survival of beech scale, so further monitoring and analysis will be necessary (Stephanson & Coe, 2017).

MAJOR CONSERVATION INITIATIVES

The USDA Forest Service Northern Research Station has developed methods to identify, breed, and propagate American beech trees that are resistant to beech scale. These methods include identifying scale-resistant American beech trees and establishing them in seed orchards. Genetic research has shown that about 50% of the seedlings produced from these orchards will inherit resistance to beech scale. Koch (2018) states that, "seeds produced in these seed orchards will be available to state and national forest managers for restoration of healthy American beech in areas decimated by beech bark disease."

Because current methods of identifying resistant trees take about a year, the USDA Forest Service, University of California at Davis, and Pennsylvania State University researchers have recently collaborated to identify genes associated with resistance, which could help expedite the screening process. The study compared frequencies of more than 3,000 genetic markers among 254 resistant trees and 260 susceptible trees collected from six different northeastern states and two Canadian provinces. Four markers, all within a single gene, were found to be associated with resistance. Further research regarding the candidate resistance gene may also provide insight into underlying mechanisms that allow specific trees to resist beech scale (Ćalić et al., 2017; Koch, 2017).

Fagus grandifolia (J. Kohout, The Morton Arboretum)

Fagus grandifolia (Fritzflohrreynolds)

EX SITU SURVEY RESULTS

Fagus grandifolia is considered exceptional, meaning its seeds cannot be stored long-term in conventional seed bank conditions of low temperature and moisture. Beech nuts were originally believed to be recalcitrant, but it has been discovered that carefully-controlled drying allows seeds to retain viability in a conventional seed bank for about five years (Bonner & Karrfalt, 2008). This is a relatively short amount of time in terms of practical storage in seed banks, therefore, other methods of long-term *ex situ* preservation are necessary for conserving genetic diversity, including living collections and new seed storage technologies such as cryopreservation (Walters & Pence, 2020).

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 *ex 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 78 collections from 15 countries reporting *Fagus grandifolia* (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 *Fagus* 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.

Fagus grandifolia (Plant Image Library)

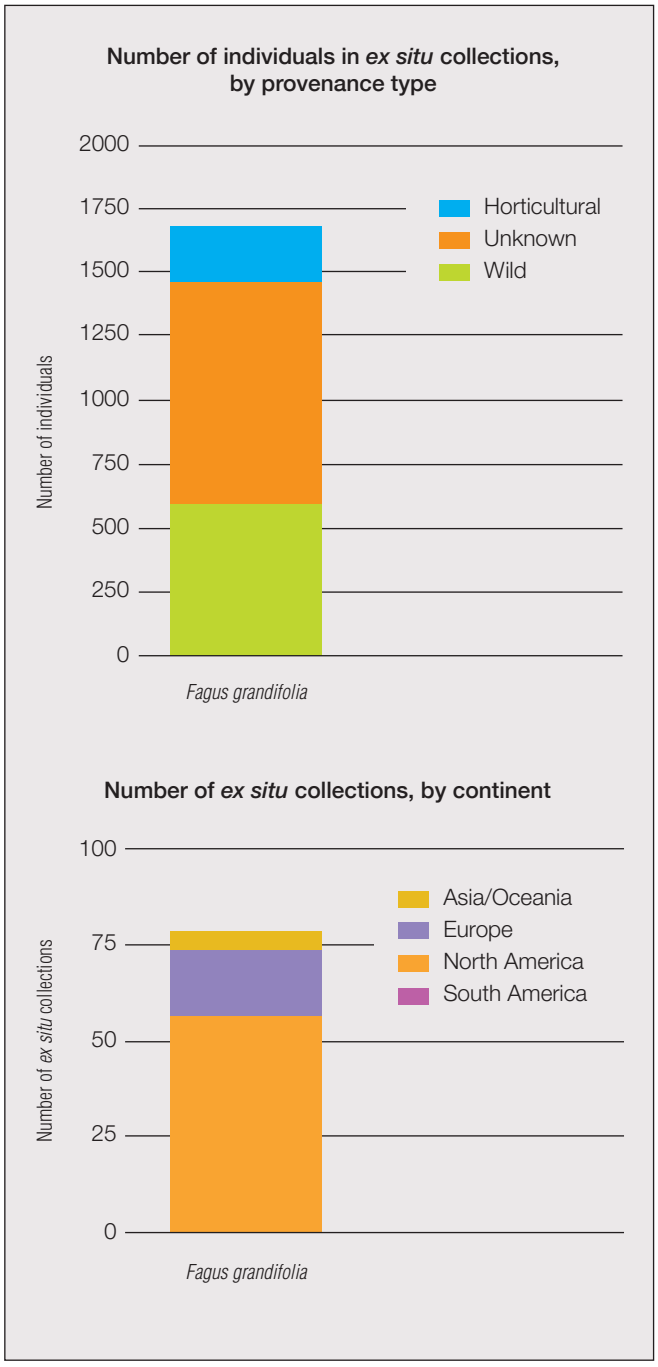

Figure 4. Results from a 2018 global accessions-level *ex situ* survey for *Fagus grandifolia.*

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 *F. grandifolia* 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 5-6; Table 2). 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.

In situ occurrence points for *F. grandifolia* 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 *F. grandifolia* 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.

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 *F. grandifolia*, about 22% of records with wild or unknown provenance were manually geolocated, while 16% had latitude and longitude provided by the institution and 62% 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).

Fagus grandifolia (Whit Andrews)

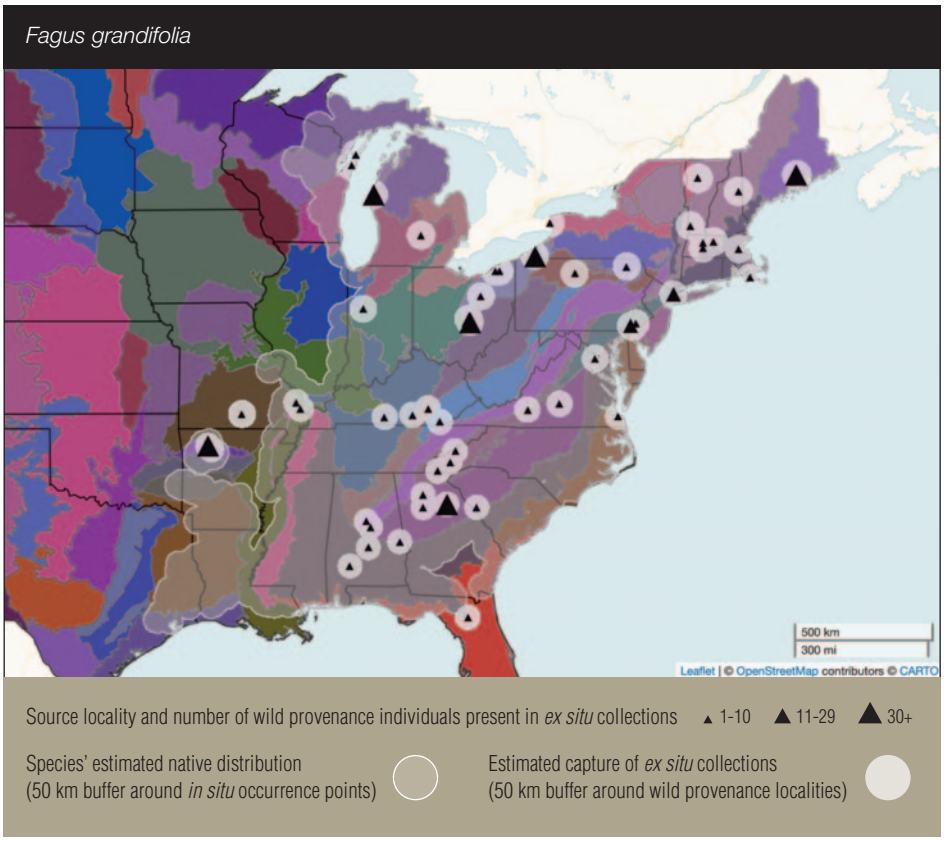

Figure 5. Native distribution and wild provenance localities of *ex situ* individuals for *Fagus grandifolia* in the U.S., based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development,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

Table 2. Estimated geographic and ecological coverage of *ex situ* collections of *Fagus grandifolia*. 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
Fagus grandifolia	57,450 / 1,894,592 **(3%)**	99 / 300 **(33%)**	308,929 / 2,212,568 **(14%)**	171 / 311 **(55%)**	933,269 / 2,486,026 **(38%)**	234 / 323 **(72%)**	**18%**	**53%**

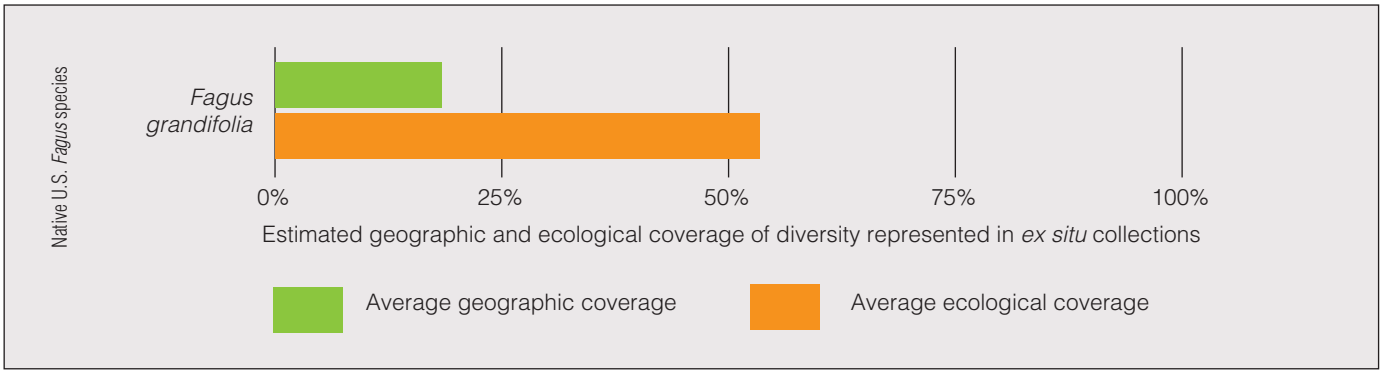

Figure 6. Average geographic and ecological coverage of *ex situ* collections for *Fagus grandifolia* (See Table 2 for details).

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 7). 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 53 institutions that provided input on conservation activities for *Fagus grandifolia*. 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.

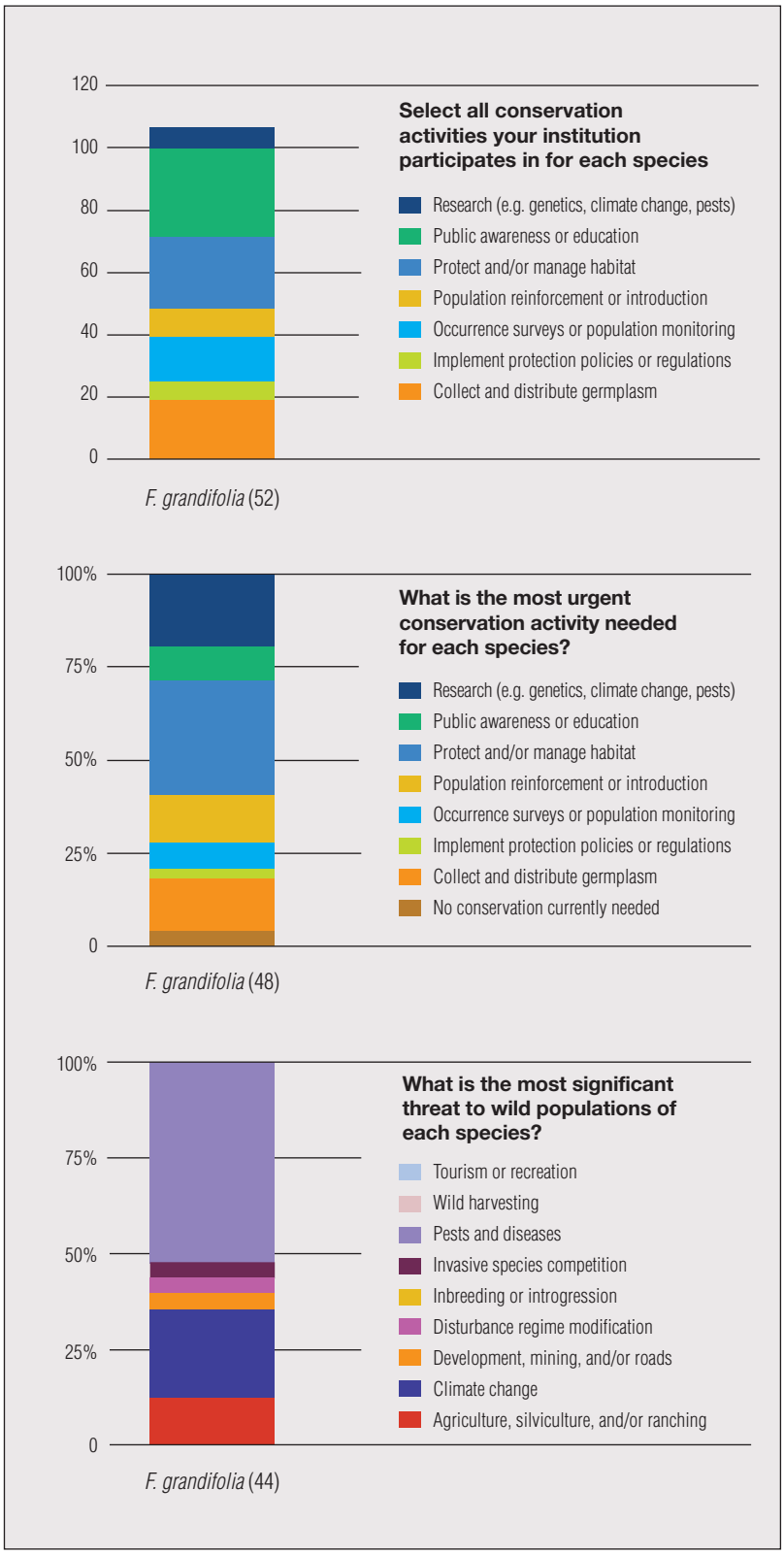

Figure 7. Results from the Tree Conservation Action Questionnaire for *Fagus grandifolia.* The number of institutions or respondents participating in each question is listed in parentheses after the species' name. See Appendix B for details regarding which institutions reported each conservation activity.

CONCLUSIONS & RECOMMENDATIONS

Species' distributions and threats: *Fagus grandifolia*, or American beech, is a dominant tree in forests throughout the northeastern U.S. and Canada, including some distribution in the Midwest and Southeast U.S. and disjunct populations in Mexico, occupying a wide variety of forest types (Figure 1). *Fagus grandifolia* is susceptible to multiple pests and diseases, though only beech bark disease (BBD) poses a significant threat (Table 1). The disease complex has devastated northeastern populations of American beech and is now well established in all beech-dominated forests in the U.S. (Figures 2-3). The disease kills about 50% of mature trees within ten years, and up to 90% of American beech trees eventually succumb (Ohio State University Extension, 2018). However, 1-3% of individuals are reported to be resistant to BBD (Stephanson & Coe, 2017). Climate change could pose a threat to American beech, including effects to BBD distribution and impact, but more research is needed (Potter et al., 2017; Stephanson & Coe, 2017).

Conservation quality of *ex situ* collections: Based on data from 78 *ex situ* collections that submitted accessions data for American beech, the species is represented by 1,719 individuals in *ex situ* collections globally, approximately 30% of which are of wild origin. Of the wild origin individuals, 484 (85%) had enough wild locality information to be mapped (Figure 5). These individuals provide an estimated 18% geographic coverage and 53% ecological coverage of the species' total native distribution (Figure 6; Table 2). Overall, there is relatively good diversity in the wild populations represented by *ex situ* collections, though further collecting could focus on the edges of American beech's distribution, for example the southwestern populations in Texas and Louisiana, which are currently unrepresented in living collections.

Conservation actions: For the Tree Conservation Action Questionnaire, 53 of the more than 200 participating institutions reported conservation activities for American beech. Public awareness or education (29 institutions) was the most common activity reported, followed by protection and/or management of habitat (23). The conservation activities most frequently identified as most urgent were to protect and/or manage habitat (14 respondents) and research (10). Pests or diseases (23 respondents) and climate change (10) were most frequently identified as the most significant threats to *F. grandifolia* (Figure 7). In response to impacts from beech bark disease, the USDA Forest Service Northern Research Station has developed methods to identify, breed, and propagate American beech trees that are resistant to beech scale (Koch, 2018). Additionally, because current methods of identifying resistant trees take about a year, the USDA Forest Service, University of California at Davis, and Pennsylvania State University researchers have recently collaborated to identify genes associated with resistance, which could help expedite the screening process (Ćalić et al., 2017; Koch, 2017).

Overall summary and recommendations: Although few institutions reported research as a current conservation activity within the questionnaire, literature review revealed multiple, robust research initiatives for American beech and the effects of beech bark disease (BBD). Research focused on BBD, including studies of ecosystem changes and stability after the disease has run its course, and climate change should continue to be pursued. *Ex situ* representation of wild *F. grandifolia* populations is substantial, but further collecting should target missing geographic and ecological areas in the species' full native distribution, especially edge populations, to safeguard against genetic diversity loss. These diverse living collections are especially important since *F. grandifolia* cannot be stored long-term in conventional seed banks, and in light of declines due to BBD. American beech remains a keystone species throughout much of the eastern U.S. and deserves continued conservation focus.

Fagus grandifolia (Ed Hedborn, The Morton Arboretum)

REFERENCES

Barstow, M. (2017). *Fagus grandifolia. The IUCN Red List of Threatened Species* 2017: e.T62004694A62004696. Retrieved from https://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T62004694A62004696.en.

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

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

Ćalić, I., Koch, J., Carey, D., Addo-Quaye, C., Carlson, J. E., & Neale, D. B. (2017). Genome-wide association study identifies a major gene for beech bark disease resistance in American beech (Fagus grandifolia Ehrh.). *BMC Genomics, 18*(1). doi: 10.1186/s12864-017-3931-z

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.

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

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

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

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

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

Koch, J. (2018). Beech Bark Disease. Retrieved from https://www.fs.fed.us/research/invasive-species/plant-pathogens/beech-bark-disease.php

Koch, J. (2017). Research Highlights: Finding beech bark disease resistant American beech trees: It's in the genes! Retrieved from https://www.fs.fed.us/research/highlights/highlights_display.php?in_high_id=1214

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

Lockman, I. B., & Kearns, H. S. J. (Eds.). (2016). *Forest Root Diseases Across the United States*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Retrieved from https://www.fs.fed.us/rm/pubs/rmrs_gtr342.pdf

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.

Meeker, J. R. (2001). *common name: forest tent caterpillar, scientific name: Malacosoma disstria Hübner (Insecta: Lepidoptera: Lasiocampidae)*. University of Florida & Florida Department of Agriculture and Consumer Services. Retrieved from http://entnemdept.ufl.edu/creatures/trees/forest_tent_caterpillar.htm

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.

Morin, R. S., Liebhold, A. M., Tobin, P. C., Gottschalk, K. W., & Luzader, E. (2007). Spread of beech bark disease in the eastern United States and its relationship to regional forest composition. *Canadian Journal of Forest Research, 37*(4), 726–736. doi: 10.1139/x06-281

Ohio State University Extension. (2018, July 31). Beech Bark Disease. Retrieved from https://ohioline.osu.edu/factsheet/plpath-tree-9

Pijut, P. M. (2006). *Diseases in Hardwood Tree Plantings. Diseases in Hardwood Tree Plantings*. Northern Research Station, USDA Forest Service Department of Forestry and Natural Resources Purdue University. Retrieved from https://www.extension.purdue.edu/extmedia/FNR/FNR-221.pdf

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. (2019). 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

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/.

Stephanson, C. A., & Coe, N. R. (2017). Impacts of Beech Bark Disease and Climate Change on American Beech. Forests, 8(155). doi: 10.3390/f8050155

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. (2020). Mapping & Reporting: National Forest Damage Agent Range Maps. Retrieved from https://www.fs.fed.us/foresthealth/applied-sciences/mapping-reporting/damage-agent-range-maps.shtml

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.

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

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


Fagus grandifolia (Cephas)

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

Fagus grandifolia (Ed Hedborn, The Morton Arboretum)

Fagus grandifolia (David J. Stang)

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)
Fagus grandifolia	Adkins Arboretum[1]	United States (MD)			X		X	X	
	Alpha Nurseries, Inc[8]	United States (MI)	X						
	Arboretum Wespelaar[1]	Belgium						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					
	Blue Mountains Botanic Garden, The[1]	Australia	X						
	Botanical Garden of the University of Turku[1]	Finland						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 Hamilton[2]	United States (OH)			X		X	X	
	Cox Arboretum and Gardens[1]	United States (GA)					X		
	Dawes Arboretum, The[1]	United States (OH)	X					X	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						
	Draves Arboretum[1]	United States (NY)			X	X		X	
	Elmhurst College[9]	United States (IL)					X	X	
	Folmer Botanical Gardens[1]	Canada					X		
	Growild, Inc[8]	United States (TN)	X				X	X	
	Holden Forests and Gardens[1]	United States (OH)	X		X				X
	Indiana Native Plant Society, Southwest Chapter[5]	United States (IN)						X	
	Johnson's Nursery, Inc.[8]	United States (WI)	X						
	Longfellow Arboretum[2]	United States (ME)		X	X	X	X	X	
	Louisiana Department of Wildlife and Fisheries[6]	United States (LA)							
	Michigan Natural Features Inventory[6]	United States (MI)			X		X		
	Mill Creek MetroParks, Fellows Riverside Gardens[1]	United States (OH)					X		
	Morris Arboretum[1]	United States (PA)					X		
	Moscow State University Botanical Garden[1]	Russian Federation	X						
	Mt. Desert Land & Garden Preserve[1]	United States (ME)			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	
	Peckerwood Garden[1]	United States (TX)	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		

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)
Fagus grandifolia	Reeseville Ridge Nursery[8]	United States (WI)	X					X	
	Rogów Arboretum of Warsaw University of Life Sciences[1]	Poland	X						
	Sister Mary Grace Burns Arboretum at Georgian Court University[1]	United States (NJ)						X	
	United States Fish and Wildlife Service, Clarks River National Wildlife Refuge[3]	United States (KY)						X	
	University of Guelph Arboretum[1]	Canada			X				
	University of Oklahoma[9]	United States (OK)			X				
	USDA Forest Service[3]	United States (DC)	X	X	X	X	X	X	X
	USDA Forest Service[3]	United States (WI)	X	X					X
	VanDusen Botanical Garden[1]	Canada						X	
	Village of Bensenville[2]	United States (IL)		X	X	X	X	X	
	Name not shared[1]	Ireland	X					X	
	Name not shared[2]	United States (PA)		X					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
Alabama	AL	Kentucky	KY	New Mexico	NM
Arkansas	AR	Louisiana	LA	New York	NY
Arizona	AZ	Massachusetts	MA	Ohio	OH
California	CA	Maryland	MD	Oklahoma	OK
Colorado	CO	Michigan	MI	Oregon	OR
Florida	FL	Minnesota	MN	Pennsylvania	PA
Georgia	GA	Missouri	MO	South Carolina	SC
Iowa	IA	Mississippi	MS	Tennessee	TN
Illinois	IL	North Carolina	NC	Texas	TX
Indiana	IN	North Dakota	ND	Utah	UT
Kansas	KS	New Jersey	NJ	Washington	WA

Fagus grandifolia (Susan McDougall)

Conservation Gap Analysis of

American Beech

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Fagus grandifolia (Ed Hedborn, The Morton Arboretum)

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Fagus grandifolia (Plant Image Library)

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