




Conservation Gap Analysis of Native U.S. Walnuts

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Juglans californica S. Watson (Southern California walnut)
Juglans cinerea L. Watson (Butternut)
Juglans hindsii (Jeps.) Jeps. ex R.E. Sm. (Northern California walnut)
Juglans major (Torr.) A. Heller (Arizona walnut)
Juglans microcarpa Berl. (Little walnut)
Juglans nigra L. (Black walnut)

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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

There are six species of walnut (*Juglans*) native to the United States. All are nut producing trees, which contribute various amounts of food and shelter to wildlife, though their native habitats differ significantly. *Juglans* species are also an important source of dyes and wood for applications such as cabinets, furniture, and construction, and have important medicinal and cultural uses to Native American peoples (Flora of North America, 1997). *Juglans nigra* and *J. cinerea* are distributed throughout the eastern U.S., *J. major* and *J. microcarpa* are found in the Southwest, *J. californica* is native to California, and *J. hindsii* is distributed in California and has recently been confirmed in Oregon (Figure 1).

Juglans californica (Southern California walnut) is endemic to California, where it can be found in self-dominated forests and woodlands from Santa Barbara County south to San Diego County. It is a small, deciduous tree growing six to 15 meters tall and "varies considerably in morphology according to the age of the tree and site characteristics." Some of the largest remaining stands of *J. californica* are located in the San Jose Hills, east of Los Angeles. Its habitat type, Southern California walnut woodland, is in decline due to "urban and rural development, overgrazing, and increased recreational use of walnut woodlands" (Esser, 1993). Regeneration in some areas has also been reduced by cattle grazing, while increased fire and competition with invasive species cause further decline. The distribution of *J. californica* has declined enough to place it within the Near Threatened category on the IUCN Red List (Stritch & Barstow, 2019).

Juglans californica (Consultaplantas)

Juglans cinerea (Butternut) is distributed throughout most of New England, and extends south to northern New Jersey, western Maryland, Virginia, and Tennessee, with isolated pockets in North Carolina, northwestern South Carolina, northern Georgia, northern Alabama, northern Mississippi, and Arkansas. Its western distribution reaches to eastern Iowa and southeastern Minnesota, including disjunct populations in Wisconsin and Michigan. Throughout most of its range, *J. cinerea* is uncommon. The native range of *J. cinerea* overlaps with that of *J. nigra*, but *J. cinerea* occurs farther north and does not extend as far south. *Juglans cinerea* is a medium-sized tree reaching between 12 and 20 meters in height, although sometimes exceeding 30 meters. It is "found most frequently in coves, on stream benches and terraces, on slopes, in the talus of rock ledges, and on other sites with good drainage" (Colandonato, 1991a). *Juglans cinerea* genetic diversity is highest in the southern part of its range (Hoban et al., 2010). Hoban et al. (2012) found a low level of hybridization with *J. ailantifolia*, the introduced Japanese walnut, in forested areas, though much higher hybridization (>60%) was found in anthropogenic landscapes (e.g., agricultural land). Due to impacts from butternut canker, population decline from historical levels is estimated to be up to 80%, which places *J. cinerea* in the Endangered category on the IUCN Red List (Stritch & Barstow, 2019).

Juglans cinerea (H. Zell)

Juglans hindsii (Northern California walnut or Hinds' black walnut) is a small to medium tree with a single stem, reaching between six and 23 meters in height and commonly lacking branches for three to 12 meters. It is most often found along streams and on disturbed slopes. *Juglans hindsii* is commercially important as a rootstock for English walnut (*J. regia*) orchards globally, which has added to confusion regarding its native range, due to potential hybridization (California Native Plant Society, 2019; Whittemore, 2012b). Potter et al. (2018) examined these questions regarding the native range of *J. hindsii* by conducting a genetic analysis of specimens matching the morphology of *J. hindsii* from across the species' possible range, from southern Oregon to southern California. They found that at least 71.5% of seemingly-wild *J. hindsii* are in fact genetically pure, while the remaining samples showed past hybridization with other North American walnut species. These new findings point to *J. hindsii* possessing a much broader distribution than originally thought; it is only known from three or four sites prior to extensive settlement of California by Europeans in the mid-19th century, but seems to have dispersed more widely in California and mostly retained its genetic integrity (Potter et al., 2018). Further research is likely necessary to continue to clarify the wild distribution of *J. hindsii*. Due to the recent acceptance of *J. hindsii* as much more broadly distributed than originally thought, the species is assessed as Least Concern on the IUCN Red List (Barstow, 2020).

Juglans hindsii (John Rusk & Katherine Greenberg)

Juglans major (Arizona walnut) has a native distribution extending from central Texas west to southwestern New Mexico and central Arizona, in addition to presence in northern Mexico. It can be found in pure or mixed stands or as scattered individuals. It is usually dominant or codominant in deciduous broad-leaved habitat, an indicator species in mixed conifer stands, and can also be found in oak woodlands or chaparral. In general though, *J. major* naturally occurs in low frequencies. It is a small to medium-sized deciduous tree reaching up to 20 meters tall, with spreading branches and a rounded crown. *Juglans major* is the only walnut that is native to the desert and "occurs along ephemeral streams with subsurface flows or perennial streams in moist sites that are occasionally flooded... [and is] also found scattered along river bottoms, canyons, floodplains, dry terraces and hillsides" (Pavek, 1993). With a broad native distribution and large populations in the U.S., *J. major* is assessed as Least Concern on the IUCN Red List (Barstow & Stritch, 2019).


Juglans major (Rowan Adams)

Juglans microcarpa (Little walnut) is distributed from southwestern Kansas west through Oklahoma to central New Mexico and Texas, and south into northeastern Mexico. At the eastern edge of its range, *J. microcarpa* hybridizes with *J. nigra*. *Juglans microcarpa* occurs abundantly in riparian woodland communities and can also be found along rocky streams, in canyons and arroyos, and on terraces of dry river beds. It is a "large, many-trunked shrub or small, clumped, spreading, low-branched tree" between six and 15 meters in height, which generally enjoys sites with relatively high moisture availability (Tirmenstein, 1990). Due to its fairly broad native distribution and lack of significant threats, *J. microcarpa* is assessed as Least Concern on the IUCN Red List (Stritch & Barstow, 2019).


Juglans microcarpa (Jerry Friedman)

Juglans nigra (Black walnut) is native to the eastern United States. It's northern distribution includes southern Minnesota, southern Wisconsin, southern Michigan, and southern Ontario, and it extends south to northwestern Florida, and to Mississippi, Arkansas, and Louisiana. Isolated populations occur in the southern half of New York, Vermont, western Massachusetts, and northwestern Connecticut, in addition to eastern Texas, western Oklahoma, central Kansas, and southeastern South Dakota. *Juglans nigra* is a deciduous tree that generally reaches 25 to 40 meters tall. It develops a long, smooth trunk and a small rounded crown when growing in the forest, in contrast to a trunk that forks low with a few ascending and spreading coarse branches in the open. *Juglans nigra* grows in a variety of sites including wet bottomlands, dry ridges, and slopes, but prefers deep, well-drained neutral soils of fertile alluvial deposits (Coladonato, 1991b). With its large distribution and stable population, *J. nigra* is assessed as Least Concern on the IUCN Red List (Stritch, 2018).


Juglans nigra (Ed Hedborn, The Morton Arboretum)

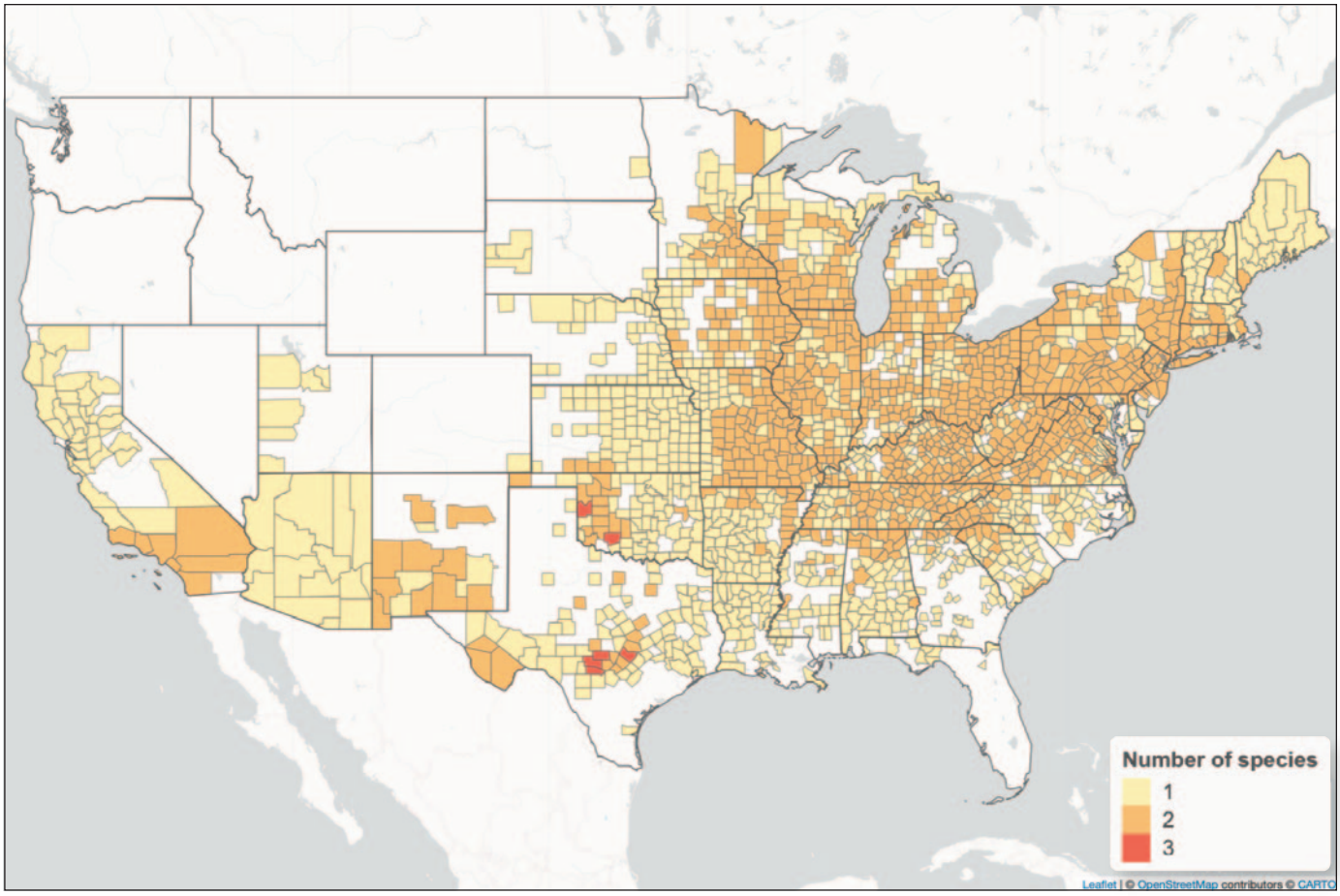


Figure 1. Species richness of native U.S. *Juglans* species by U.S. county, including *J. californica, J. cinerea, J. hindsii, J. major, J. microcarpa*, and *J. nigra*. County level distribution data from USDA PLANTS and Biota of North America Program (BONAP) have been combined to estimate species presence (Kartesz, 2018; USDA NRCS, 2018).

Juglans nigra (Ed Hedborn, The Morton Arboretum)

Juglans cinerea (Ed Hedborn, The Morton Arboretum)

PESTS & DISEASES

Native U.S. *Juglans* species face a variety of pests and diseases. Some are widely devastating as single agents, such as butternut canker or thousand cankers disease, and others contribute to a suite of pressures that inhibit reproduction, cause decline, and sometimes lead to mortality. 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 native U.S. *Juglans* 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. Where possible, we have also provided distribution maps of significant pests and diseases identified in Table 1 (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.

Juglans major (Susan McDougall)

Table 1. The most serious insect, disease, and parasitic plant agents affecting native U.S. *Juglans* species, from the results of Potter et al. (2019a), 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. (2019a).

Host species	Insect, Disease, or Parasitic Plant Agent									
	Black stem borer (*Xylosandrus germanus*)*	Blackline (Cherry leafroll virus)	Bunch disease (*Phytoplasma* strains in subgroup of *Prunus* X-disease group)	Butternut canker (*Sirococcus clavigignenti-juglandacearum*)*	Flatheaded apple tree borer (*Chrysobothris femorata*)	Nectria canker (*Nectria ditissima*)	Sooty canker (*Fusicoccum mangiferum*)	Thousand cankers disease (*Geosmithia morbida*/ *Pityophthorus juglandis*)	Walnut caterpillar (*Datana integerrima*)	White rot (*Phellinus weirianus*)
Juglans californica								3		
Juglans cinerea			1	10				5		
Juglans hindsii		5					1	3		
Juglans major								1		1
Juglans microcarpa			3					3		
Juglans nigra	1				1	3		5	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%)

Butternut canker (*Ophiognomonia clavigignenti-juglandacearum*)

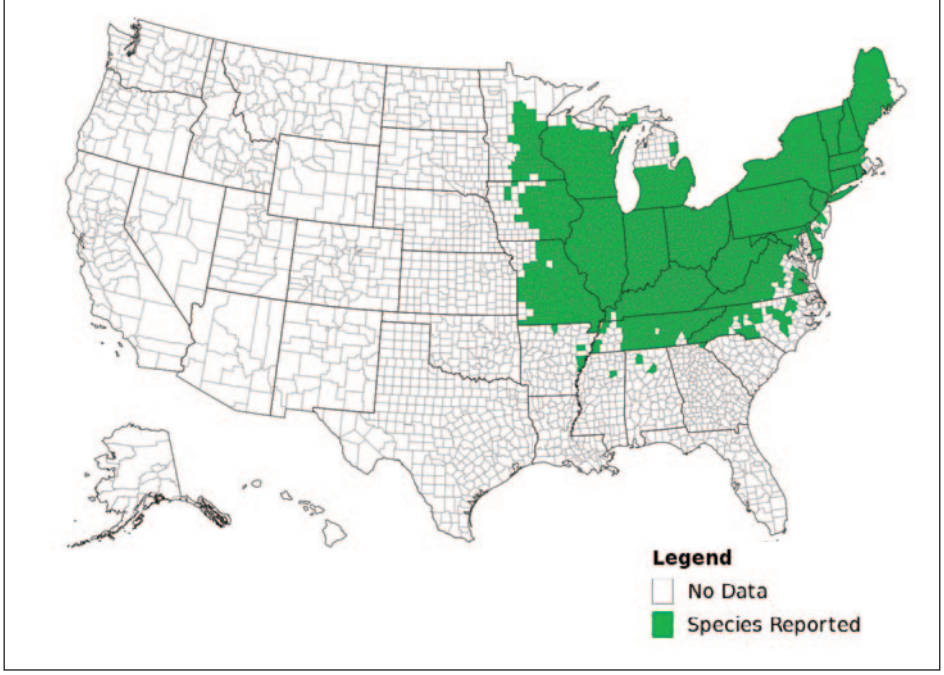


Figure 2. Distribution of butternut canker (*Ophiognomonia clavigignenti-juglandacearum*), created by EDDMapS. Managed by University of Georgia's Center for Invasive Species and Ecosystem Health, EDDMapS is a web-based mapping system for documenting invasive species distribution and facilitating Early Detection and Rapid Response programs EDRR (EDDMapS, 2020).

Thousand cankers disease *(Geosmithia morbida/Pityophthorus juglandis)*

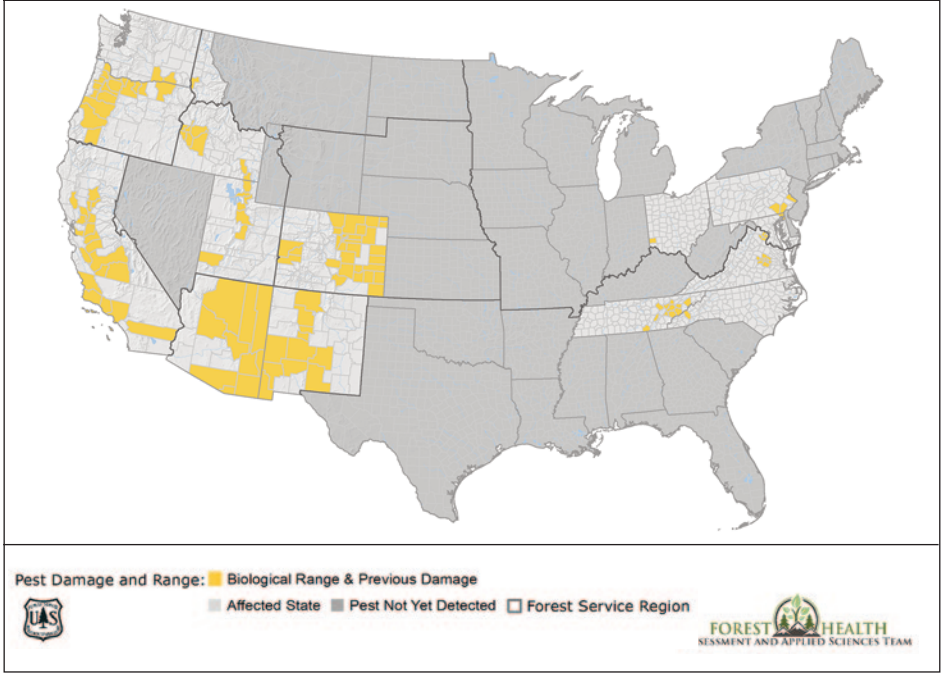
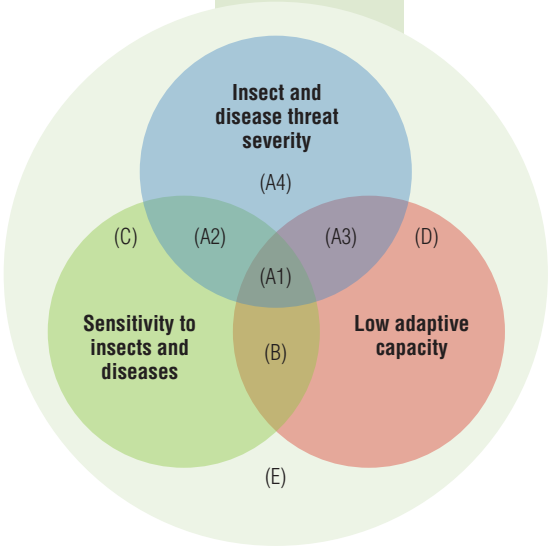


Figure 3. National Forest Damage Agent Range Map for thousand cankers disease (*Geosmithia morbida/Pityophthorus juglandis*), created by the USDA Forest Service, Forest Health Assessment and Applied Sciences Team. Data are "an integration of various sources, reviewed by regional authorities…intended to display the biological extent of major damage agents, or the range over which they have been a managerial concern" (USDA Forest Service, 2019).

Table 2. Pest and disease vulnerability of native U.S. *Juglans* species, from the results of a USDA Forest Service study that analyzed 419 native U.S. tree species. 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)
Juglans cinerea	A2	11
Juglans californica	C	66
Juglans hindsii	B	73
Juglans microcarpa	D	95
Juglans major	D	280
Juglans nigra	E	366



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

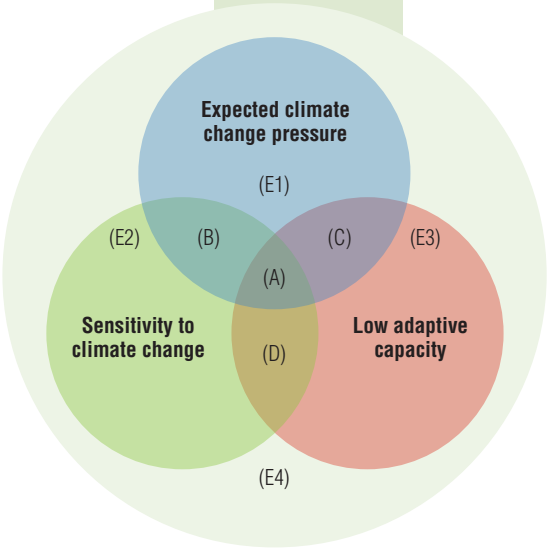

Juglans californica (Joe Decruyenaere)

CLIMATE CHANGE VULNERABILITY

Native U.S. *Juglans* species face varying impacts from climate change. 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 native U.S. *Juglans* species, from the results of a USDA Forest Service study that analyzed 339 native U.S. tree species. 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)
Juglans microcarpa	A	2
Juglans cinerea	B	57
Juglans major	B	62
Juglans californica	B	71
Juglans nigra	C	104
Juglans hindsii	C	136



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

EX SITU SURVEY RESULTS

Because *Juglans* species are considered exceptional, meaning their seeds cannot be stored long-term in conventional seed bank conditions of low temperature and moisture, other methods of long-term *ex situ* preservation are necessary. The seeds of *Juglans* species can be dried and frozen but do not retain viability for long periods, losing viability within one to ten years (Bonner, 2008). Therefore, living collections of *Juglans* species are an important tool for conserving genetic diversity, in addition to 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 94 collections from 19 countries reporting native U.S. *Juglans* species (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 *Juglans* 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.


Juglans nigra (Ed Hedborn, The Morton Arboretum)

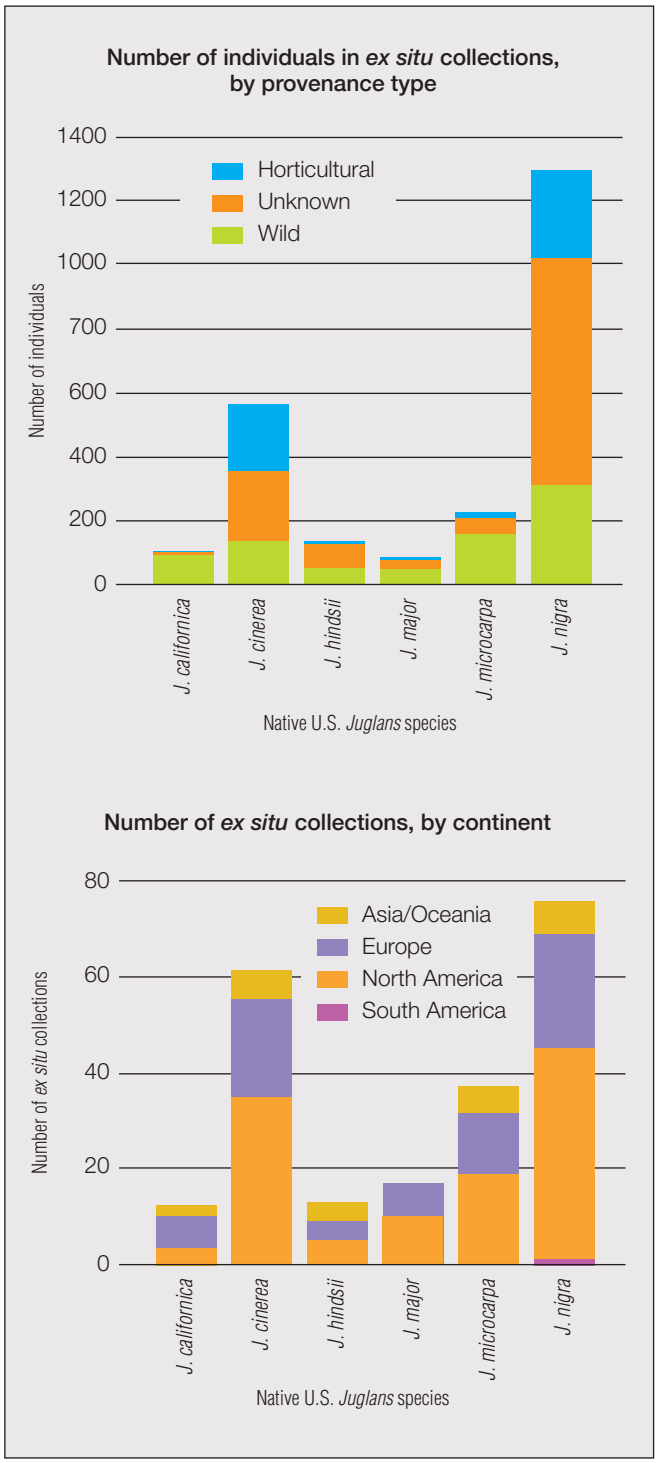


Figure 4. Results from a 2018 global accessions-level *ex situ* survey for native U.S. *Juglans* species.

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 5-11; 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.


Juglans hindsii (Susan McDougall)


Juglans cinerea (Ed Hedborn, The Morton Arboretum)

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 target native U.S. *Juglans* species, about 23% of records with wild or unknown provenance were manually geolocated, while 21% had latitude and longitude provided by the institution and 56% 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).

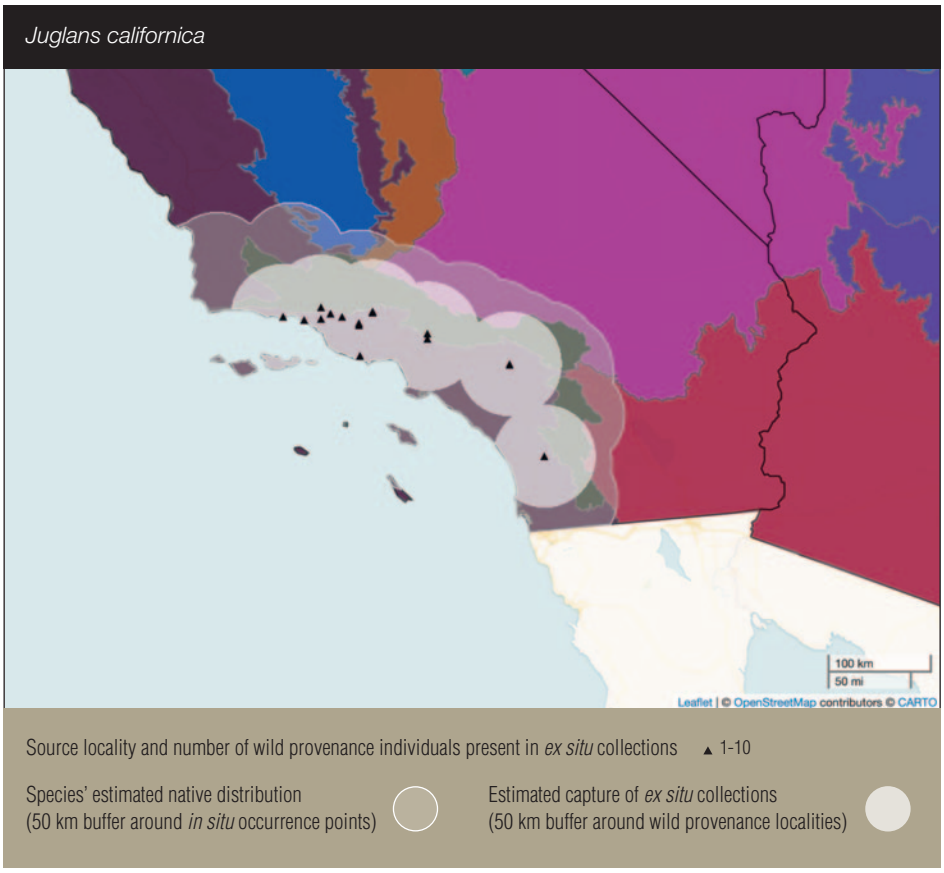


Figure 5. Native distribution and wild provenance localities of *ex situ* individuals for *Juglans californica* in the U.S., based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development, 2013a). In addition to standard *in situ* occurrence point filters applied to all target species, *J. californica* occurrence points were further refined by removing records more than 100 km outside the California Floristic Provinces where the species is native (Whittemore, 2012a).

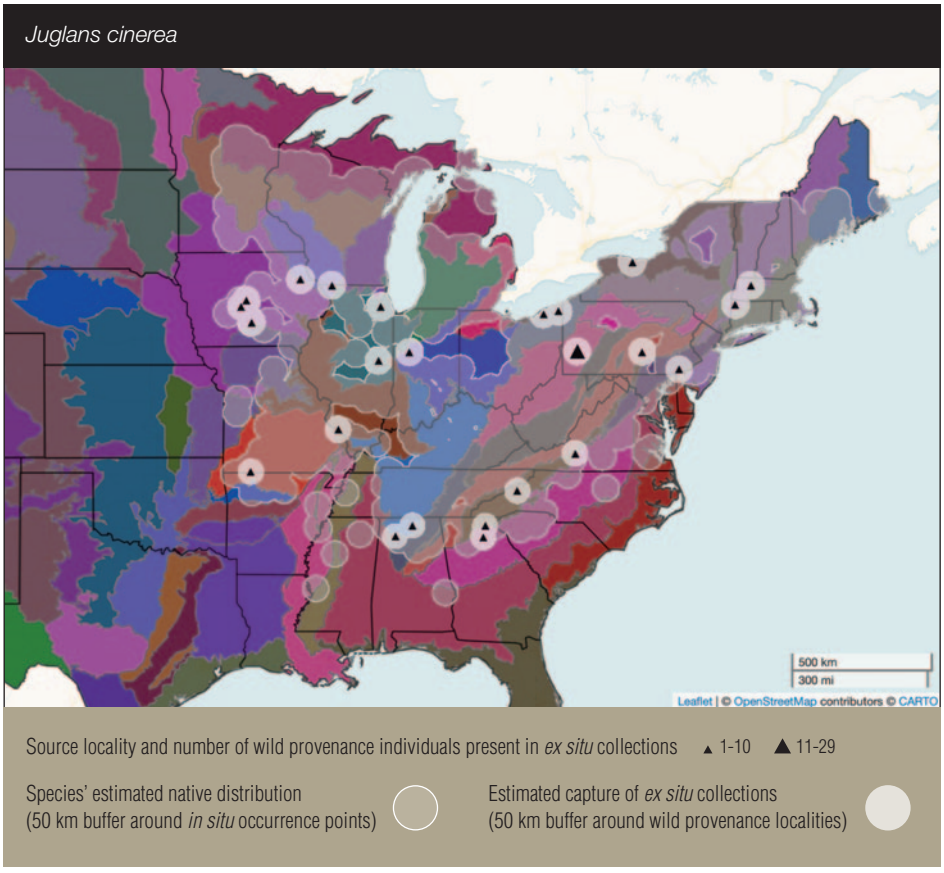


Figure 6. Native distribution and wild provenance localities of *ex situ* individuals for *Juglans cinerea* in the U.S., based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development, 2013a).

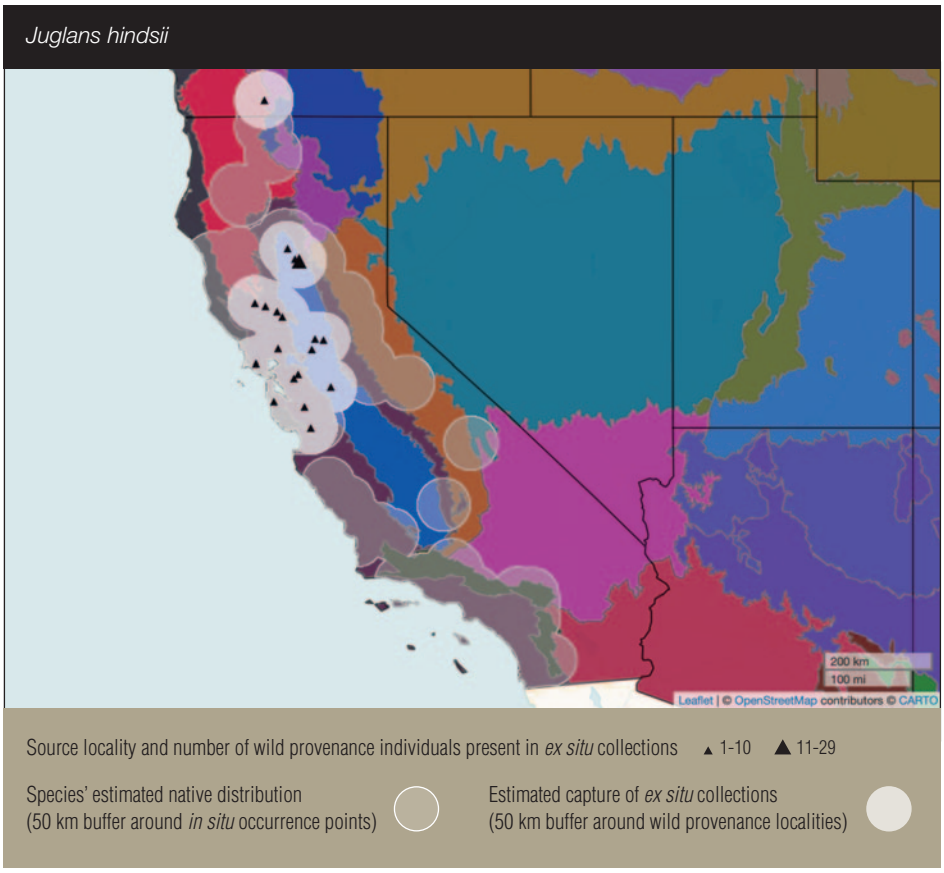


Figure 7. Native distribution and wild provenance localities of *ex situ* individuals for *Juglans hindsii* in the U.S., based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development, 2013a). There is not currently enough information to further refine the *in situ* distribution of *J. hindsii*, but it is possible that some outliers do not represent native populations but rather introduced or hybridized specimens.

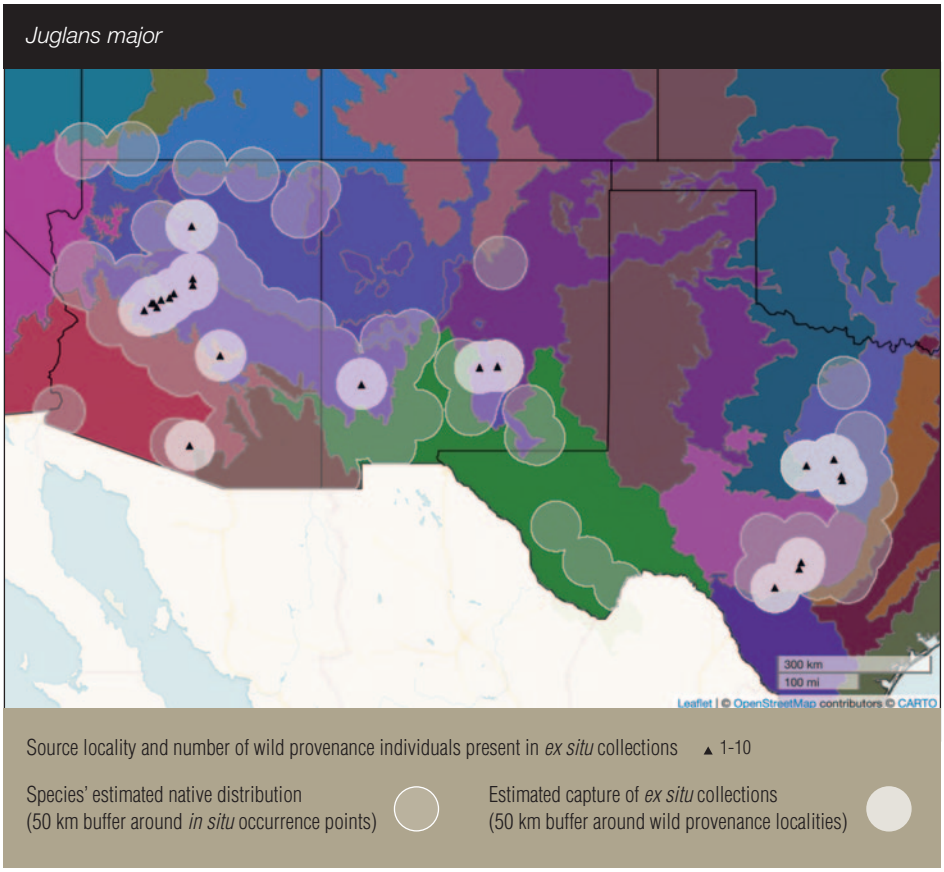


Figure 8. Native distribution and wild provenance localities of *ex situ* individuals for *Juglans major* in the U.S., based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development, 2013a).

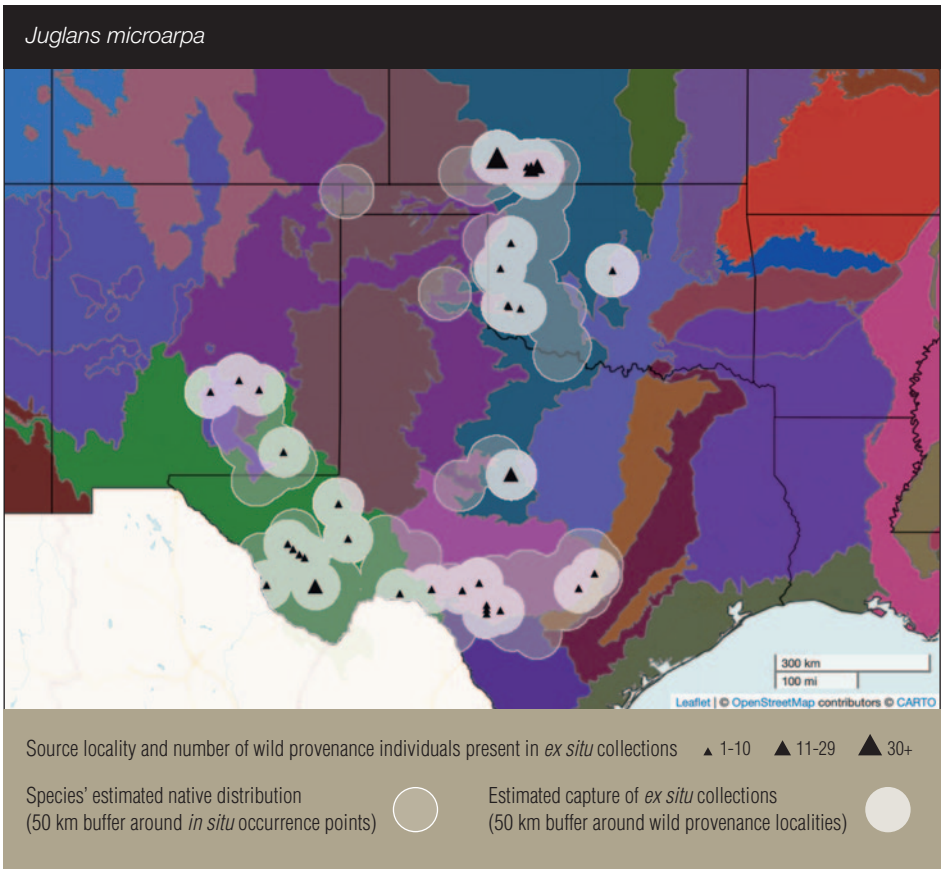


Figure 9. Native distribution and wild provenance localities of *ex situ* individuals for *Juglans microcarpa* in the U.S., based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development,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

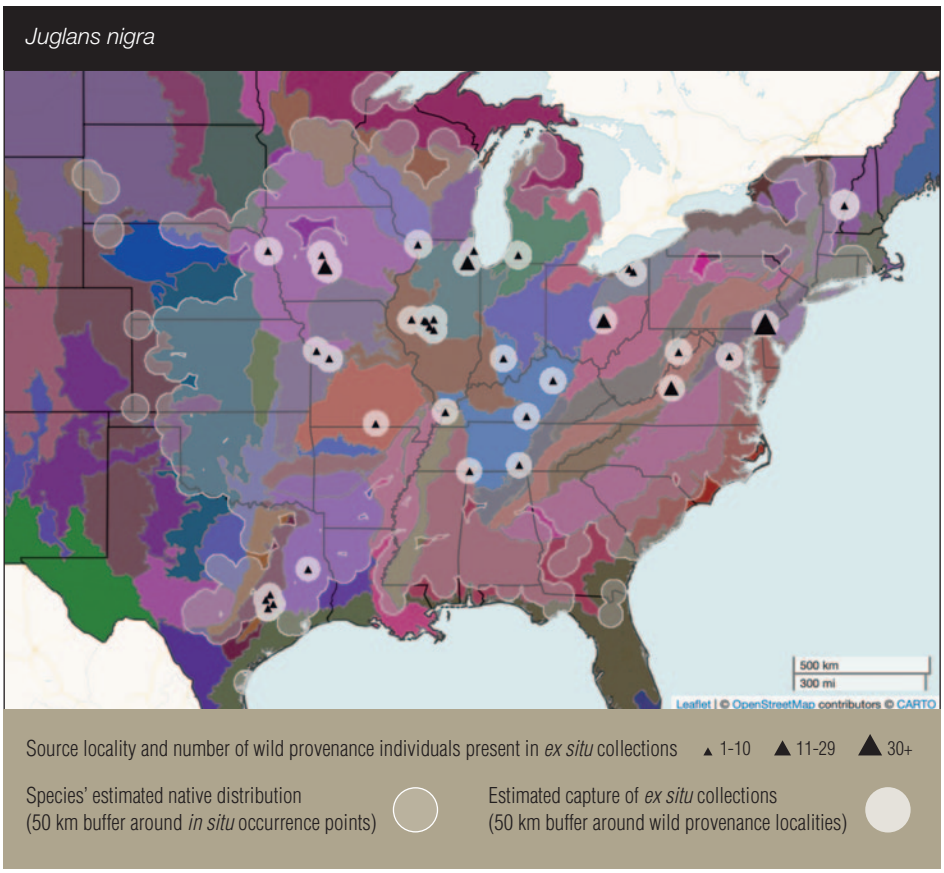


Figure 10. Native distribution and wild provenance localities of *ex situ* individuals for *Juglans nigra* in the U.S., based on 50 km buffers around *in situ* occurrence points and *ex situ* source localities. Background colors show EPA Level III Ecoregions (U.S. EPA Office of Research & Development, 2013a).

Table 4. Estimated geographic and ecological coverage of *ex situ* collections of native U.S. *Juglans* 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
Juglans californica	8,692 / 37,999 **(23%)**	14 / 39 **(36%)**	32,255 / 58,238 **(55%)**	28 / 46 **(61%)**	67,069 / 92,534 **(72%)**	47 / 59 **(80%)**	**50%**	**59%**
Juglans cinerea	29,367 / 920,224 **(3%)**	63 / 256 **(27%)**	165,821 / 1,745,828 **(9%)**	99 / 279 **(35%)**	561,481 / 2,242,196 **(25%)**	154 / 303 **(51%)**	**13%**	**37%**
Juglans hindsii	18,268 / 100,838 **(18%)**	49 / 122 **(40%)**	63,617 / 210,509 **(30%)**	66 / 144 **(46%)**	135,383 / 351,503 **(39%)**	94 / 171 **(55%)**	**29%**	**47%**
Juglans major	20,397 / 194,468 **(10%)**	27 / 73 **(37%)**	94,618 / 442,724 **(21%)**	42 / 93 **(45%)**	289,149 / 784,212 **(37%)**	63 / 122 **(52%)**	**23%**	**45%**
Juglans microcarpa	33,796 / 113,618 **(30%)**	32 / 47 **(68%)**	155,492 / 304,700 **(51%)**	49 / 59 **(83%)**	407,959 / 572,514 **(71%)**	61 / 70 **(87%)**	**51%**	**79%**
Juglans nigra	40,080 / 2,219,597 **(2%)**	76 / 367 **(21%)**	208,495 / 3,141,672 **(7%)**	119 / 399 **(30%)**	738,280 / 3,708,308 **(20%)**	177 / 428 **(41%)**	**9%**	**31%**

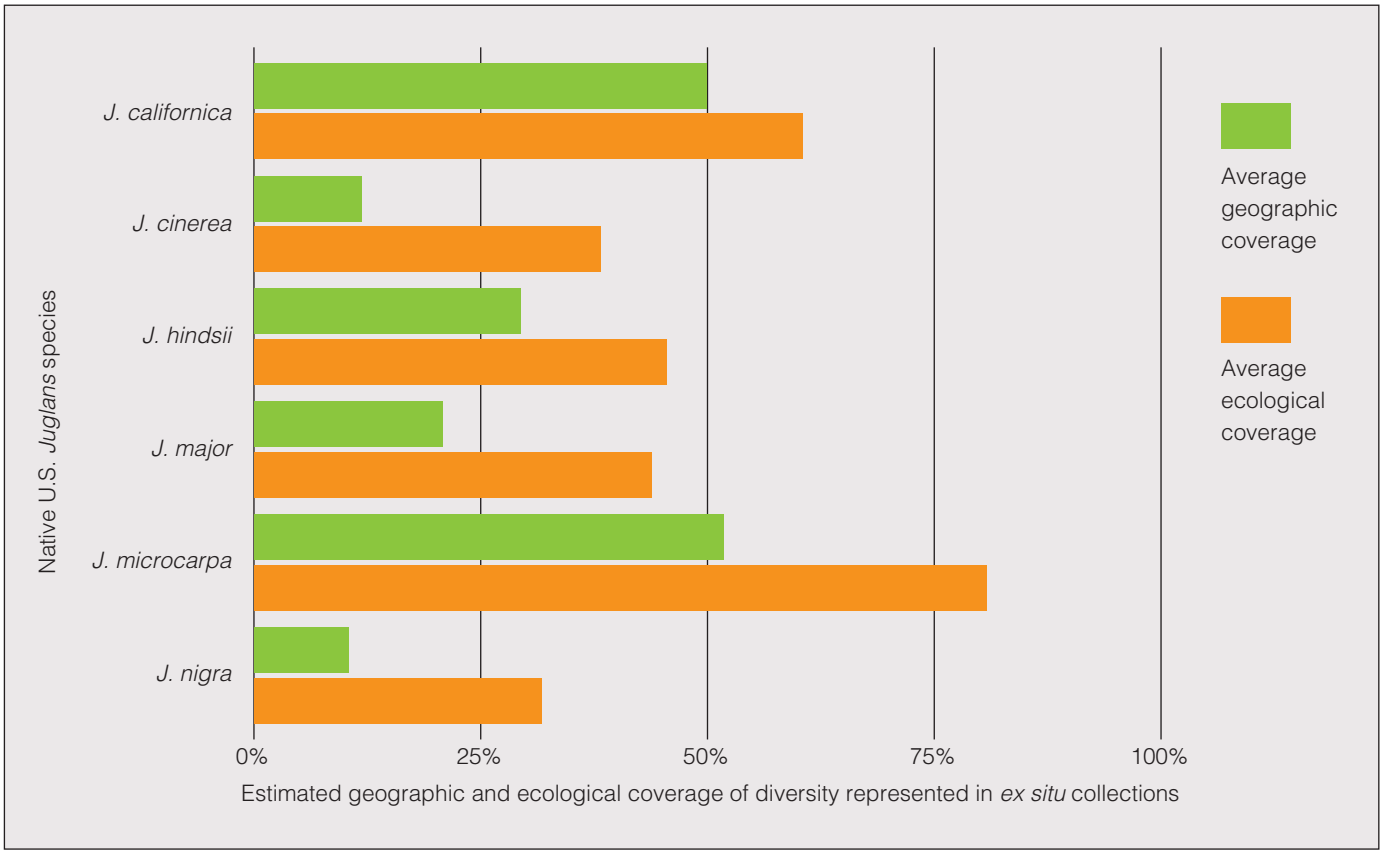


Figure 11. Average geographic and ecological coverage of *ex situ* collections for native U.S. *Juglans* species (See Table 4 for details).

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 12). 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 67 institutions that provided input on conservation activities for priority native U.S. *Juglans* species. Institutions reporting that they could "provide information regarding current conservation activities, most urgent conservation needs, and/or primary threats to wild populations" included 11 for *J. californica*, 65 for *J. cinerea*, 13 for *J. hindsii*, and 19 for *J. microcarpa*. Respondents were given the opportunity to fill in other native U.S. *Juglans* species that they considered of conservation concern; four respondents listed *J. major* and five listed *J. nigra*. 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.

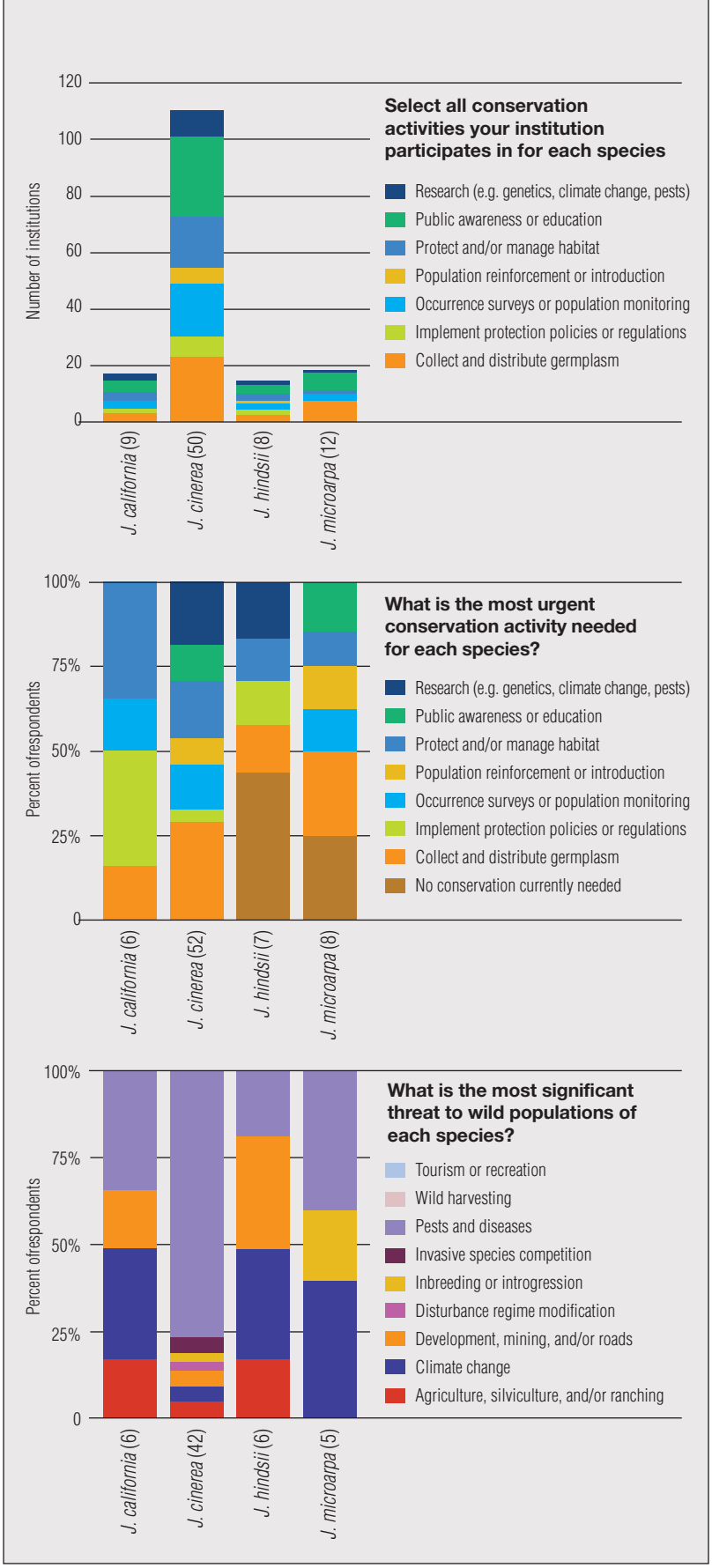


Figure 12. Results from the Tree Conservation Action Questionnaire for priority native U.S. *Juglans* species. The number of institutions or respondents participating in each question is listed in parentheses after the species' name. See Appendix B for details regarding which institutions reported each conservation activity.

CONCLUSIONS & RECOMMENDATIONS

Species' distributions and threats: There are six *Juglans* species native to the United States (Figure 1). *Juglans cinerea* and *J. nigra* are distributed throughout the eastern half of the country, though *J. cinerea* has been devastated by butternut canker, a fungal disease introduced in the 1960s, and is now much rarer in the wild. *Juglans major* and *J. microcarpa* have scattered distributions in the south-central and southwestern U.S., including Arizona, New Mexico, Texas, Oklahoma, and Kansas. *Juglans californica* is endemic to California, where it is distributed along the southern coast and mountains, while *J. hindsii* is distributed in California and Oregon, concentrated in the central California foothills and coastal mountains, especially near the San Francisco Bay Area.Though, recent studies have found that the distribution of *J. hindsii* may be broader than once thought and extend from southern Oregon to southern California (Potter et al., 2018). Native U.S. *Juglans* species are susceptible to a variety of pests and diseases, with thousand cankers disease being the most devastating after butternut canker (Tables 1-2; Figures 2-3). All six species are believed to be highly vulnerable to climate change based on climate change models and life history traits, though *J. cinerea* and *J. major* may be able to adapt to changes, while *J. hindsii* and *J. nigra* may have the ability to persist (Table 3).

Conservation quality of *ex situ* collections: Based on data from 94 *ex situ* collections that submitted accessions data for native U.S. *Juglans* species, *J. nigra* and *J. cinerea* are represented by the most *ex situ* individuals (1,290 and 487, respectively), but the majority (nearly 80%) are of unknown or horticultural origin. Relatively few individuals (170 for *J. nigra* and 88 for *J. cinerea*) had the spatial data necessary for mapping their wild *ex situ* source locality, and the resulting average geographic (9% and 13%, respectively) and ecological (31%, 37%) coverage were the lowest of any native U.S. *Juglans* species, though they do have the largest ranges. *Juglans microcarpa* is also represented by a large number of individuals in *ex situ* collections (223) but has a much higher percentage of wild origin individuals (76%), including more than 160 that were able to be mapped to their wild source locality. The average geographic (51%) and ecological (79%) coverage for *J. microcarpa* was the highest of any native U.S. *Juglans* species, and point to relatively robust *ex situ* preservation of the species. *Juglans hindsii*, *J. major*, and *J. californica* are less represented in *ex situ* collections (148, 80, and 55 individuals, respectively), each with about 50 wild origin individuals in collections and less than 40 individuals mapped to their wild source locality. Geographic and ecological coverage for these three species is moderate to substantial, ranging from 50% (geographic) and 59% (ecological) for *J. californica*, to 23% and 45% for *J. major* (Figures 4-11; Table 4).

Conservation actions: Across the four target native U.S. *Juglans* species included in the Tree Conservation Action Questionnaire, public awareness or education was the most common activity reported, followed by collection and distribution of germplasm. The conservation activities most frequently identified as most urgent varied significantly by species. Pests or diseases, climate change, and land use conversion were most frequently identified as the most significant threats to target *Juglans* species (Figure 12). Since our questionnaire provides information on a subset of all conservation activities for target species, the nearly ten institutions reporting conservation activities for each target species points to a good level of conservation energy. *Juglans cinerea* is the most imperiled U.S. *Juglans* species, however a proportionally high amount of conservation action was reported for the species. We note that pest and disease resistance breeding was not a specific category provided in the questionnaire, but it may be the key to halting declines in some species, especially *J. cinerea*. Future conservation action, including seed collection and resistance breeding, for *J. cinerea* may be assisted by its recent addition to TreeSnap, an app that allows citizens to record species' occurrence, disease condition, seed production, and other information (see treesnap.org). Further research of threats and mitigation strategies is a priority for the other five species.

Overall summary and recommendations: *Juglans nigra* and *J. cinerea* are the only native U.S. walnut species with extensive native distribution mapping through the Forest Inventory and Analysis (FIA) Program of the USDA Forest Service, though *J. californica* is well-tracked by the California Natural Diversity Database (CNDDB; Nelson, 2019). *Juglans hindsii* is monitored by the California Native Plant Society (CNPS) Rare Plant Program (2019) but due to taxonomic confusion and possible hybridization, continued research regarding its current wild distribution is warranted. The two remaining native U.S. species, *J. major* and *J. microcarpa*, would benefit from further scouting, verification of herbarium specimens, and refinement of species distribution models, to give a clearer picture of their wild distribution. Both pests and diseases and climate change are significant threats to native U.S. *Juglans* species, and should continue to be monitored and researched. While butternut canker is the most urgent threat, dozens of institutions are actively working to find solutions and build public awareness. Thousand cankers disease has not yet risen to the level of impact of butternut canker, therefore research, mitigation, and public education should continue to be high priorities. Although most native U.S. *Juglans* species are represented by more than one hundred individuals across tens of *ex situ* collections globally, these individuals often do not have clear records of source location, and do not cover a significant proportion of the species' native distribution and the ecoregions in which they are found. *Juglans microcarpa* is the only species with sufficient *ex situ* coverage of wild populations, while *J. californica* also has substantial coverage but needs further targeted collections due to its continuing decline. *Juglans cinerea* will benefit most from a continuation of the efforts already underway to collect and breed the species. Therefore *J. nigra, J. major,* and *J. hindsii* are the most important targets for future collecting, to build *ex situ* collections. Native U.S. walnuts are highly valuable economically, ecologically, culturally, and aesthetically, and through collaboration and prioritization, we can help them thrive long into the future.

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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

Juglans cinerea (Ed Hedborn, The Morton Arboretum)

Juglans microcarpa (Jerry Friedman)

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

Juglans nigra (The Morton Arboretum)

Juglans major (Whitney Cranshaw)

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)
Juglans californica	California Department of Fish and Wildlife[6]	United States (CA)		X	X	X			
	California Native Plant Society[5]	United States (CA)		X	X	X		X	
	Reveg Edge, The[8]	United States (CA)				X			
	Royal Botanic Garden Edinburgh[1]	United Kingdom	X					X	
	Santa Barbara Botanic Garden[1]	United States (CA)	X						
	United States National Arboretum[3]	United States (DC)							X
	University of California[9]	United States (CA)			X			X	X
	USDA Agricultural Research Service, National Clonal Germplasm Repository[3]	United States (CA)	X						
	Westonbirt, The National Arboretum[1]	United Kingdom						X	X
Juglans cinerea	Adkins Arboretum[1]	United States (MD)			X		X	X	
	Aldrich Berry Farm & Nursery, Inc[8]	United States (WA)	X						
	Alpha Nurseries, Inc[8]	United States (MI)	X						
	Arkansas Natural Heritage Commission[6]	United States (AR)			X		X	X	X
	Atlanta Botanical Garden[1]	United States (GA)	X						
	Bernheim Arboretum and Research Forest[1]	United States (KY)	X	X	X		X		
	Blue Mountains Botanic Garden, The[1]	Australia	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	X	X	
	Brooklyn Botanic Garden[1]	United States (NY)	X					X	
	City of Hamilton[2]	United States (OH)			X		X	X	
	City of Kansas City, Missouri[2]	United States (MO)				X			
	Delaware Division of Fish and Wildlife[6]	United States (DE)			X				
	Donald E. Davis Arboretum at Auburn University[1]	United States (AL)	X					X	
	Draves Arboretum[1]	United States (NY)			X	X		X	
	Elmhurst College[9]	United States (IL)					X	X	
	Frostburg State University[9]	United States (M)D	X	X	X		X	X	X
	Growild, Inc[8]	United States (TN)	X						
	Holden Forests and Gardens[1]	United States (OH)					X		
	Indiana Native Plant Society, Southwest Chapter[5]	United States (IN)						X	
	Louisiana Department of Wildlife and Fisheries[6]	United States (LA)					X		
	Maryland Department of Natural Resources[6]	United States (MD)			X				
	Michigan Natural Features Inventory[6]	United States (MI)			X		X		
	Minnesota Department of Natural Resources[2]	United States (MN)		X	X			X	
	Moscow State University Botanical Garden[1]	Russian Federation	X						
	Natural Resources Canada[3]	Canada	X	X	X				X
	New York Natural Heritage Program[6]	United States (NY)			X			X	
	North Carolina Natural Heritage Program[6]	United States (NC)			X		X	X	
	Parque Botânico da Tapada da Ajuda, Instituto Superior de Agonomia[9]	Portugal						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)
Juglans cinerea (contd)	Pennsylvania Natural Heritage Program, Western Pennsylvania Conservancy[6]	United States (PA)			X		X		X
	Reeseville Ridge Nursery[8]	United States (WI)	X					X	
	Rogów Arboretum of Warsaw University of Life Sciences[1]	Poland	X						
	Royal Botanic Garden Edinburgh[1]	United Kingdom	X					X	
	State Botanical Garden of Kentucky, The Arboretum[1]	United States (KY)	X					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 National Arboretum[3]	United States (DC)	X						X
	University of Guelph Arboretum[1]	Canada	X	X	X			X	
	USDA Agricultural Research Service, National Clonal Germplasm Repository[3]	United States (CA)	X						
	USDA Forest Service[3]	United States (DC)	X	X	X	X	X	X	X
	USDA Forest Service[3]	United States (IN)	X	X	X	X	X		X
	USDA Forest Service[3]	United States (MI)	X	X	X	X	X	X	X
	USDA Forest Service[3]	United States (WI)	X	X					X
	USDA Forest Service, Allegheny National Forest[3]	United States (PA)		X	X	X	X		X
	USDA Forest Service, Hardwood Tree Improvement and Regeneration Center[3]	United States (IN)	X			X			X
	USDA Forest Service, National Forest System[3]	United States (GA)							X
	VanDusen Botanical Garden[1]	Canada						X	
	West Virginia Native Plant Society[5]	United States (WV)			X				
	West Virginia Wesleyan College[9]	United States (WV)					X	X	
	Westonbirt, The National Arboretum[1]	United Kingdom						X	X
	WRD Environmental, Inc.[8]	United States (IL)					X	X	
	Name not shared[3]	United States (IN)						X	X
	Name not shared[1]	Ireland	X					X	

Juglans hindsii (Susan McDougall)

Juglans californica (California State University, San Bernardino)

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)
Juglans hindsii	California Department of Fish and Wildlife[6]	United States (CA)		X	X		X		
	California Native Plant Society[5]	United States (CA)		X	X		X	X	
	L.E. Cooke Co[8]	United States (CA)				X			
	Reveg Edge, The[8]	United States (CA)					X		
	United States National Arboretum[3]	United States (DC)							X
	USDA Agricultural Research Service, National Clonal Germplasm Repository[3]	United States (CA)	X						
	Westonbirt, The National Arboretum[1]	United Kingdom						X	X
	Name not shared[1]	Ireland	X					X	
Juglans microcarpa	Arboretum San Miguel[1]	Argentina					X	X	
	City of Columbia Stephens Lake Park Arboretum[2]	United States (MO)	X					X	
	Denver Botanic Gardens[1]	United States (CO)	X						
	Peckerwood Garden[1]	United States (TX)	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	
	University of Oklahoma[9]	United States (OK)			X				
	USDA Agricultural Research Service[3]	United States (TX)							X
	USDA Agricultural Research Service, National Clonal Germplasm Repository[3]	United States (CA)	X						
	Westonbirt, The National Arboretum[1]	United Kingdom						X	X
	Name not shared[1]	Ireland	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

Juglans microcarpa (Krzysztof Ziarnek)

Conservation Gap Analysis of Native

U.S. Walnuts

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Front cover images:
Juglans californica (Joe Decruyenaere)
Juglans cinerea (H. Zell)
Juglans hindsii (Susan McDougall)
Juglans major (Rowan Adams)
Juglans microcarpa (Krzysztof Ziarnek)
Juglans nigra (Ed Hedborn)

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Juglans hindsii (Susan McDougall)

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