Conservation Gap Analysis of Native U.S. Oaks

Emily Beckman, Abby Meyer, Audrey Denvir, David Gill, Gary Man,
David Pivorunas, Kirsty Shaw, and Murphy Westwood

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

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

BOTANIC GARDENS CONSERVATION INTERNATIONAL is the world's largest plant conservation network, comprising more than 500 botanic gardens in over 100 countries, and provides the secretariat to the IUCN/SSC Global Tree Specialist Group. BGCI was established in 1987 and is a registered charity with offices in the UK, US, China, Taiwan and Kenya.

THE USDA FOREST SERVICE stewards over 193 million acres of forest and grasslands on behalf of the American people with the mission to sustain the health, diversity, and production of the Nation's forests and grasslands to meet the needs of present and future generations. Besides the management of National Forest System lands, the USDA Forest Service provides technical and financial assistance to States, universities, and other organizations to support this mission. Additionally, the Agency conducts world renowned research helping to provide answers on pressing issues facing forest managers.

FAUNA & FLORA INTERNATIONAL (FFI), founded in 1903 and the world's oldest international conservation organization, acts to conserve threatened species and ecosystems worldwide, choosing solutions that era sustainable, are based on sound science and take account of human needs.

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

Recommended citation: 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.

Cover photos
Front cover: *Quercus havardii*, Sean Hoban
Back cover: *Quercus chapmanii*, Ron Lance

Design
John Morgan. www.seascapedesign.co.uk

Conservation Gap Analysis of Native

U.S. Oaks

July 2019

Emily Beckman[1], Abby Meyer[2], Audrey Denvir[3], David Gill[4], Gary Man[5], David Pivorunas[5], Kirsty Shaw[6], and Murphy Westwood[1,6]

[1]The Morton Arboretum [2]Botanic Gardens Conservation International, U.S. [3]University of Texas, Austin
[4]Fauna & Flora International [5]USDA Forest Service [6]Botanic Gardens Conservation International

The Morton Arboretum

BOTANIC GARDENS CONSERVATION INTERNATIONAL

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

FAUNA INTERN

Quercus garryana (Emily Beckman)

ACKNOWLEDGEMENTS

Many thanks to all who provided *ex situ* accessions data, shared spatial distribution points, reported conservation activities, and contributed to species profiles. These data are critical to a successful conservation gap analysis and we hope the results presented in this report provide a valuable resource for directing future oaks conservation initiatives. A special thanks to NatureServe, BONAP, and USDA PLANTS for providing valuable *in situ* occurrence data. And many thanks to the Quercus Multisite group of the American Public Gardens Association Plant Collections Network (PCN) for sharing *ex situ* collections data, as well as providing firsthand accounts of collecting expeditions and conservation research. A full list of contributors can be found in Appendix A. Finally, thanks to the USDA Forest Service, the Science & Conservation Department and leadership team of The Morton Arboretum, Botanic Gardens Conservation International (BGCI), and the Stanley Smith Horticultural Trust for making this project possible through financial and organizational support.

ACRONYMS

AOO	Area of Occupancy
BGCI	Botanic Gardens Conservation International
BONAP	Biota of North America Program
CAE50	Combined Area *Ex situ*
CAI50	Combined Area *In situ*
EOO	Extent of Occurrence
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FIA	Forest Inventory and Analysis
FNAI	Florida Natural Areas Inventory
GBIF	Global Biodiversity Information Facility
NGO	Non-governmental Organization
IOS	International Oak Society
IUCN	International Union for Conservation of Nature
PAD-US	U.S. Geological Survey Gap Analysis Program Protected Areas Database
PCA	Plant Conservation Alliance
PCN	Plant Collections Network
SERNEC	SouthEast Regional Network of Expertise and Collections
USDA	United States Department of Agriculture
USDI	United States Department of the Interior

IUCN RED LIST THREAT CATEGORIES

- **CR** Critically Endangered
- **EN** Endangered
- **VU** Vulnerable
- **NT** Near Threatened
- **LC** Least Concern
- **DD** Data Deficient

NATURESERVE GLOBAL THREAT RANKS

- **G1** Critically Imperiled
- **G2** Imperiled
- **G3** Vulnerable
- **G4** Apparently Secure
- **G5** Secure
- **GNR** Not Ranked

Quercus dumosa (Abby Meyer)

EXECUTIVE SUMMARY

Quercus ajoensis (Beth Fallon)

Oaks are critical to the health and function of forest and shrubland habitats in the United States, but many native oaks are threatened with extinction in the wild. Ongoing conservation efforts exist for some species, but with growing threats and limited resources and time, prioritization and coordination of conservation actions is critical. To facilitate these efforts, we conducted a comprehensive survey of both the achievements and most urgent needs for *in situ* (on-site) and *ex situ* (off-site) conservation of priority at-risk oak species in the U.S.

Of the 91 native U.S. oaks, we identified 28 species of conservation concern based on extinction risk, vulnerability to climate change, and representation in *ex situ* collections. For each of these 28 species we completed an in-depth analysis of native distribution and ecology, status of wild populations, threats, geographic and ecological coverage of *ex situ* collections, and current conservation actions. This report presents a summary of these results for native oaks across the U.S., examining patterns in threats and conservation efforts for the most at-risk species. We also provide detailed summaries of findings (species profiles) for each of the 28 species of concern, which include clear recommendations for the most urgently needed conservation activities.

The 28 species of conservation concern are concentrated in a few regional hotspots, such as coastal southern California (including the Channel Islands), southwestern Texas, and the southeastern U.S. (Florida, southern Alabama, coastal Georgia and South Carolina). About half of the species of concern are trees and the other half are shrubs. Climate change is the most common threat among all species of concern, with over 80% of the species impacted or predicted to be impacted by shifting climate. Human modification of natural systems (e.g., disturbance regime modification, pollution) and human use of the landscape (e.g., development, mining, roads) are the next most common threats, each affecting 75% of the species.

To form a clear picture of current efforts to protect at-risk oaks, we conducted a conservation action questionnaire. A total of 331 individuals from 255 organizations submitted responses to the questionnaire, representing a range of sectors including private companies, NGOs, governing bodies (city, county, state, national), and universities. Respondents most commonly reported conservation actions for species of concern with lower vulnerability, and for species with native distributions in the southeastern U.S. The conservation actions most frequently reported included population surveys (40 institutions, 24 species), propagating germplasm (34, 25), and collecting wild germplasm (26, 26), while the actions least commonly reported were conservation genetics research (12, 17) and reintroduction and/or translocation (11, 12).

We also conducted an *ex situ* collections survey for all native U.S. oak species. A total of 162 institutions from 26 countries submitted accessions data in response. The 91 native U.S. oak species are collectively represented by more than 30,000 plants living in *ex situ* collections globally, though there is a wide range in the number of *ex situ* plants per species. The majority of plants in *ex situ* collections are of unknown or horticultural origin. Only 44% of plants are documented as wild origin, and approximately 7% of these have no locality information. While some oak species of conservation concern have been the focus of extensive collecting efforts, many are poorly represented in *ex situ* collections. Nine species of conservation concern are represented by fewer than 15 plants in *ex situ* collections and four species of concern aren't held in any collections in North America. We estimate that 20 of the 28 species of concern have less than 50% of their native U.S. geographic range represented in *ex situ* collections, and 13 species have less than 50% of their ecological diversity represented. For each species of conservation concern, we provide maps that inform future collecting efforts by identifying populations that are geographically and/or ecologically underrepresented in *ex situ* collections.

It is clear that botanic gardens and arboreta, government agencies at all levels, universities, and conservation organizations are doing important work to advance the conservation of U.S. oaks at risk of extinction. Collaboration and coordination across institutions and sectors is critical for effective species conservation, as no one institution can do all activities for all species. Cross-sector collaborative efforts to protect at-risk oak species have proven to deliver results. Despite the many challenges—such as clear communication of activities and efficient data sharing—these multi-disciplinary partnerships have the most promise for future conservation impact. This gap analysis of U.S. oaks is designed to eliminate some of these challenges and facilitate the sharing of information and development of partnerships. By providing actionable recommendations and a list of stakeholders currently engaged in conservation efforts for the 28 oak species of conservation concern, we hope this report will catalyze efforts to preserve our native oaks for generations to come.

INTRODUCTION AND OBJECTIVES

Pepperwood Preserve, California (Emily Beckman)

Oaks play a critical role both ecologically and economically in North America, with more than 200 oak species known across Canada, Mexico, and the United States. Wide diversity in leaf morphology, habit, and climatic adaptations allow oaks to exist in most major terrestrial habitats of North America. These keystone species provide critical food and habitat for animals, and sustain essential ecosystem services, including carbon storage, erosion and flood control, and air quality maintenance. Oaks are also valuable sources of timber, livestock feed, tannins, and other products.

In the United States, there are 91 native oak species, 16 of which are listed by the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (hereafter "IUCN Red List") as globally threatened with extinction. *The Red List of US Oaks* (Jerome *et al*., 2017) identifies the threats to oaks, including habitat loss, natural systems modification, land use change, climate change, and pests and diseases. A conservation gap analysis—a comprehensive evaluation of conservation needs and successes, both *in situ* (on-site, within native habitats) and *ex situ* (off-site, within living collections or seed banks)—has never been completed for oaks. This type of analysis can be used to identify broad conservation and threat trends across a genus as a whole, in addition to providing a clear picture of the current state of conservation for each species. It can also guide efforts among the conservation community to promote closer coordination, enabling efficient use of limited resources for conservation action.

There are several conservation challenges associated with oaks that necessitate conservation gap analysis and coordination of efforts. Oak acorns are recalcitrant, meaning they are unable to survive the drying and freezing conditions of a conventional seed bank. They are therefore dependent on alternative methods of long-term *ex situ* preservation including living plant collections and cryogenic tissue preservation. Because oaks are long lived, slow to reproduce, and can be huge canopy trees, living collections of high conservation value must be spread across many institutions working in close coordination. Oaks also prove to be very difficult to propagate vegetatively. They do not root easily from cuttings and produce high levels of tannins, which make tissue culture protocols difficult to optimize. Lastly, hybridization among oak species is common, which can make species identification challenging when collecting seed in the wild. Hybridization can also cause problems when using *ex situ* collections to produce acorns of "true species" amidst a high concentration of many potentially-interbreeding oak species.

In light of these challenges, we conducted a conservation gap analysis of native U.S. oak species. Our goal was to better understand the state of conservation needs and opportunities for U.S. oaks, and to provide a clear road map forward for the community of researchers, land managers, and conservationists working to protect these important trees. By integrating multiple threat metrics and platforms, we were able to identify potentially vulnerable species outside those listed as threatened by the IUCN Red List and NatureServe. This ensures a comprehensive and proactive conservation strategy for species that are currently threatened, as well as those that may be at risk in the near future. For each species of concern, we determined a set of specific recommendations to guide conservation efforts by characterizing the following:

- Native distribution, including protected area coverage
- Threats to species; past, present, and predicted
- Conservation value of existing *ex situ* collections in botanic gardens and arboreta globally
- *In situ* and *ex situ* conservation activities; past, present, and planned

This analysis utilized a new approach to determine the conservation value of *ex situ* collections, and relied on a broad array of input and participation by the oak conservation community to vet spatial data, report conservation activities, and aid in the formation of conservation recommendations. This report includes a genus-wide summary of results for oaks across the entire U.S., as well as 28 individual species profiles that go into greater detail for each species of concern. The results are designed to facilitate easy comparison of circumstances across all of the species of concern, allowing identification of the activities and species of greatest conservation urgency. Although this analysis, like any prioritization methodology, has inherent limitations and biases, our overarching goal is to provide information that can be useful to botanic garden staff, conservationists, land managers, private individuals, and researchers. This report aims to guide scientifically informed and strategic use of limited time and resources to protect U.S. oaks of conservation concern.

METHODS

Quercus acerifolia (Deb Brown)

U.S. OAK SPECIES RICHNESS

We began by looking broadly at native oaks in the U.S. to assess national distribution patterns. We combined county level occurrence data from USDA PLANTS and Biota of North America Program (BONAP) to determine species richness within each county and create a heat map based on these values. This provided an estimate of oak diversity hotspots in the U.S. States gather species occurrence data in slightly different ways, sometimes resulting in abrupt changes in apparent species richness across state borders on the heat map. These differences do not reflect actual species distribution patterns.

EX SITU COLLECTIONS

In January 2017 we distributed a request to institutions with *ex situ* collections to provide their *Quercus* accessions data including any associated wild provenance details. Data were accepted through July 2017. The following collections were targeted for the *ex situ* collection survey:

- Arboreta accredited at Level III or IV through ArbNet
- Institutions that reported holding native U.S. oak species to the BGCI PlantSearch database
- Participants of the *Global Survey of* Ex situ *Oak Collections* (BGCI, 2009)
- The *Quercus* Multisite group of the American Public Gardens Association Plant Collections Network

The final contact list included over 500 institutions globally, whose curators and plant record managers were emailed directly. We also reached a broader audience through a BGCI online news story and Cultivate newsletter, International Oak Society (IOS) newsletter article, American Public Gardens Association professional development community board posts, Plant Conservation Alliance (PCA) Listserv email, and social media outreach.

To create a unified dataset, we used R scripts to standardize, filter, and compile all submitted accession records. A field naming scheme was manually applied to each dataset, for merging and comparing records among all contributing institutions. Specific data fields that were standardized include: provenance type (wild, cultivated from wild, horticultural, unknown), location within garden (nursery, greenhouse, collections, propagation), and number of plants alive. The dataset was also refined to include records for species and botanical taxa only, and exclude hybrids as well as cultivars listed without a specific epithet. Finally, we added or standardized latitude and longitude coordinates for wild collection locations when possible. When coordinates were not provided by an institution, we manually geolocated each accession using locality and source data, other spatial information available online, or coordinates provided from another accession with the same locality description. We also created a field to record how each coordinate pair was assigned. When only county level locality data were provided, we assigned a geographic county centroid; these are the coarsest data included in the spatial dataset.

Some assumptions were made during the compilation of *ex situ* collections data. First, we assumed all reported accessions to be living plant specimens because oak acorns are recalcitrant and cannot easily be stored using conventional seed banking methods (species with recalcitrant seeds are also known as exceptional species). Throughout this report, "*ex situ* collections" is used as an equivalent of "living collections", however it is possible a small number of accessions are held in a pollen bank, in tissue culture, or in cryopreservation. Second, for the 2017 *ex situ* collections survey, institutions were asked to report the number of individuals representing each accession. When these data were not available or provided, we assumed the accession consisted of one individual. Therefore when number of plants is reported in analyses, it represents a minimum estimate of the total number of plants in *ex situ* collections. Lastly, the term "accession" can have slightly different meanings and situational applications across institutions. We assumed the definition of accession to be, "plant material (individual or group) of a single taxon and propagule type with identical or closely similar parentage acquired from one source at the same time" as defined in *From Idea to Realisation – BGCI's Manual on Planning, Developing and Managing Botanic Gardens* (Gratzfeld, 2016).

SPECIES OF CONSERVATION CONCERN

To begin prioritizing the 91 native U.S. oaks, we identified species of conservation concern (hereafter "species of concern") by integrating the following metrics:

- *The Red List of US Oaks* (Jerome *et al*., 2017): species ranked as Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), or Data Deficient (DD)
- NatureServe conservation status ratings (NatureServe, 2017): species ranked Critically Imperiled (G1), Imperiled (G2), Vulnerable (G3), or Apparently Secure (G4)
- USDA Forest Service Project CAPTURE risk assessment of tree species' vulnerability to climate change (Potter *et al*., 2017): species falling within any of the vulnerability categories (A-E) of the study
- *Ex situ* representation, based on the 2017 *ex situ* collections survey conducted as part of this study: less than 20 plants in *ex situ* collections and/or less than ten *ex situ* institutions containing the species

Each native U.S. oak species was assigned a certain number of points per metric based on its level of severity (e.g., for The Red List of US Oaks, CR = 5 points, EN = 4 points, VU = 3 points, NT = 2 points, DD = 1 point, LC = 0 points; for a complete summary of how points were allocated for each metric, see Appendix B). A total score was calculated for each species across all metrics. Species with more than three total points were deemed "species of concern" for this report. The threshold value of three was determined because it 1) captured all of the species assessed in a category of conservation concern listed by the IUCN Red List and NatureServe, 2) resulted in a manageable number of species to evaluate within the scope of this study, and 3) reflected a natural break in the data we included. Species with less than 10% of their native distribution within the U.S. were not included as species of concern.

Quercus boyntonii in its typical habitat: sandstone outcrop within pine-oak-hickory forest of Alabama (Sean Hoban)

Population of *Quercus oglethorpensis* in Bienville National Forest, Mississippi (Matt Lobdell)

VULNERABILITY OF WILD POPULATIONS

We quantitatively assessed the vulnerability status of wild populations of the U.S. oak species of concern through a scoring matrix that calculates an average vulnerability score for each species (Table 1). This matrix allows for visualization of the specific demographic factors driving the final vulnerability score for each species and provides a means of comparison and prioritization across species. Higher average vulnerability scores represent species with the most at-risk populations. The scoring matrix considers six factors relating to demographic circumstances of the species in the wild, and ranks each as emergency, high, moderate, low, or no vulnerability. Four factors are modeled after assessment criteria used by the IUCN Red List and/or NatureServe: population size, range and/or endemism, population decline, and fragmentation. Specific qualitative and quantitative thresholds for these indicators are based on thresholds used within the IUCN Red List. Two additional demographic indicators not explicitly measured by IUCN Red List or NatureServe assessment methodologies are included: regeneration and/or recruitment and genetic variation and/or integrity (Table 2). These additional indicators provide the opportunity to more precisely pinpoint the various dimensions of vulnerability facing species in the wild. They also play a significant role in the vulnerability of certain oak species. While these six demographic indicators rarely act in isolation (e.g., a species with an extremely small population size is also likely to exhibit low genetic diversity), by evaluating them individually and scoring them in a matrix, the main demographic risks to populations in the wild become clear. This type of visualization and cross-species comparison provides additional context to an IUCN Red List or NatureServe assessment.

The vulnerability scoring matrix (Table 1) can be considered a visualization of the symptoms of threat, without making assumptions or drawing conclusions about underlying causes (i.e., the threats). Each vulnerability category was assigned a score, with an increasing score as vulnerability increases in severity. For example, a factor evaluated as "emergency" received a score of 40, whereas a "low" vulnerability factor received a score of five. The scores for each factor were used to calculate an overall average vulnerability score per species. If the vulnerability for a particular factor could not be determined due to lack of information, the factor was ranked as "unknown" and given no score. Unknown factors were not included when calculating average vulnerability score, so as not to down weight the final scores for poorly understood species.

Table 1. Vulnerability scoring matrix identifying the most severe demographic issues affecting each U.S. oak species of conservation concern. A hypothetical species has been used to complete the matrix. Cells are highlighted where the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only demographic indicators with sufficient data (i.e., excluding unknown indicators) and allows for objective comparison among species. Descriptions of the demographic indicators can be found in Table 2.

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	10
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	5
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	40
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	–
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	0
						Average vulnerability score	15

Table 2. Descriptions of demographic indicators contributing to the average vulnerability score.

Demographic indicator	Description
Population Size	Number of mature individuals that are reproductively mature (IUCN, 2012).
Range/endemism	Three different measures can be used to assess this factor, including extent of occurrence (EOO), area of occupancy (AOO), and number of locations, as defined by IUCN. EOO = "the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon" (IUCN, 2012); AOO = the area within a taxon's EOO that is actually occupied by the taxon (IUCN, 2012); location = "a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present" (IUCN Standards and Petitions Subcommittee, 2017). This indicator is meant to capture the risk of extinction associated with the size and/or spatial characteristics of a species' range; including the likelihood that one threatening event could wipe out all subpopulations.
Population decline	Past, current, or predicted future reduction in population size over ten years or three generations, whichever is longer (IUCN, 2012).
Fragmentation	Isolation of subpopulations from each other. Includes genetic isolation either at the pollen or seed level, and/or the likelihood that a nearby subpopulation can recolonize a locally extirpated subpopulation. The IUCN Standards and Petitions Subcommittee (2017) considers a species severely fragmented when "most (>50%) of its total area of occupancy is in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance."
Regeneration/recruitment	Reproductive ability of the species. Includes factors such as pollen and seed production, viability, and seedling establishment. While oaks do use masting and vegetative reproduction strategies, many species are suffering from a lack of regeneration, establishment, and/or sexual reproduction, which have negative impacts on the demographic structure of a species or population.
Genetic variation/integrity	Quality and depth of the gene pool. Takes into account issues such as inbreeding, levels of heterozygosity, and introgression with other species.

THREATS TO WILD POPULATIONS

Based on extensive literature review and expert input, we identified the root causes (i.e., threats) driving the decline of wild populations identified in the vulnerability matrix. Using the Threats Classification Scheme (Ver. 3.2) of the IUCN Red List (Conservation Measures Partnership, 2016), we identified 10 threat categories that applied to the U.S. oak species of concern:

- Human use of species: wild harvesting
- Human use of landscape: agriculture/silviculture/ranching/grazing
- Human use of landscape: residential/commercial development/mining/roads
- Human use of landscape: tourism/recreation
- Human modification of natural systems: disturbance regime modification/pollution/eradication
- Human modification of natural systems: invasive species competition
- Climate change: habitat shifting/drought/temperature extremes/flooding
- Genetic material loss: inbreeding/introgression
- Pests/pathogens
- Extremely small/restricted population

Each threat category was individually considered regarding severity, likelihood, and distribution among subpopulations for each species of concern, and ranked as high, medium, low, or no impact. These rankings were used to determine the most impactful threats to each species of concern, which, in combination with known conservation activities (see below), aided in the prioritization of recommended conservation actions. Current threats, lasting impacts of past threats, as well as predicted threats were all considered. Individual species were not limited in the number of threats that could apply. Threat rankings are meant to identify the factors most impacting a specific species, and are not quantitatively comparable between species (i.e., the same threat may have the strongest impact on two different species and thus ranked high for both, but could be impacting one species more severely than the other).

CONSERVATION ACTIVITIES

We examined past, present and future planned conservation activities for each U.S. oak species of concern. *The Global Strategy for Plant Conservation 2011-2020* (Conference of the Parties, 2011), North American Botanic Garden Strategy for Plant Conservation 2016-2020 (BCGI, 2016), IUCN Conservation Actions in Place and Conservation Actions Needed Classification Schemes (Ver. 2.0; Conservation Measures Partnership, 2016), and Global Trees Campaign Addendum from the ArbNet Arboretum Accreditation Program application (The Morton Arboretum, 2017) were used to identify 10 conservation action categories.

The 10 conservation action categories include:

- Land protection
- Sustainable management of land
- Population monitoring/occurrence surveys
- Wild collecting/*ex situ* curation
- Propagation/breeding programs
- Reintroduction/reinforcement/translocation
- Research
- Education/outreach/training
- Species protection policies
- Sustainable management of species

Conservation Action Questionnaire

In addition to literature review and expert input, we examined conservation activities for each U.S. oak species of concern by distributing a conservation action questionnaire to gather data on past, present, or planned *in situ* and *ex situ* conservation initiatives. Through extensive research we compiled a targeted and diverse contact list for the questionnaire, which included individuals and organizations outside of the botanic garden community. However, we look at these findings as a minimum estimate of the conservation actions for each species. In June and July 2017, we directly emailed a link to the questionnaire to over 1,000 recipients including:

- USDA Forest Service regional botanists and geneticists, land managers, and oak experts
- All 500+ institutions contacted for the 2017 *ex situ* collections survey
- International Oak Society members, via a newsletter article and website article
- Plant Conservation Alliance (PCA) Listserv
- Collaborating researchers at universities
- Center for Plant Conservation (CPC) participating institutions
- Attendees of the 2016 USDA Forest Service Conference "Gene Conservation of Forest Trees: Banking on the Future"
- SEINet and SERNEC herbaria consortium institutional collaborators
- Relevant organizations working in states where the species of concern naturally occur, including:
  - Native plant societies
  - NGOs (e.g., foundations, conservancies, land trusts, research institutes, conservation trusts)
  - State natural heritage program botanists
  - State-level forestry and land management departments (e.g., fish and wildlife, natural resources, environmental protection, conservation agencies)
  - USDI Bureau of Land Management field offices and National Park Service regional directors

If more than one individual from an institution reported the same conservation activity for a specific species of concern, these responses were counted as a single report of the activity.

Spatial Analyses

To create a set of high-confidence data points representing the known native U.S. distribution of each species of concern, we compiled and standardized a variety of spatial point datasets. Dataset manipulation was performed using R scripts. A species' native distribution outside the U.S. was not considered in this study, due to incongruence among national spatial datasets needed for this analysis. Raw spatial point data sources for U.S. oak species of concern included:

- Global Biodiversity Information Facility (GBIF); downloaded March 2018 (gbif.org)
- Herbaria Consortiums, downloaded February 2018 via SERNEC (SouthEast Regional Network of Expertise and Collections) Data Portal (sernecportal.org)
- iDigBio Integrated Digitized Biocollections; downloaded May 2018 (idigbio.org)
- Hipp *et al*. (2017) occurrence point dataset (github.com/andrew-hipp/oak-convergence-2017)
- The national network of forest survey plots managed by the Forest Inventory and Analysis Program (FIA) of the USDA Forest Service; downloaded July 2018 (fia.fs.fed.us/tools-data). Data points may be "fuzzed" by up to one mile by FIA, but this margin of error is not likely to have a significant effect on the results of the spatial analysis.
- Communication with experts, including records from collection trips and research projects
- Geolocated wild provenance localities of the accessions from the 2017 *ex situ* collections survey
- Florida Natural Areas Inventory (FNAI); received August 2017 (fnai.org)
- The Alabama Natural Heritage Program; downloaded August 2017 (alnhp.org)
- State plant atlases, including Alabama Plant Atlas and Atlas of Florida Plants; downloaded August 2017 (floraofalabama.org; florida.plantatlas.usf.edu)
  - When no other spatial data points existed for a county in which there was a reported species of concern, the county centroid was used. These coarser-level datasets include:
  - Biota of North America Program (BONAP); received June 2018 (Kartesz, 2018; bonap.net)
  - NatureServe; downloaded June 2017 (explorer.natureserve.org)
  - USDA PLANTS Database, maintained by the Natural Resources Conservation Service; received May 2017 (plants.usda.gov)

For each species of concern, we utilized these documented *in situ* occurrence point datasets in combination with geolocated wild provenance records from the 2017 *ex situ* collections survey to approximate how well current *ex situ* collections represent the geographical and ecological breadth of wild populations. This included identification of populations and ecoregions not yet represented in living *ex situ* collections. Based on methods outlined in Khoury *et. al*. (2015), circular buffers with a radius of 50 km were placed around each *in situ* occurrence point. Each point plus its buffer zone provided an approximation of distinct populations, and taken collectively serve as the inferred native range of the species. A radius of 50 km was chosen because this appears to be the reasonable maximum distance that wind-dispersed oak pollen has been found to travel (Ashley *et al*., 2015; Schueler & Schlünzen, 2006). A 50 km buffer was also placed around the source locality point of each plant living in *ex situ* collections, together representing the native distribution "captured" in *ex situ* collections. We estimated geographic and ecological coverage of *ex situ* collections using the following formulas:

CAE50 = (Combined Area *Ex situ*) Combined total area of 50 km circular buffers around *ex situ* accession wild provenance collection points
CAI50 = (Combined Area *In situ*) Combined total area of 50 km circular buffers around all documented *in situ* occurrence points
Ecoregions = U.S. Environmental Protection Agency (EPA) Level IV Ecoregions of the Conterminous United States (U.S. EPA Office of Research & Development, 2013)

Geographic coverage = CAE50 / CAI50
Ecological coverage = # of Ecoregions in CAE50 / # of Ecoregions in CAI50

For each species of concern, we also estimated the proportion of the inferred native range (CAI50) within protected areas. This was calculated by finding the spatial intersection of CAI50 and the U.S. Geological Survey Gap Analysis Program 2016 Protected Areas Database (PAD-US; Version 1.4).

PRIORITY CONSERVATION ACTIONS

The identified threats to wild populations were compared with reported past, current and planned conservation activities. This allowed identification of priority conservation actions, which should be continued, strengthened, and/or initiated to appropriately address each species' circumstances. Expert reviewers were identified for each U.S. oak species of concern, and invited to confirm species data and provide recommendations for activities they believed will be most beneficial to the future stability or recovery of the species.

Scrubby flatwoods of central Florida, dominated by *Quercus inopina* (Ron Lance)

Quercus alba (Emily Beckman)

RESULTS AND ANALYSIS

U.S. OAK SPECIES RICHNESS

There are 91 oak species native to the United States, many of which are keystone species across the majority of forest and shrubland habitats in the U.S., with the highest diversity located in the southern half of the country (Figure 1). The major hotspot for oak diversity spans the Southeast, including North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Arkansas. Southern California and Brewster County in southwestern Texas also contain considerable oak species diversity. See *The Red List of US Oaks* (Jerome *et al.*, 2017) for more details regarding *Quercus* distribution, as well as ecological information, at both genus-wide and species levels.

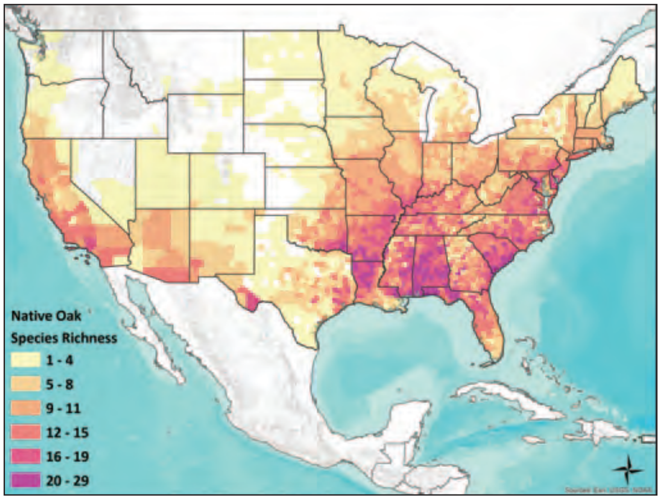


Figure 1. Native U.S. oak species richness by county. County level distribution data from USDA PLANTS and Biota of North America Program (BONAP) have been combined to estimate species richness.

EX SITU COLLECTIONS OF ALL U.S. OAKS

A total of 162 institutions from 26 countries submitted accessions data in response to our *ex situ* collections survey of native U.S. oak species (Figure 2; Appendix C). This included all 20 member institutions of the Quercus Multisite collection of the Plant Collections Network, a long-term collaboration between the American Public Gardens Association and the USDA Agricultural Research Service that provides coordination among Nationally Accredited Plant Collections. Respondent institutions located within the United States total 89 (55%). Of the institutions reporting U.S. oak species, 86 (53%) reported species of concern, and 52 (32%) provided enough data to geolocate wild collection locations of species of concern to at least county level.

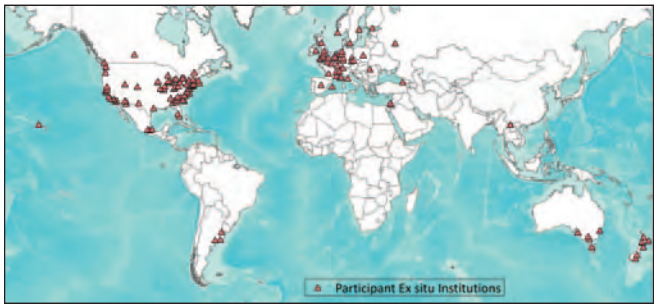


Figure 2. Location of the 162 institutions that responded to the *ex situ* collections survey of native U.S. oak accessions data.

The 91 native U.S. oak species are represented by at least 34,167 plants living in *ex situ* collections globally. There is a wide range in the number of *ex situ* plants per species—over three orders of magnitude difference between the most and least common species in collections (*Q. rubra* [4018 plants], *Q. tardifolia* [0 plants]; Figure 3). Four species are represented by over 2,000 individuals each (*Q. alba, Q. bicolor, Q. macrocarpa, Q. rubra*), but the majority of U.S. oak species are represented by fewer than 150 plants in *ex situ* collections. The majority of plants in *ex situ* collections are of unknown or horticultural origin (39% and 17%, respectively). Only 44% of plants are documented as wild origin, and approximately 7% of these have no source information. This pattern was fairly consistent within each species, with the exception of *Q. ajoensis, Q. carmenensis, Q. cedrosensis, Q. chihuahuensis, Q. depressipes*, and *Q. similis*, which are represented exclusively by wild origin plants, though each has less than ten plants in *ex situ* collections. There are five species whose cultivated plants are of at least 75% wild origin and also number more than 500 (*Q. agrifolia, Q. douglasii, Q. engelmannii, Q. lobata, Q. stellata*). *Quercus alba* is the species with the most wild origin plants in collections (1,555 individuals; 49% of total accessions), while four species are represented by less than 20% wild origin plants (*Q. coccinea, Q. palustris, Q. rubra, Q. virginiana*). No species has zero wild origin plants in *ex situ* collections, with the exception of *Q. tardifolia*, which is not currently held in any *ex situ* collections.

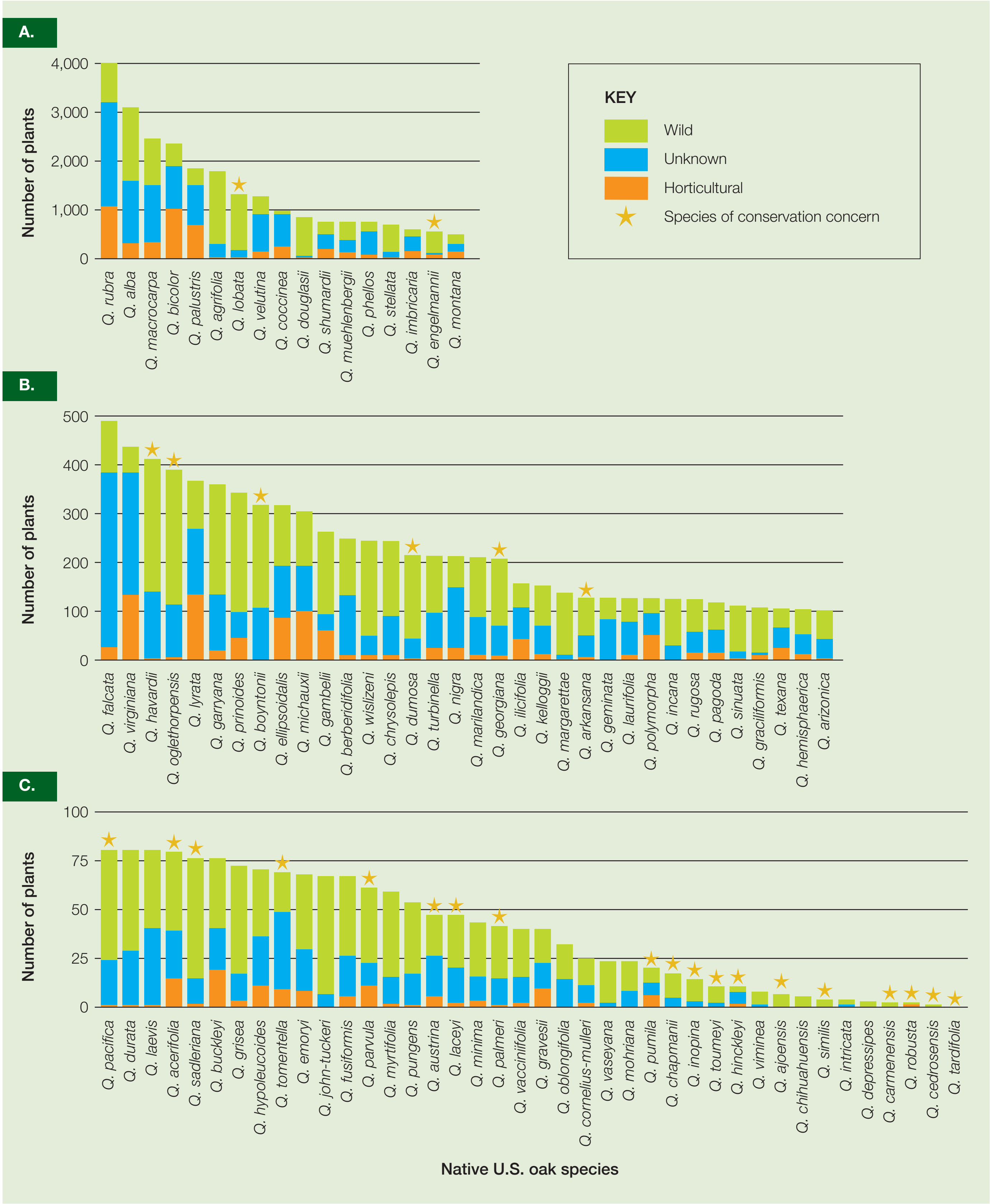


Figure 3. *Ex situ* collections survey results for all native U.S. oak species: number of plants per species in *ex situ* collections, categorized by provenance type. **(A)** Species with more than 500 plants in *ex situ* collections. **(B)** Species with 100-500 plants in *ex situ* collections. **(C)** Species with fewer than 100 plants in *ex situ* collections. Note change in scales. See Appendix C for exact numbers of plants in *ex situ* collections.

Twenty-one (23%) native U.S. oak species can be found in more than 50 *ex situ* collections globally, but 16 (18%) are represented in fewer than ten collections (Figure 4). *Quercus inopina* is found in only five *ex situ* collections; *Q. ajoensis, Q. intricata, Q. toumeyi*, and *Q. viminea*, are found in three collections; *Q. chihuahuensis, Q. robusta*, and *Q. similis* are found in two collections; *Q. carmenensis*, *Q. cedrosensis*, and *Q. depressipes* are in one collection; *Q. tardifolia* is not held in any *ex situ* collections. Six species (*Q. ajoensis, Q. carmenensis, Q. chihuahuensis, Q. depressipes, Q. robusta, Q. similis*) are only found in European *ex situ* collections, and one species (*Q. cedrosensis*) is only found in a North American collection. Most *ex situ* collections that hold U.S. oak species are located in North America (97, 60%), but a substantial number of collections are in Europe (46, 28%) and Oceania (16, 10%), with a few in South America (2, 1%) and Asia (1, <1%). See Appendix C for a table of the results presented in Figure 3 and 4.

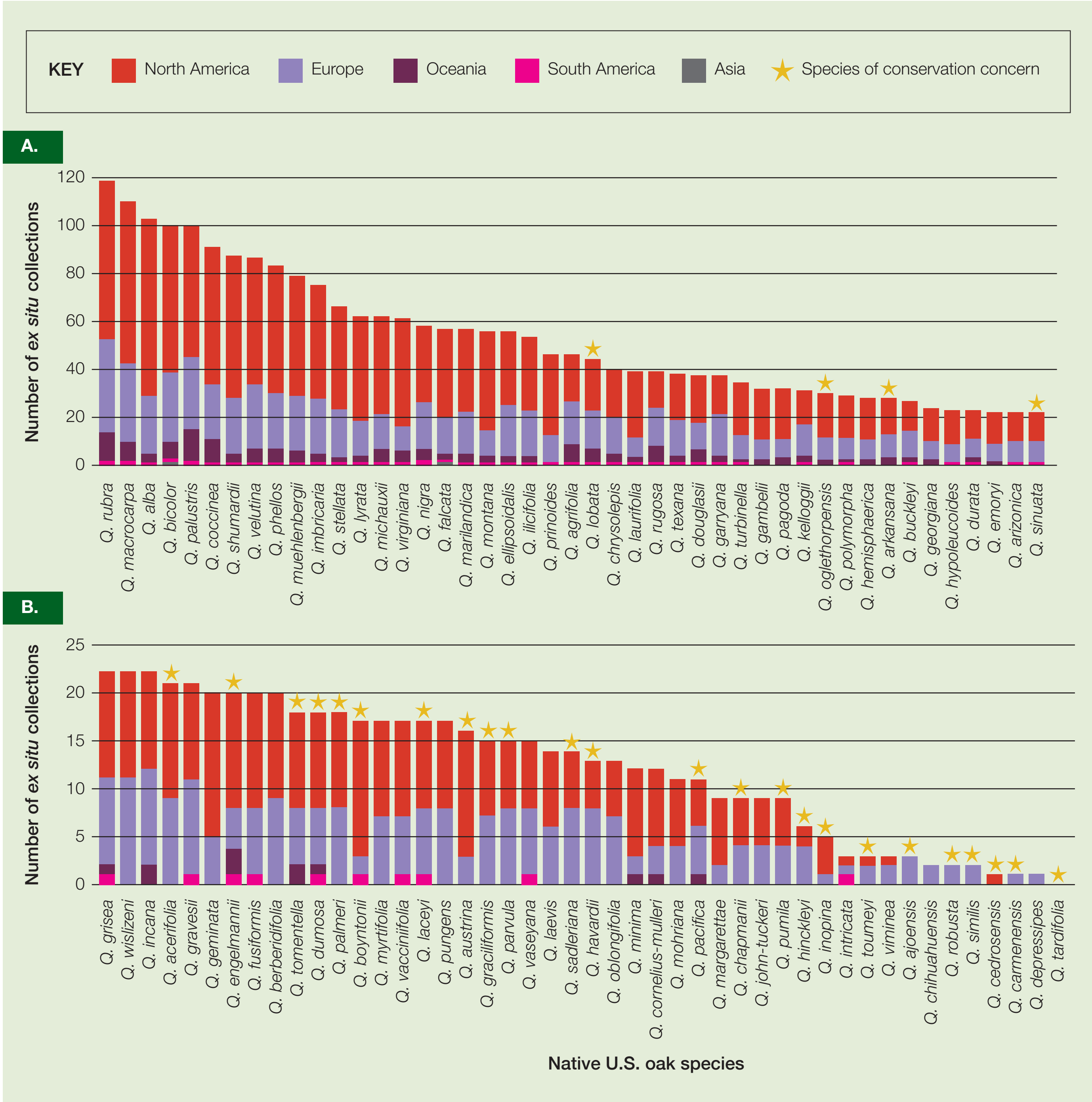


Figure 4. *Ex situ* collections survey results for all native U.S. oak species: number of *ex situ* collections per species, categorized by *ex situ* collection location. **(A)** Species in more than 25 *ex situ* collections. **(B)** Species in fewer than 25 *ex situ* collections. Note change in scales.

SPECIES OF CONSERVATION CONCERN

We identified 30 U.S. oak species of conservation concern, two of which were removed because less than 10% of their native distribution is within the U.S., resulting in a final list of 28 species of concern (Table 3; Appendix B). These are not the only native U.S. oak species necessitating conservation action, but rather provide a starting point as to the current species and regions of priority for U.S. oak conservation.

Results and recommendations for each U.S. oak species of conservation concern are presented in Appendix E. Results include native distribution and ecology, status of wild populations, threats, known *ex situ* accessions, conservation actions reported in the questionnaire and other known conservation activities, and conservation gaps and recommendations. Species profiles are presented in alphabetical order but can also be categorized as follows:

- California
  - Channel Island endemics: *Q. pacifica, Q. tomentella*
  - Southern region: *Q. cedrosensis, Q. dumosa, Q. engelmannii*
  - Northern region and/or broad distribution: *Q. lobata, Q. parvula, Q. sadleriana*

- Southwestern U.S.
  - Texas limited-range endemics: *Q. carmenensis, Q. graciliformis, Q. hinckleyi, Q. robusta, Q. tardifolia*
  - Concentrated in Arizona: *Q. ajoensis, Q. palmeri, Q. toumeyi*
  - Broad distribution: *Q. havardii, Q. laceyi*

- Southeastern U.S.
  - State endemics: *Q. acerifolia, Q. boyntonii*
  - Concentrated in Florida: *Q. chapmanii, Q. inopina, Q. pumila*
  - Broad distribution: *Q. arkansana, Q. austrina, Q. georgiana, Q. oglethorpensis, Q. similis*

The 28 species of concern are located almost entirely in the southern and western U.S. (Figure 5). Hotspots are found in coastal California (including the Channel Islands), western Texas, southern Alabama, Florida, and coastal Georgia and South Carolina. About half of the species of concern are small trees and the other half shrubs. All of the shrubs are located in the western U.S. except *Quercus chapmanii, Q. inopina*, and *Q. pumila*, which occupy coastal scrub and flatwood habitats, especially in Florida. Of the other oak species of concern in the Southeast, the majority *(Q. acerifolia, Q. arkansana, Q. austrina, Q. boyntonii, Q. georgiana*) prefer fairly specialized habitats that generally include some combination of bluffs, steep slopes, sandy soil, and rock outcrops. *Quercus oglethorpensis* and *Q. similis* are the remaining southeasterly oaks and inhabit more moist areas. In the West, rare oaks occupy a variety of habitats, including moist woodland, deep sandy plains, and volcanic slopes. Seven species of concern in the West are trees (*Q. engelmannii, Q. graciliformis, Q. laceyi, Q. lobata, Q. robusta, Q. tardifolia*, *Q. tomentella*), six are shrubs (*Q. ajoensis, Q. dumosa, Q. havardii, Q. hinckleyi, Q. palmeri*, *Q. sadleriana*), and the remaining five species can appear in a shrub form or grow to trees. The largest species of concern is *Q. lobata*, sometimes reaching 35 meters in height (Jepson Flora Project, 2018), and the smallest is *Q. hinckleyi*, with a maximum height of 0.75 meters (Backs *et al*., 2015).

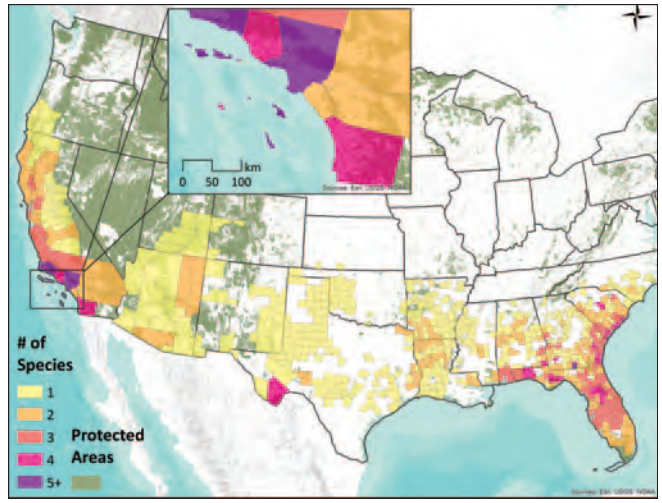


Figure 5. Species richness by county for U.S. oak species of conservation concern, with protected areas shown in green; Protected Areas Database (PAD-US) layer created by the USGS National Gap Analysis Program (GAP), last updated in May, 2016.

Of the species of concern, 16 (57%) are considered threatened (CR, EN, VU) and five (18%) have been assessed as Least Concern (LC) on the IUCN Red List; the remaining seven (25%) species are Near Threatened (NT) or Data Deficient (DD; Table 3). NatureServe ranks ten (36%) species as threatened (G1, G2), eight (29%) as Vulnerable (G3), and nine (32%) as Apparently Secure (G4, G5); one species has not yet been ranked by NatureServe (*Q. sadleriana*). The four species not considered threatened by either the IUCN Red List or NatureServe (i.e., LC and G4 or G5) were included in this analysis based on one of two factors: poor representation in *ex situ* collections (*Q. chapmanii* [16 plants, 8 collections], *Q. inopina* [14 plants, 5 collections], *Q. similis* [4 plants, 2 collections]) or severe climate change impact projections (Potter *et al.* 2017; *Q. laceyi*).

Quercus georgiana (Ryan Russell)

Table 3. List of U.S. oak species of conservation concern, showing general native distribution and habit, and threat ranks according to two widely recognized species threat assessment platforms: IUCN Red List and NatureServe. The source for habit data is *Flora of North America North of Mexico* (1997) unless otherwise indicated. Threat rankings are color coded based on the severity of threat level within each platform. IUCN Red List categories and NatureServe rankings are not directly comparable, as they employ different methodologies, but the severity of rankings generally correspond. See Appendix B for information regarding the selection process for species of conservation concern.

Species name	Native distribution	Habit	IUCN Red List threat category	NatureServe global threat rank[•]
Quercus acerifolia	W Arkansas	Tree or shrub < 15 m	EN	G1
Quercus ajoensis	S Arizona	Shrub or rarely tree 2-3 m	VU	G2G4
Quercus arkansana	E Texas, SW Arkansas, Louisiana, Alabama, Georgia, NW Florida	Tree < 15 m	VU	G3
Quercus austrina	Alabama, N Florida, Georgia, South Carolina, SE North Carolina	Tree < 20 m	VU	G4?
Quercus boyntonii	Central Alabama	Shrub < 2 m or rarely tree < 6 m	CR	G1
Quercus carmenensis	Possibly SW Texas	Shrub 0.5-2 m or tree < l2 m	EN	G2?
Quercus cedrosensis	S California	Shrub 2-3 m or tree < 5 m*	VU	G2?
Quercus chapmanii	S Alabama, Florida, SE Georgia, SE South Carolina	Shrub 0.5-3 m	LC	G4G5
Quercus dumosa	Coastal S California	Shrub 1-4 m*	EN	G2
Quercus engelmannii	S California	Tree 5-25 m*	EN	G3
Quercus georgiana	N Alabama, Georgia, N South Carolina, SW North Carolina	Tree < 15 m	EN	G3
Quercus graciliformis	SW Texas	Tree < 8 m	CR	G1
Quercus havardii	SE Utah, NE Arizona, SW Colorado, E New Mexico, NW Texas, Oklahoma	Shrub 0.3-1.5 m	EN	G4
Quercus hinckleyi	SW Texas	Shrub < 1 m	CR	G2
Quercus inopina	Central Florida	Shrub < 5 m	LC	G4
Quercus laceyi	S Central Texas	Tree 5-8 m	LC	G4
Quercus lobata	W California	Tree < 35 m*	NT	G4
Quercus oglethorpensis	NE Louisiana, Central Mississippi, Central Alabama, Georgia, W South Carolina	Tree < 20 m	EN	G3
Quercus pacifica	Channel Islands (SW California)	Shrub < 2 m or tree < 5 m*	EN	G3
Quercus palmeri	W California, Arizona	Shrub 2-6 m*	NT	G3G5
Quercus parvula	W California	Shrub 1-6 m or tree < 30 m*	NT	G4Q
Quercus pumila	SE Mississippi, Florida, S Georgia, E South Carolina, SE North Carolina	Shrub < 1 m	LC	G3G5
Quercus robusta	SW Texas	Tree < 13 m	DD	G1Q
Quercus sadleriana	NW California, SW Oregon	Shrub 1-3 m*	NT	GNR
Quercus similis	E Texas, Louisiana, Arkansas, Mississippi, Alabama, Georgia, South Carolina	Tree < 25 m	LC	G4
Quercus tardifolia	SW Texas	Tree < 15 m**	DD	G1
Quercus tomentella	Channel Islands (SW California)	Tree < 20 m*	EN	G3
Quercus toumeyi	SE Arizona, SW New Mexico, W Texas	Shrub or tree < 9 m***	DD	G4

*Jepson eFlora (Jepson Flora Project, 2018); **Rare Plants of Texas: A Field Guide (Polle, 2007); ***Trees of the American Southwest (Petrides, 2005); Q = Questionable Taxonomy; ? = Inexact Numeric Rank; [•]All G1 ranks are color coded red, although the G1 ranking overlaps with both CR and EN categories on the IUCN Red List

KEY

- Critically Endangered (CR) / Critically Imperiled (G1)
- Endangered (EN) / Critically Imperiled (G1)
- Vulnerable (VU) / Imperiled (G2)
- Near Threatened (NT) / Vulnerable (G3)
- Least Concern (LC) / Apparently Secure (G4)
- Data Deficient (DD) / Not Ranked (GNR)

VULNERABILITY OF WILD POPULATIONS

We ranked the U.S. oak species of concern based on the average vulnerability scores of their wild populations (Table 4). Three of the top four most vulnerable species of concern (*Q. tardifolia, Q. robusta, Q. graciliformis*) are located in the Chisos Mountains of Brewster County in far southwestern Texas and have very limited distributions. *Quercus hinckleyi*, with a vulnerability score equal to that of *Q. graciliformis*, is located in Presidio County, Texas, just northwest of the other three most vulnerable species. The fourth most vulnerable species, *Q. ajoensis*, has a small, fragmented distribution in the valleys of southern Arizona. *Quercus boyntonii* joins *Q. ajoensis* as fourth most vulnerable and *Q. acerifolia* follows behind in fifth; both are found on very specific habitat types and endemic to a single state: Alabama and Arkansas, respectively.

Quercus robusta (Shannon Still)

Some species of concern stand out as especially vulnerable because of the dire situation of specific demographic indicators (Table 4). *Quercus tardifolia* ranks highly (i.e., emergency or high vulnerability) or has an unknown status for every demographic indicator, with the exception of population fragmentation; though it should be noted that ongoing taxonomic debate may deem the species an uncommon hybrid. *Quercus graciliformis, Q. robusta*, and *Q. hinckleyi* also emerge with high scores in the population size and range and/or endemism demographic indicators. They, along with *Q. tardifolia*, have relatively few known individuals and are found in an area of less than 25 km^2. Though the species is still widespread across California, *Q. lobata* has the highest vulnerability score for population decline across all oak species of concern. This is due to the conversion of over 90% of the species' original habitat for development or agriculture (Standiford, 2015). *Quercus lobata* is also ranked highest in the regeneration and/or recruitment category, along with *Q. oglethorpensis*. Seven (25%) species of concern could not be ranked within this category due to a lack of data. *Quercus ajoensis* has the highest rank in the fragmentation category due to its scattering in disjunct valleys, which is likely to prevent gene flow. Finally, the genetic variation and/or integrity category is led by *Q. tardifolia, Q. robusta, Q. boyntonii*, and *Q. carmenensis*, though this demographic indicator is also lacking data; the vast majority of species of concern have no quantitative molecular data regarding levels of genetic diversity. Scores in this category are generally based on inferred levels of hybridization and introgression (based on observed hybrids and introgressed traits in the wild) or predicted inbreeding due to very small population size. *Quercus hinckleyi, Q. boyntonii, Q. georgiana, Q. oglethorpensis, Q. lobata, Q. havardii, Q. pacifica*, and *Q. tomentella* are currently the only species with genetic studies completed or underway.

We also compared vulnerability rankings to the IUCN Red List categories and NatureServe ranks for the species of concern (Table 3). All species assessed as CR on the IUCN Red List (*Q. boyntonii, Q. graciliformis, Q. hinckleyi*) fall within the top seven most vulnerable species in our analysis, and two of the three DD species have the top two average vulnerability scores (*Q. robusta, Q. tardifolia*; Figure 5). One of the fourth most vulnerable species (*Q. ajoensis*) is an outlier compared to the IUCN Red List ranking, where it is assessed as VU. This difference is mostly due to new information regarding the species' native distribution, which has been found to be smaller and more fragmented than previously believed due to more precise identification of hybrids. Based on the results of this gap analysis, we suggest the completion of a new IUCN Red List assessment for *Q. ajoensis*. *Quercus austrina* (VU) also stands out, as here it are ranked equally with or higher than four of the nine EN species. The only NT or LC species ranked above EN or VU species in our analysis are *Q. lobata* and *Q. inopina*. When compared to the NatureServe ranking system, six of the eight G1 and G2 species (*Q. acerifolia, Q. boyntonii, Q. graciliformis, Q. hinckleyi, Q. robusta, Q. tardifolia*) are among the top seven most vulnerable species in our analysis, with *Q. dumosa* (G2) and *Q. cedrosensis* (G2?) as the exceptions.

Possibly *Quercus tardifolia* (Adam Black)

Quercus hinckleyi (Emily Griswold)

Table 4. Results from vulnerability scoring matrix (see Table 1) for wild populations of U.S. oak species of conservation concern. Vulnerability scores for each demographic indicator are color coded based on severity. These scores are used to calculate the average vulnerability score for each species.

Species of concern	Demographic indicators						Average vulnerability score
	Population Size	Range / Endemism	Population Decline	Fragmentation	Regeneration / recruitment	Genetic Variation / Integrity	
Q. tardifolia	Emergency	Emergency	Insufficient data	No	Insufficient data	High	25.0
Q. robusta	Emergency	Emergency	No	High	Insufficient data	High	24.0
Q. graciliformis	High	Emergency	Low	No	Moderate	Moderate	14.2
Q. hinckleyi	High	High	Low	High	Moderate	Moderate	14.2
Q. ajoensis	Moderate	Moderate	Low	Emergency	Low	Moderate	13.3
Q. boyntonii	Moderate	High	Moderate	Moderate	Moderate	High	13.3
Q. acerifolia	Moderate	High	Low	High	Moderate	Moderate	12.5
Q. carmenensis	Low	Moderate	Low	High	Insufficient data	High	12.0
Q. georgiana	Moderate	Moderate	Moderate	High	Moderate	Moderate	11.7
Q. oglethorpensis	Moderate	Low	Low	High	High	Moderate	11.7
Q. dumosa	Moderate	Moderate	Moderate	High	Moderate	Low	10.8
Q. austrina	Insufficient data	Low	Low	High	Moderate	Moderate	10.0
Q. engelmannii	Low	Low	Moderate	High	Moderate	Insufficient data	10.0
Q. arkansana	Low	Low	Low	High	Moderate	Moderate	9.2
Q. lobata	No	No	High	Moderate	High	No	8.3
Q. pacifica	No	High	Low	High	Moderate	No	8.3
Q. tomentella	Moderate	Moderate	No	High	Low	Low	8.3
Q. cedrosensis	Low	Low	Moderate	Moderate	Insufficient data	Moderate	8.0
Q. inopina	No	Low	Low	Moderate	Moderate	Insufficient data	6.0
Q. havardii	No	No	Moderate	Moderate	Moderate	Low	5.8
Q. palmeri	No	No	No	Moderate	Moderate	Moderate	5.0
Q. parvula	Low	Low	Moderate	Low	No	Insufficient data	5.0
Q. similis	No	No	Moderate	Low	Insufficient data	Insufficient data	5.0
Q. toumeyi	No	No	Low	Low	Low	Moderate	4.2
Q. pumila	No	No	Low	Moderate	Insufficient data	Low	4.0
Q. laceyi	No	No	Moderate	Low	Insufficient data	Insufficient data	3.8
Q. chapmanii	No	No	Low	Moderate	No	Insufficient data	3.0
Q. sadleriana	No	Low	No	Low	Low	Insufficient data	3.0

Quercus graciliformis (Shannon Still)

KEY

- Emergency vulnerability; score = 40
- High vulnerability; score = 20
- Moderate vulnerability; score = 10
- Low vulnerability; score = 5
- No vulnerability; score = 0
- Insufficient data; not considered

THREATS TO WILD POPULATIONS

Climate change is the most common threat among all U.S. oak species of concern, with all 28 species impacted or predicted to be impacted at some level by shifting climate (Table 5). Human use of the landscape (e.g., residential and commercial development, mining, roads) and human modification of natural systems (e.g., fire and fire suppression, eradication, pollution) are the second and third most common threats among species of concern, affecting 22 (79%) and 20 (71%) species, respectively. Half of the 20 species impacted by human modification of natural systems are assigned high impact, and the other half are ranked as medium impact. This is the only threat category with no species assigned low impact. However, both climate change and human modification of landscape are very complex issues and rankings could significantly change with continued research, especially ongoing advancements in climate change and ecological niche modeling for oaks. When habitat is cleared for residential and commercial uses, there is a direct relationship to a species' distribution and population size; but when these habitat modifications cause a change in natural processes like fire regime or water availability, it takes time to document the ecological effects and years of research to determine appropriate management strategies for mitigation in the specific ecosystem affected. Climate change is also a multifaceted issue that will require long-term monitoring of natural areas as well as *ex situ* studies to understand the differing effects experienced across landscapes.

Wild harvesting is by far the least common threat to species of concern (Table 5). Only four (14%) species are known to be threatened by wild harvesting (*Q. boyntonii, Q. lobata, Q. similis, Q. toumeyi*), and all instances are ranked as low impact. In general there is minimal wild harvesting occurring in the U.S., compared to previous centuries, and many of the species of concern are either scrubby, providing poor timber, or located in areas that are remote or difficult to traverse (e.g., moist ravines). Tourism and/or recreation is the only other category with no species impacted at a high level. Twelve (80%) of the 15 species of concern threatened by tourism and/or recreation experience a low level of impact.

Quercus toumeyi with galls (Tim Thibault)

Dieback of a *Quercus arkansana* main stem due to fire or drought, with suckers sprouting up from roots (Jared Chauncey)

Other threats to species of concern include, listed in descending order of number of species of concern impacted: land use for ranching, agriculture, and/or silviculture (19 species; 68%); genetic material loss due to inbreeding and/or introgression (19; 68%); invasive species competition (14; 50%); extremely small or restricted populations (10; 36%); pests and/or pathogens (10; 36%).

While pests and/or pathogens have not been noted as a primary threat for many species of concern currently, this is likely due to a lack of data on current and projected future impacts of pests and disease. Sudden oak death (SOD), which is caused by the fungus *Phytophthora ramorum*, is the most common and threatening pathogen affecting U.S. oaks today (Rizzo *et al*., 2002). Of the species of concern, *Q. parvula* is at the highest risk of losing wild populations to infection and has already had significant losses; the potential of infection in *Q. arkansana* and *Q. boyntonii* has also been noted, but little effect is yet recorded. Other native U.S. oaks including Coast live oak (*Q. agrifolia*) and California black oak (*Q. kelloggii*), which are currently ranked as LC on the Red List, have been highly affected by SOD. Much concern has also been expressed regarding "oak decline." This phenomenon occurs when typically non-lethal stresses, such as drought and defoliating pests or fungal pathogens, are combined and overwhelm the oaks' defenses, potentially resulting in widespread mortality (Bendixsen *et al*., 2015). Species within the red oak group (such as the LC species *Q. velutina*, and EN species of concern *Q. georgiana*) are most susceptible to oak decline, though no native U.S. oaks are currently assessed as threatened on the Red List due specifically to levels of oak decline. Continued research and monitoring of SOD and oak decline is vital, and a re-evaluation of threat status for LC species affected by these diseases is recommended if the threat progresses in severity and/or range. Other specific pests and pathogens have been observed in the western U.S., including invasive Polyphagous and Kuroshio shot hole borers carrying the *pathogenic* fungus *Fusarium euwallaceae*—resulting in *Q. engelmannii* and *Q. lobata* decline—and California oakmoths (*Phryganidia californica*), which defoliated *Q. pacifica* on Santa Cruz Island (Stouthamer *et al*., 2017; M. Pesendorfer pers. comm., 2018). In the East, hydrological changes have allowed chestnut blight (*Cryphonectria parasitica*) to cause serious losses within *Q. oglethorpensis* populations (Coder, 2003). Other pests and pathogens need further research to determine if negative effects are present, including various species of galls observed on *Q. acerifolia, Q. pacifica*, and *Q. toumeyi*.

Case Study 1:
Research opportunity: decline of *Quercus arizonica* and *Q. emoryi* in Pinal County, Arizona
Hilary Cox

Native oaks experiencing severe decline within Oracle State Park, Arizona, due to an unknown suite of factors (Hilary Cox)

As a volunteer with the National Phenology Network I have been monitoring plants along the Phenology Trail at Oracle State Park for the past three years. Two Arizona oaks are on my species list: *Quercus arizonica* and *Quercus emoryi*.

Phenology is the study of recurring plant, animal, or insect life cycles such as leafing out and flowering of plants, migration of birds or insects (e.g. dragonflies), and emergence of insects. Nature's Notebook is a program set up by NPN which gives 'citizen scientists' the opportunity to record valuable phenological observations and submit them within a unified database. These data can be used by scientists, educators, policy makers, and resource managers to aid in understanding the response of plants, animals and insects to climate and other environmental changes.

Right at the start of my project I was given the heads-up by one of the rangers that many of the oaks in the park were in decline or dying. Since that time I have taken many pictures of the area, showing the extent of the decline.

I believe there are multiple factors contributing to this decline, including climate change and drought (which may or may not be triggered by climate change). However, I am also aware that encroaching development in the form of a luxury retirement community, which has 7 golf courses, is almost certainly responsible for water table depletion, a third factor. A second such development, with 5,000 units planned, is under construction as we speak. It is several miles closer to Oracle State Park than the first, and will likely cause increased water pressure on the native oaks. The Pinal County AMA (Active Management Area) is responsible for maintaining an appropriate water management plan.

I feel that the situation calls for study. Determining the likely cause(s) of oak decline in this region is critical to preserving the southern Arizona oak-woodland ecosystem. For example, Oracle State Park is proud to house seven different owl species, which rely on oaks to provide necessary cavities for nesting and roosting. I know of no conservation efforts directed at oak ecosystems within the Park itself; they have enough on their hands just trying to keep the trails, even the park itself, open. I would suggest investigating decline as well as a concurrently studying a control area.

Quercus similis (Tim Boland)

Quercus engelmannii (Laura Camp)

Table 5. Impact level of known threats to U.S. oak species of conservation concern. Species are listed by average vulnerability score from highest (*Q. tardifolia*) to lowest (*Q. sadleriana*). See Appendix E for descriptions of threats affecting each species of concern.

Species of concern (Average vulnerability score)	Human use of species	Agriculture, silviculture, ranching, grazing	Residential/ commercial development, mining, roads	Tourism/recreation	Disturbance regime modification, pollution, eradication	Invasive species competition	Climate change	Genetic material loss	Pests/ pathogens	Extremely small/restricted population
Q. tardifolia (25.0)		Low		Low		Low	Moderate	High		High
Q. robusta (24.0)				Low		Low	Moderate	Moderate		High
Q. graciliformis (14.2)			Low	Low		Low	Moderate	Moderate		High
Q. hinckleyi (14.2)		Low	Moderate	Low			Moderate	Moderate		High
Q. ajoensis (13.3)		Low		Moderate	Moderate	Moderate	High	Moderate		High
Q. boyntonii (13.3)	Low		Low	Low	Moderate	Moderate	Moderate	High	Low	Moderate
Q. acerifolia (12.5)			High	Low	High		Low	Moderate	Moderate	Moderate
Q. carmenensis (12.0)		Moderate				Low	Low	High		High
Q. georgiana (11.7)		Moderate	Moderate	Low	Moderate		High	Moderate	Moderate	
Q. oglethorpensis (11.7)		Moderate	Moderate		High	Low	Moderate	Moderate	Moderate	
Q. dumosa (10.8)			High		Moderate		Moderate			
Q. austrina (10.0)		Moderate	Moderate	Low	Moderate		Low	High		
Q. engelmannii (10.0)		Moderate	High		High		High		Moderate	
Q. arkansana (9.2)		High	High		High	Moderate	High	Moderate	Low	
Q. lobata (8.3)	Low	High	High		High	Low	Moderate		High	
Q. pacifica (8.3)		High	Low	Low	Moderate	Moderate	Low		Low	Moderate
Q. tomentella (8.3)		Low	Low	Low		High	Low	Low		Moderate
Q. cedrosensis (8.0)		High	High		Moderate	Moderate	Low	Moderate		
Q. inopina (6.0)		Low	Moderate	Low	High		Low			
Q. havardii (5.8)		High	Moderate	Moderate	Moderate		High	Low		
Q. palmeri (5.0)			High		Moderate		Low	Moderate		
Q. parvula (5.0)			Moderate		High		High		High	
Q. similis (5.0)	Low	High	Moderate				Moderate			
Q. toumeyi (4.2)	Low	Moderate			Moderate	Low	Moderate	High	Low	
Q. pumila (4.0)			Moderate	Low	High		Low	Low		
Q. laceyi (3.8)		Moderate					High			
Q. chapmanii (3.0)			Moderate	Moderate	High		Low			
Q. sadleriana (3.0)		Low	Low		High	Low	Moderate			

KEY

- High impact threat
- Moderate impact threat
- Low impact threat
- Not a significant threat

Surveying a Mississippi population of *Quercus oglethorpensis* (Matt Lobdell)

CONSERVATION ACTIVITIES

Ex situ Collections of Species of Concern

Earlier we reported on *ex situ* collections for all native U.S. oak species. In this section we look in more detail at *ex situ* collections for species of concern. Some U.S. oak species of concern have been the focus of extensive collecting efforts and are represented by hundreds of plants in dozens of institutions. In comparison to common species, however, many species of concern are poorly represented in *ex situ* collections (Figure 3 and 4, showing all U.S. oak species). Among species of concern, species with moderate vulnerability are generally better represented in collections than species with high or low vulnerability rankings (Figure 6, showing only species of concern). Obstacles to *ex situ* representation can include taxonomic confusion, challenging field conditions and/or accessibility, and collecting permit restrictions for very rare species with high vulnerability rankings. Less vulnerable species (i.e., low rankings) may also be perceived as common and given less priority for wild collecting.

Support from the Tree Gene Conservation Partnership, a collaboration between the American Public Gardens Association and USDA Forest Service's Forest Health Protection, has played a significant role in enhancing surveying, collecting, and propagation of vulnerable species across their native range. The goal of the Partnership is to support the establishment of living gene banks for at-risk U.S. tree species. *Quercus acerifolia, Q. arkansana, Q. dumosa, Q. havardii*, and *Q. oglethorpensis* have all benefited from greatly improved *ex situ* collections because of collecting grants provided by the Partnership, reflected by the high numbers of wild plants now in *ex situ* collections (Figure 6). Proposals targeting *Q. ajoensis, Q. cedrosensis, Q. georgiana, Q. sadleriana, Q. toumeyi*, and species from the Trans-Pecos region of Texas (*Q. carmenensis, Q. graciliformis, Q. robusta, Q. tardifolia*) also received grant funding in 2018, but results from these projects are not yet available.

Quercus graciliformis acorns collected for *ex situ* propagation (Shannon Still)

Wild-collected *Quercus havardii* in propagation at The Morton Arboretum, Illinois (Emily Beckman)

Five species of concern are reported in more than 20 *ex situ* collections: *Q. lobata* (41 collections, 25% of participating *ex situ* collections), *Q. oglethorpensis* (30, 19%), *Q. arkansana* (28, 17%), *Q. georgiana* (24, 15%), and *Q. acerifolia* (21, 13%; Figure 6). Among species of concern, *Q. lobata* (1369 plants) and *Q. engelmannii* (566) have the highest number of plants in *ex situ* collections, and are represented completely by wild-origin plants. *Quercus ajoensis* (7 plants), *Q. similis* (4), *Q. carmenensis* (2), and *Q. cedrosensis* (1) are also represented by 100% wild-origin plants. *Quercus hinckleyi, Q. tomentella*, and *Q. pumila* are represented by the lowest percent of wild-origin plants (20%, 27%, and 40%, respectively). Species with fewer than five total plants in *ex situ* collections include *Q. tardifolia* (0 plants), *Q. carmenensis* (1), *Q. cedrosensis* (1), *Q. robusta* (2), *Q. toumeyi* (2), *Q. ajoensis* (3), and *Q. parvula* (3).

Case Study 2:

Safeguarding the diversity of Arkansas oak

Jared Chauncey, Missouri Botanical Garden

Mixed woodland scrub habitat of *Quercus arkansana* at Eglin Air Force Base, Florida (Jared Chauncey)

Quercus arkansana, or Arkansas oak, is a small, scrubby tree (4-12 meters tall) that grows in shade, occurs in scattered populations across the southeastern U.S., and is difficult to distinguish from other oaks. It occurs in habitats of mixed scrub forest, along ridges and bluffs near small waterways, preferring well drained soil. These features make Arkansas oak rare and its conservation difficult.

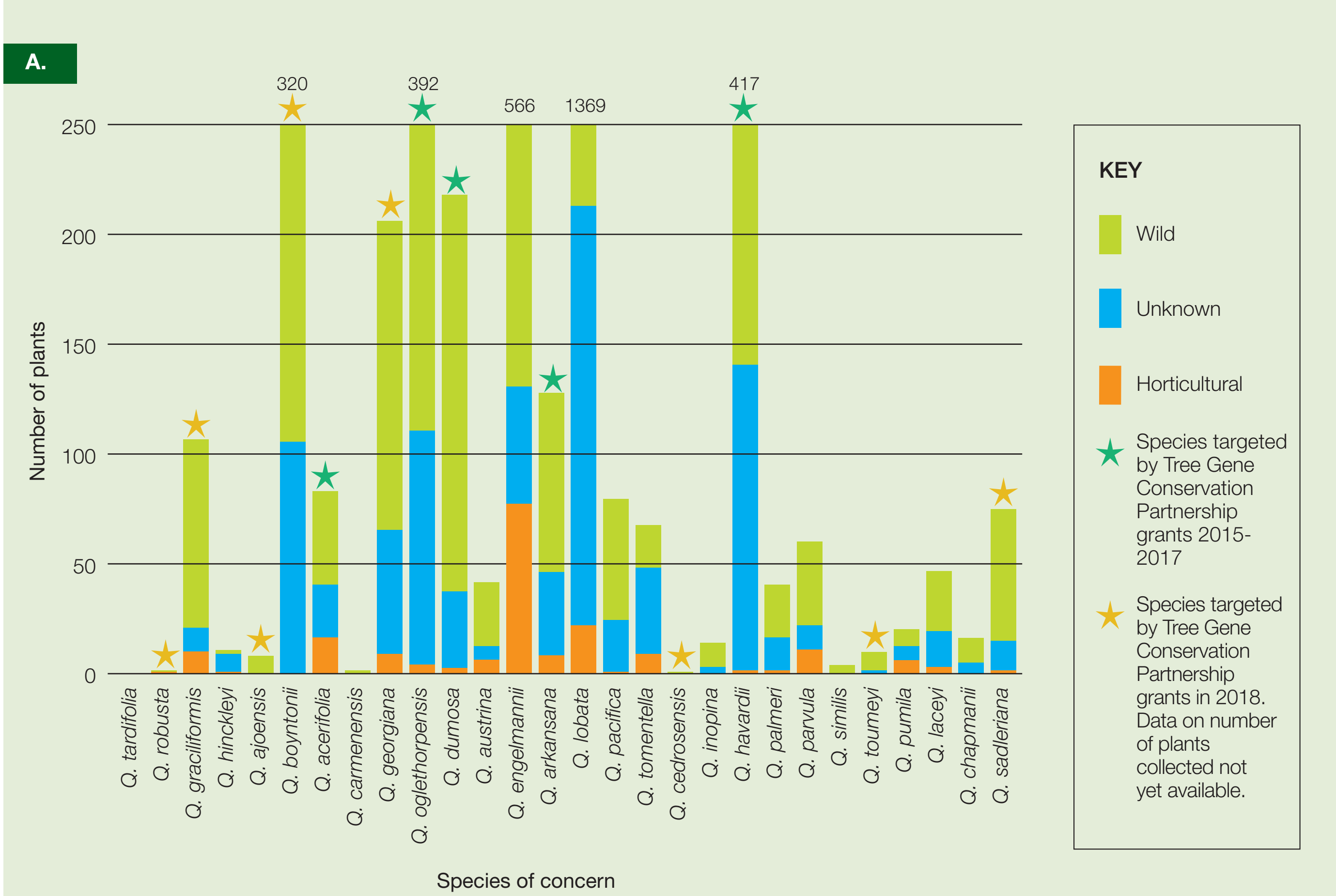
The biggest threats to *Q. arkansana* are logging, development, climate change, forest management practices, and misidentification. These are compounded by its small, scattered, isolated populations. To conserve the genetic diversity of this species, the Missouri Botanical Garden, Bellefontaine Cemetery and Arboretum, and Donald E. Davis Arboretum are surveying and collecting germplasm. These efforts were supported in 2017 through a Tree Gene Conservation Partnership grant awarded by the American Public Gardens Association and USDA Forest Service. Material of *Q. arkansana* will then be distributed to gardens representing major oak collections and a range of compatible environments.

Using herbarium specimens, our group visited many recorded Arkansas oak sites to assess populations and collect acorns. We identified a few sites where *Q. arkansana* had been documented ten to 50 years prior but was no longer present. Multiple sites had also experienced development, logging, and road construction, leaving suppopulations of only one or two Arkansas oaks in pockets of woodland. Due to small size, scattered populations, resemblance to other oaks, and hybridization, this species is commonly removed as low quality red oak wood, without recognizing its rarity, even where protected.

Disjunct population of *Quercus arkansana* in Screven County, Georgia, the easternmost known occurrence of the species (Jared Chauncey)

The distribution of *Q. arkansana* among both public and private lands also creates unique challenges. Because the majority of Arkansas oak's scattered range occurs on private land, collaboration with private landowners is critical for successful conservation. This was highlighted upon our visit to the easternmost population of this species (Screven County, Georgia), which is located on privately-owned land and isolated from other populations by more than 300 kilometers. The property owners granted permission to collect acorns and prune for health in the future. Valuable populations of Arkansas oak also exist on public lands, which experience threats from climate change, land management practices, and isolation of populations. In Alabama, it is especially common to see central individuals within scrub habitat exhibiting dieback. Drought is suspected as the cause, and is expected to increase over the range of *Q. arkansana* with climate change, though managed fire damage may also contribute. Land management in the area focuses on timber and the re-establishment of Longleaf pine and Red cockaded woodpecker, proving incompatible with Arkansas oak preservation. But, populations in ravine and steephead habitat are less threatened by these management factors due to difficulty of access.

Initial efforts within our project have included surveys of populations, with detailed records linking location, habitat ecology, pictures, and DNA to specific individuals. These data will stay linked to each sample of germplasm when distributed to gardens for *ex situ* conservation. Leaf samples will be stored in the Missouri Botanical Garden DNA bank, awaiting sequencing and study of the population and phylogenetics by additional collaborators. This will provide better understanding of the origin and conservation priorities of this diverse and scattered species. These efforts form a strong base of data and preserved material for research and conservation, but strong efforts and collaborations among a variety of organizations—including private landowners, national departments such as the USDA Forest Service and Department of Defence, state departments, NGOs, and botanic gardens/ arboreta—are still needed to secure the future of Arkansas oak.



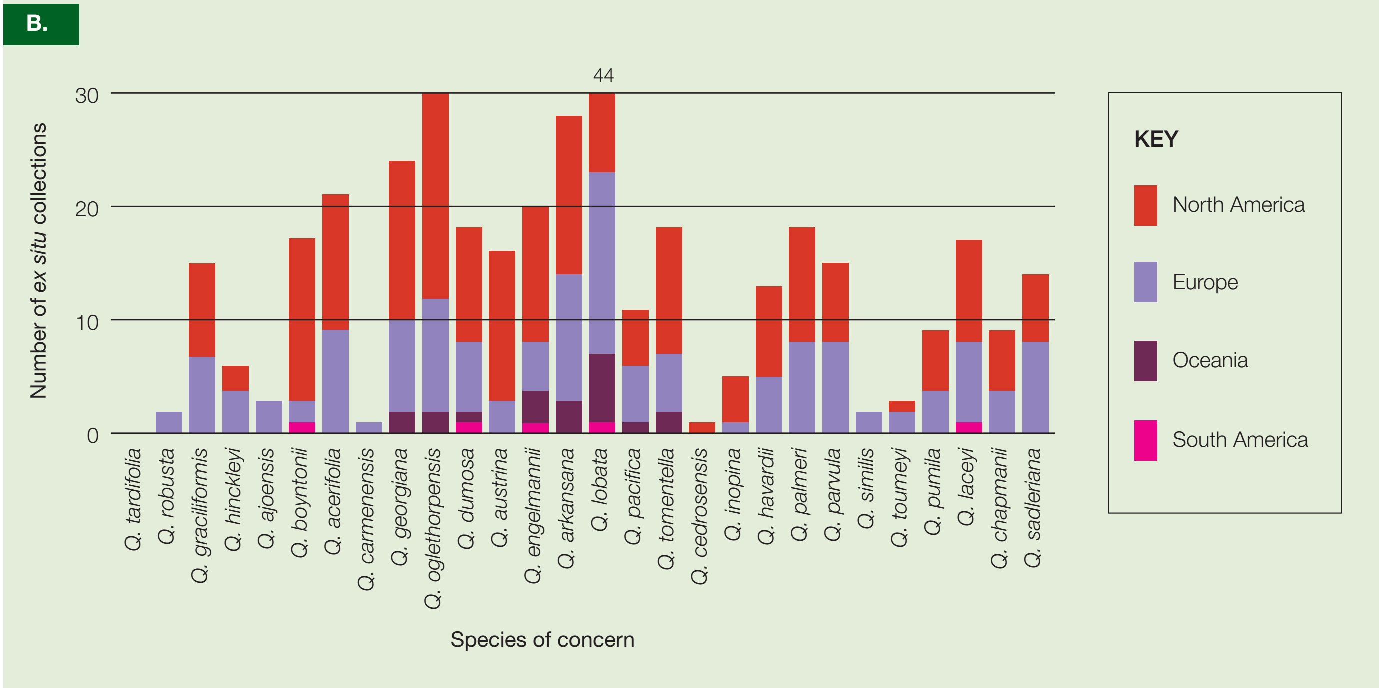


Figure 6. *Ex situ* epresentation of U.S. oak species of conservation concern. **(A)** Number of plants per species in *ex situ* collections, categorized by provenance type. The Tree Gene Conservation Partnership is a collaboration between the American Public Gardens Association and USDA Forest Service's Forest Health Protection, aimed at enhancing *ex situ* collections of vulnerable species. **(B)** Number of *ex situ* collections per species, categorized by collection location. Numbers above a bar indicate the value exceeds the limits of the chart. Species are listed by average vulnerability score from highest (*Q. tardifolia*) to lowest (*Q. sadleriana*). See Appendix C for exact numbers of plants in *ex situ* collections.

Conservation Action Questionnaire

A total of 328 individuals from 252 organizations submitted responses to the 2017 conservation action questionnaire, including 78 institutions that provided input on U.S. oak species of concern (Appendix D). Only one species of concern (*Q. ajoensis*) received no feedback on conservation activities. Several sectors responded to the questionnaire including private companies, NGOs, governing bodies (city, county, state, national), and universities (Figure 7A). Arboreta and botanic gardens contributed the most responses for species of concern (42%), followed by universities (13%), private companies or unaffiliated individuals (9%), state governments (9%), and regional NGOs (8%).

Individuals from institutions in California, Florida, Texas, and Georgia provided the most conservation action data for species of concern (16, 14, 9, and 5 respondents, respectively), which covered the majority of hotspots for at-risk oak species (Figure 7B). Two states with high species of concern richness (Figure 5), Mississippi and South Carolina, are not represented by questionnaire respondents. Detailed results from the 2017 conservation action questionnaire can be found in Appendix D.

Quercus ajoensis (Beth Fallon)

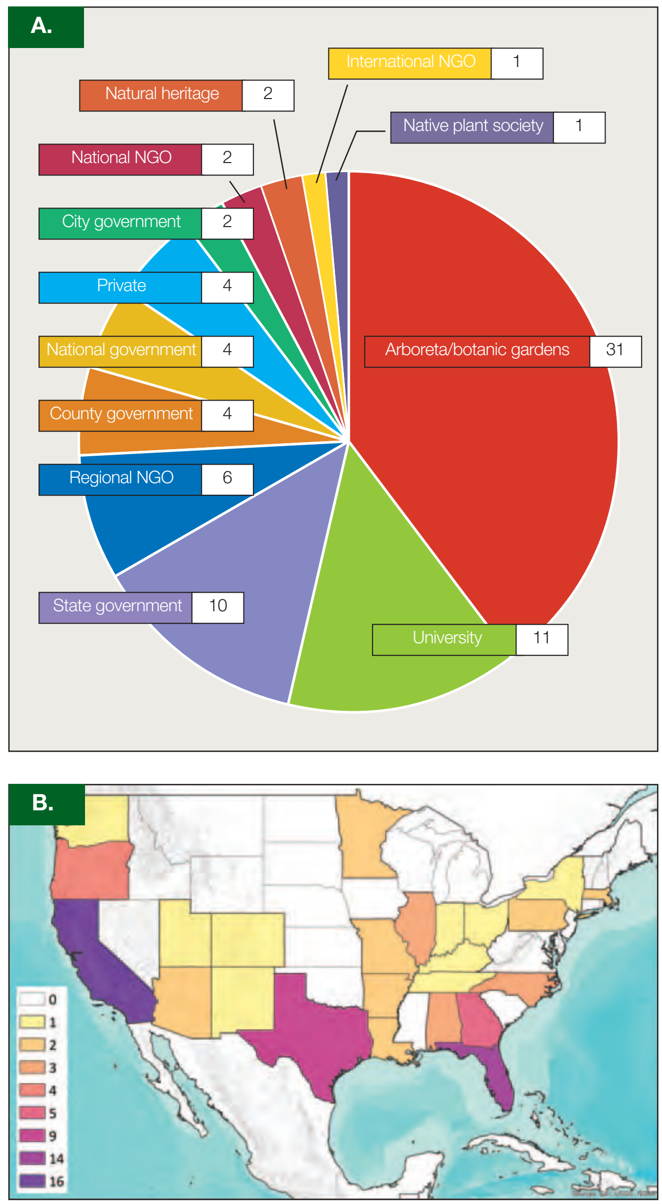


Figure 7. Number of respondents to the conservation action questionnaire regarding U.S. oak species of conservation concern, by **(A)** sector type and **(B)** state.

Quercus acerifolia sapling in Mount Magazine State Park, Arkansans (Kris Bachtell)

The distinct west-Texas habitat of *Quercus hinckleyi* (Emily Griswold). Below: *Quercus parvula* (Vernon Smith)

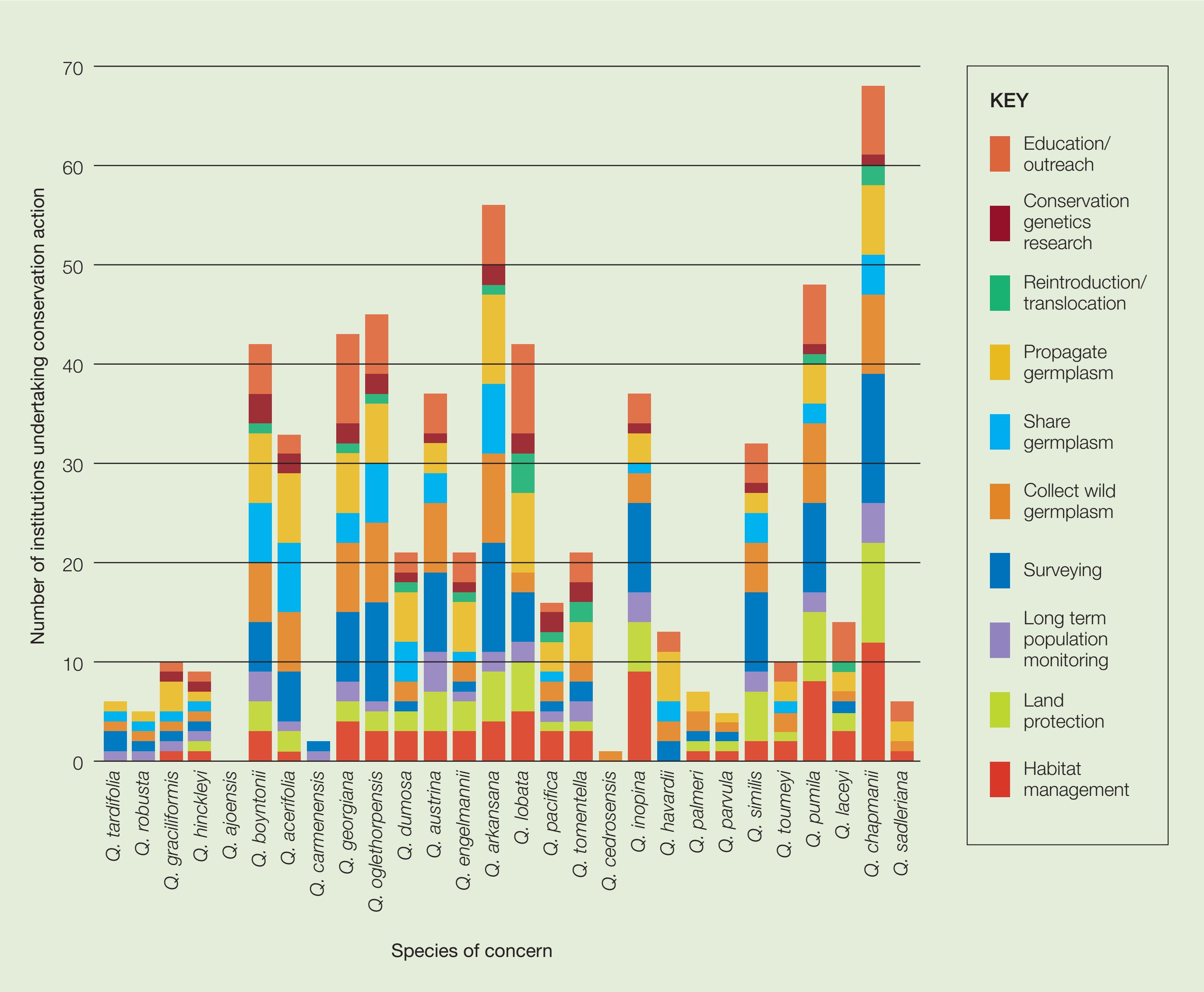
Most questionnaire respondents reported conservation action for species of concern with moderate vulnerability (i.e., those species that fall in the middle of the range based on average vulnerability score: *Q. arkansana, Q. austrina, Q. georgiana, Q. oglethorpensis, Q. lobata*; Figure 8). Many respondents also reported conservation activities for the two species most widespread in Florida (*Q. chapmanii, Q. pumila*), which are among the least vulnerable of the species of concern, as well as Southeast native species with moderate to high vulnerability (*Q. acerifolia, Q. boyntonii*). More respondents also reported conservation actions for species with native distributions in the southeastern U.S., in comparison to those in the West, with *Q. lobata* (19 respondents) as the only exception. *Quercus chapmanii* and *Q. arkansana* received the most responses (27 and 24 respondents, respectively). Among the conservation action categories reported for all species of concern, surveying (106 respondents), propagating germplasm (99), and collecting wild germplasm (91) were reported most frequently. This is to be expected considering botanic gardens and arboreta, which specialize in these types of conservation activities, were the most frequent respondents to the questionnaire. Reintroduction and/or translocation (17 respondents) and long term population monitoring (35) were among the activities least reported. It is unclear whether these activities are actually happening less frequently, or if they are less frequently reported due to a smaller number of participants from institutions or sectors focusing on long-term *in situ* conservation. One possible reason for a lack of reintroduction, reinforcement, and translocation activities is the sequence of other actions that are needed to reach this stage of conservation, including occurrence surveys, wild collecting efforts, propagation, and site selection (research, finding and/or acquiring land), as well as potential management of the site after planting. Unexpectedly, conservation genetics research (27 respondents) was also reported infrequently. The sectors with the highest number of respondent institutions—botanic gardens, arboreta, and universities—are those that would seem to be the most likely participants in conservation oriented research. It is possible that there is in fact relatively little conservation research occurring for oak species of concern currently. It is also possible, however, that the questionnaire did not provide an adequate description of which research activities qualified for this category.

Four species of concern with a broad native distribution across the southeastern U.S. received the most reports of collecting wild germplasm (*Q. arkansana* [9 respondents], *Q. chapmanii* [8], *Q. oglethorpensis* [8], *Q. pumila* [8]; Figure 8). The three species whose native distribution reaches into the Florida peninsula (*Q. chapmanii, Q. inopina, Q. pumila*) are among the most reported for both habitat management (12, 9, and 8 respondents, respectively) and land protection (10, 5, and 7, respectively). *Quercus chapmanii* and *Q. austrina* received the most reports (4) of long term population monitoring.

Surveying was most reported for *Q. chapmanii* (13 respondents), *Q. arkansana* (11), and *Q. oglethorpensis* (10). *Quercus arkansana* received the most reports of propagating and sharing germplasm (9 and 7 respondents, respectively), along with *Q. lobata* (8 respondents propagating germplasm) and *Q. acerifolia* (7 respondents sharing germplasm). *Quercus lobata* was also most reported for reintroduction and/or translocation and education and/or outreach (4 and 9 respondents, respectively), with *Q. georgiana* also receiving nine reports of education and/or outreach. Conservation genetics research was most reported for *Q. boyntonii* (4 respondents). Reintroduction and/or translocation was the only category reported for less than half of the species of concern (12 species; 42%), and conservation genetics research was the second least-reported (17 species; 61%).

Three-year-old *Quercus oglethorpensis* saplings in a hoophouse at The Morton Arboretum, Illinois, collected from native populations across the southeastern U.S. (Emily Beckman)

Quercus pumila (Ron Lance)



Quercus lobata (Asa Dotzler)

Figure 8. Results of the conservation action questionnaire for each U.S. oak species of conservation concern. Species are listed by average vulnerability score from highest (*Q. tardifolia*) to lowest (*Q. sadleriana*). See Appendix D for a list of institutions reporting activities for each species of concern.

Spatial Analyses

An important measure of the conservation quality of *ex situ* collections is the degree to which they represent the full breadth and depth of genetic diversity found in the wild for a given species. Because extensive molecular studies are lacking for almost all of the U.S. oak species of concern, 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 genetic diversity, including the suite of adaptive and potentially adaptive traits, is captured in *ex situ* collections (CPC, 2018; Khoury *et al*., 2015). Because our calculations of geographic and ecological coverage are based on a rough estimation of the distribution of a species (for a summary of the calculations and a visualization of the spatial data, see Figure 9), and only address the portion of a species' distribution within the U.S., the values reported here should be viewed as rough estimates and taken with some caution. Further, it should be noted that within this spatial analysis a wild population represented by a single plant in *ex situ* collections would appear to be adequately captured, whereas ideally each population would be represented by tens to hundreds of plants to capture all of the alleles present (CPC, 2018). With these assumptions and caveats in mind, these spatial analyses, and especially the maps within the individual species profiles (Appendix E), can be used to prioritize populations for future wild collecting efforts.

We found that only eight (29%) of the 28 species of concern are estimated to have *ex situ* collections that represent more than 50% of the species' geographic range within the U.S. (Figure 10). There are three species of concern (*Q. carmenensis, Q. cedrosensis, Q. tardifolia*) with no *ex situ* collections representing germplasm from the species' native U.S. distribution. *Quercus carmenensis* and *Q. cedrosensis* both have a few plants present in *ex situ* collections that were collected in Mexico, while *Q. tardifolia* is not represented at all in living collections, but also has serious taxonomic questions that need to be addressed to confirm its status as a true species. Other species with less than 25% geographic coverage in *ex situ* collections include three relatively widespread oaks from the Southeast (*Q. similis, Q. austrina, Q. pumila*), and one species from the Southwest: (*Q. palmeri*). For each species, estimated levels of geographic coverage and ecological coverage are generally similar, but some notable exceptions exist. *Quercus hinckleyi, Q. ajoensis, Q. tomentella*, and *Q. chapmanii* have an ecological coverage that is more than 40% greater than their geographic coverage, while *Q. pumila, Q. toumeyi, Q. pacifica, Q. dumosa, Q. robusta*, and *Q. austrina* have more than a 25% difference between the two estimates. This could occur when much of the species' ecological diversity is represented within a relatively small, well-sampled geographic area, or when a species has a wide ranging distribution across a relatively homogenous habitat. Ecological coverage is higher than geographic coverage for every species of concern except *Q. oglethorpensis*. Five (18%) species of concern (*Q. acerifolia, Q. graciliformis, Q. hinckleyi, Q. pacifica, Q. robusta*) have 100% ecological coverage in *ex situ* collections.

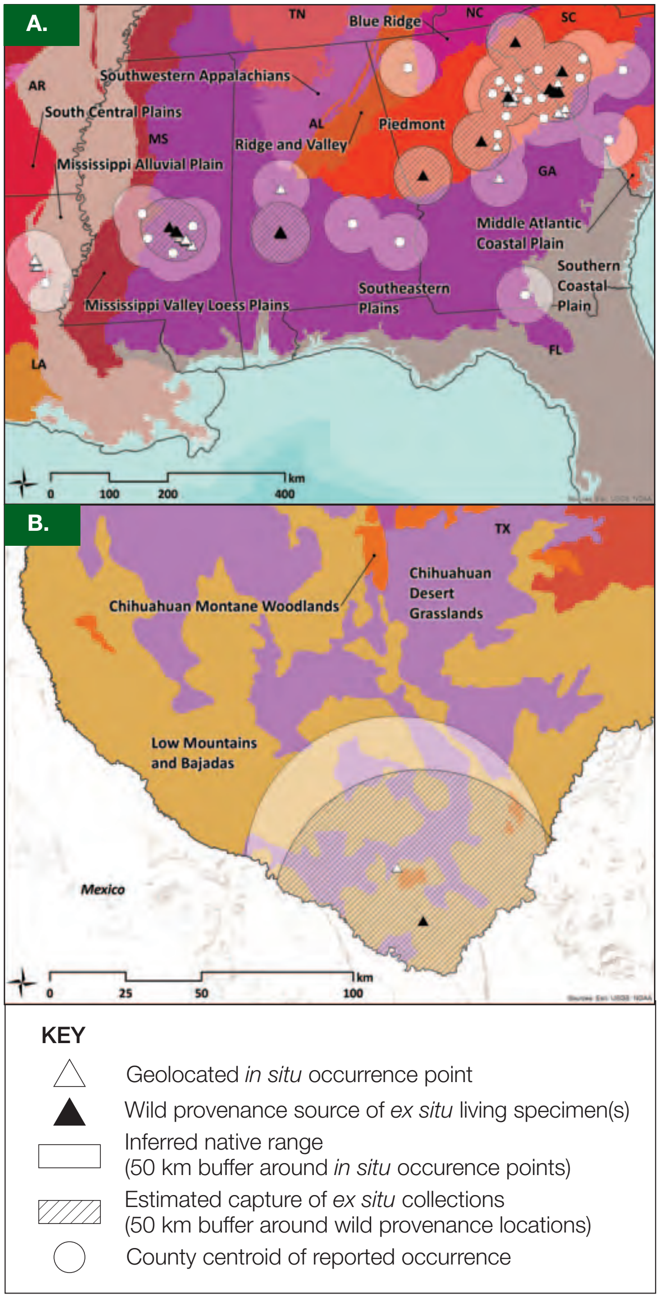


Figure 9. Examples of the maps generated for each species of conservation concern, showing *in situ* occurrence points and *ex situ* collection source localities, which are used to estimate geographic and ecological coverage of *ex situ* collections. **(A)** *Quercus oglethorpensis*; U.S. EPA (2013) Level III Ecoregions are colored and labeled. **(B)** Quercus robusta; U.S. EPA (2013) Level IV Ecoregions are colored and labelled. A 50 km buffer was placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native distribution captured in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections = CAI50 / CAE50; ecological coverage = # of EPA Level IV Ecoregions in CAE50 / # of ecoregions in CAI50. See Appendix E for maps of all species of conservation concern.

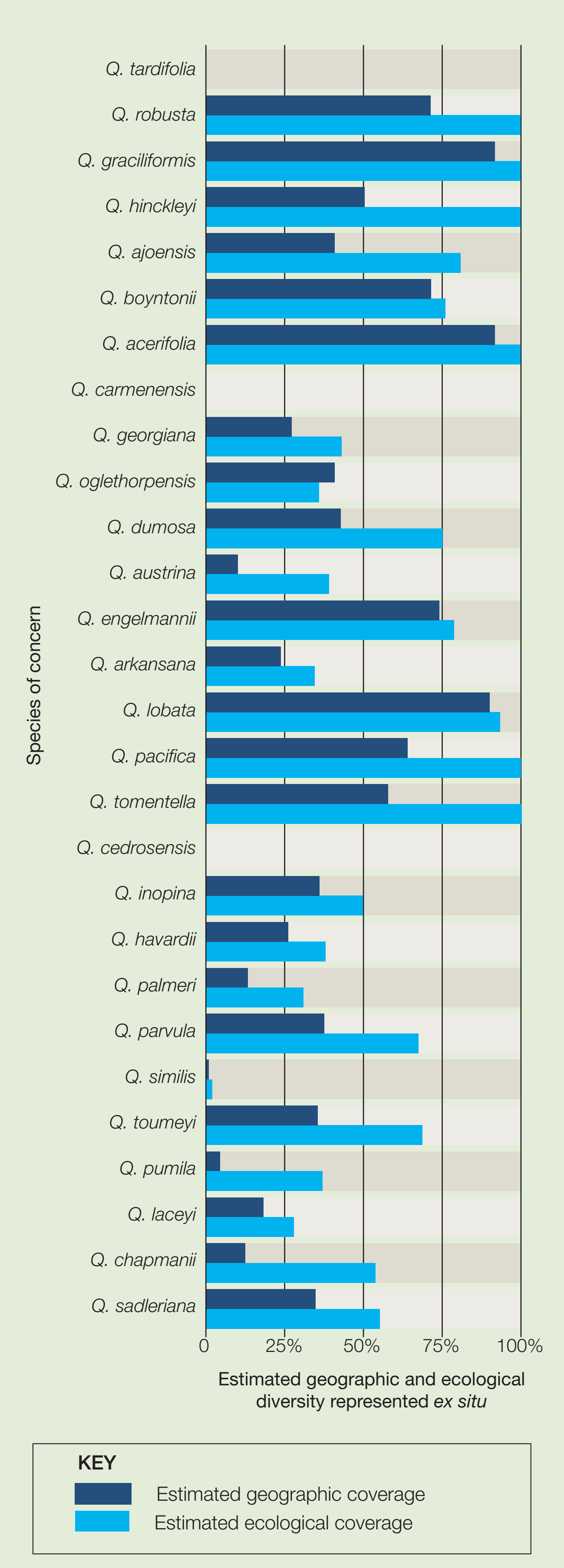


Figure 10: Estimated geographic and ecological coverage of *ex situ* collections for species of conservation concern. Species are listed by average vulnerability score from highest (*Q. tardifolia*) to lowest (*Q. sadleriana*).

These species all have a small range size and exist in only a few ecoregions. Of the 28 species of concern, 12 (43%) have less than 50% ecological coverage, four of which (*Q. carmenensis, Q. cedrosensis, Q. similis, Q. tardifolia*) have less than 25% coverage. Species with low (<25%) geographic or ecological coverage are a high priority for strategic collecting to improve the conservation quality of *ex situ* collections.

To characterize the degree of habitat security for each species of concern, we estimated the percent of each species' inferred native range that is covered by protected areas (Figure 11). A Texas endemic, *Q. laceyi* has the smallest proportion of its inferred native range (3%) within protected areas. The next least protected species are all located in the Southeast: *Q. boyntonii, Q. georgiana, Q. oglethorpensis, Q. arkansana, Q. similis, Q. austrina,* and *Q. pumila*. This reflects the general pattern of protected areas in the U.S.; more protected land exists west of Texas, with comparatively very little in the East.

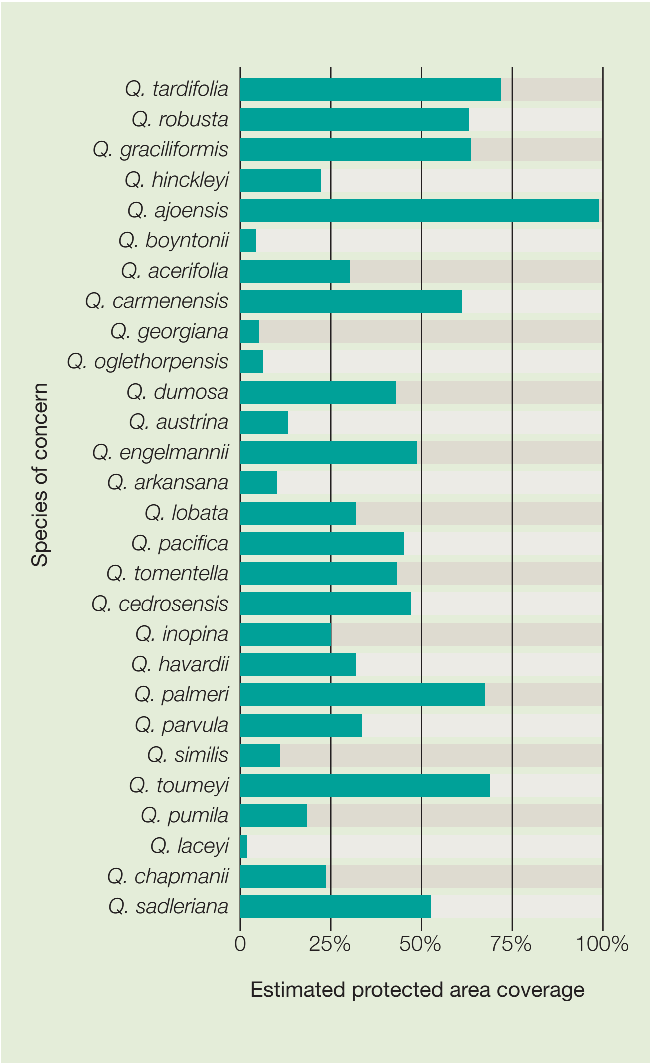


Figure 11: Estimated proportion of species' inferred native range contained within protected areas, for each species of conservation concern. Species are listed by average vulnerability score from highest (*Q. tardifolia*) to lowest (*Q. sadleriana*).

The species in the West with a lower percent of protected area coverage than species native to the eastern U.S. are *Q. havardii* and *Q. hinckleyi*, which are mostly distributed in Texas. One important factor that is not considered in this analysis is the management of different protected areas, specifically the types of activities and extraction permitted. This makes a significant difference in the conservation value of protected land, especially as it pertains to the needs of the species within an ecosystem.

Using our methodology, both the estimated geographic and ecological coverage of *ex situ* collections as well as estimated protected area coverage are generally more accurate for species with a larger native distribution (Figure 9A). Because 50 km buffers were placed around a species' documented *in situ* occurrence points to approximate the species' native distribution, relatively small but important distinctions among wild populations can be lost for narrow endemics.

If populations are less than 50 km apart but separated by mountains or other physical barriers that make the exchange of genes unlikely, it is still very important to capture this diversity in *ex situ* collections. For example, *Q. robusta* has an estimated geographic coverage of 69% and estimated ecological coverage of 100%, but one of its two populations is not yet represented in *ex situ* collections; Figure 9B). It is also valuable to have *ex situ* collections that represent as many individuals as possible for species with an extremely small population size, since these species are probably already experiencing a population bottleneck; in these cases, every allele should be captured (CPC, 2018). For protected area coverage, it is common to know the precise number of wild populations within protected areas when there are few populations, and therefore these observations eliminate the need for an estimated protected area coverage based on 50 km buffers. For example, we estimate *Q. robusta* to have 63% protected area coverage, but it is known to exist entirely on protected land.

Quercus sadleriana (Donald Owen, California Department of Forestry and Fire Protection)

PRIORITY CONSERVATION ACTIONS

Finally, we synthesized these findings to identify priority conservation actions for each U.S. oak species of conservation concern. In many cases all conservation activities would be beneficial, but we have identified highest priority and recommended conservation activities for each species (Table 6). These actions can be used as a starting point for further collaboration and site-specific conservation action planning. Marking an action as highest priority or recommended does not indicate the action is not already occurring. Rather, it signifies that further efforts in that conservation action category are needed to ensure the health and protection of that species of concern. For this analysis, botanic gardens and arboreta provided the majority of data and expertise. As such, it is likely that the conservation actions reported (and the perceived effort gaps) are slightly biased towards activities for which public gardens are particularly well equipped, namely wild collecting and field surveys, propagation and breeding, *ex situ* conservation, and research. When following the conservation recommendations outlined below, we encourage practitioners to engage with local stakeholders from all sectors—the garden community, private landowners, government agencies at all levels, and conservation NGOs—to ensure that there are no ongoing conservation efforts that were missed in this analysis. Ideally an integrated conservation model (Oldfield & Newton, 2012) would be followed for each of these species of concern, with all of the actions presented in Table 6 being carried out in a coordinated and strategic approach.

Two categories—population monitoring and/or occurrence surveys, and research—are recommended for every species of concern (Table 6). Population monitoring and/or occurrence surveys is a high priority conservation action for 17 (61%) species and recommended for 11 (39%) species. No obvious geographic patterns emerge regarding the need for population monitoring and/or occurrence surveys, but two groups of species for which this activity is highest priority do share some specific demographic traits. Species with a highly restricted distribution and/or small population size (*Q. acerifolia, Q. boyntonii, Q. graciliformis, Q. pacifica, Q. robusta, Q. tardifolia, Q. tomentella*) are in urgent need of population monitoring and/or occurrence surveys. These activities ensure early detection of population declines and emerging threats, such as pests, disease, or habitat destruction. Further, some of these rare species may actually have additional currently unknown wild populations, which are especially important to discover and protect when relatively few individuals exist. The second group of species with high priority for population monitoring and/or occurrence surveys includes those with sparse, inaccurate, or incomplete native distribution data, either due to taxonomic uncertainty, lack of exploration, difficult accessibility, high fragmentation, or frequent extirpation of wild populations (*Q. ajoensis, Q. arkansana, Q. austrina, Q. carmenensis, Q. cedrosensis, Q. georgiana, Q. oglethorpensis, Q. parvula, Q. similis, Q. toumeyi*). For example, a previously unexplored 145 acre parcel was recently discovered to contain one of the largest known populations of *Q. georgiana*, in addition to a previously unreported population of *Q. boyntonii* (P. Thompson pers. comm., 2018). Because many species of concern occur most frequently on private lands, especially in the Southeast, there still exist large tracts of unbotanized potential habitat, which, if surveyed, could result in a more diverse group of opportunities for land protection and wild collection for *ex situ* preservation.

Research is a high priority for 15 (54%) of the species of concern and recommended for 13 species (46%; Table 6). Several types of research activities were frequently identified as urgently needed to better understand the fundamental biology, ecology, and threats facing species of concern (Table 7). Climate change modeling and population genetics are the most common types of research needed. In some cases, basic taxonomic and field survey research to confirm the identity and native distribution of a species is needed before additional conservation activities can take place (e.g., *Q. tardifolia*). Based on the results of these studies, scientifically informed conservation actions can be implemented.

Wild collecting is the third most common conservation need, with 26 of 28 species of concern requiring this activity (Table 6). We do not recommend wild collecting as a priority for *Q. tardifolia* or *Q. lobata* due to taxonomic uncertainty for the former and already very strong *ex situ* collections for the latter. Species with highly restricted distributions and/or insufficient *ex situ* representation (few individuals, few *ex situ* collections, or low geographic and/or ecological coverage) are considered highest priority for wild collecting activities (15 species; 54%). The maximum amount of genetic diversity is preserved *ex situ* as an insurance policy against extinction and to provide material for research, propagation, and public education.

Case Study 2:
The importance of genetics in conservation

Janet Rizner Backs, PhD, Department of Biological Sciences, University of Illinois at Chicago

Janet Rizner Backs standing near a clump of *Quercus hinckleyi* (Janet Backs)

Quercus hinckley is a threatened scrub oak currently found in a limited area in West Texas, U.S. Its Chihuahua Desert habitat extends into Mexico, so it may be found there, although its present status has not been documented. Since the end of the last Ice Age, *Q. hinckleyi's* natural range has become more and more xeric, and the species has become more and more rare. Today it is found in a few locations near Shafter, Texas, and within Big Bend Ranch State Park, Texas. Recent genetic research (Backs *et al*., 2016; Backs *et al*., 2015) found 123 unique individuals out of 204 stems sampled, indicating extensive cloning. Results of the DNA analysis of these leaf samples have implications both for setting conservation priorities and management plans, as well as working towards understanding isolated and threatened species in general.

Four findings are especially significant and would not have been apparent without genetic analysis. First, as with many scrub oaks, *Q. hinckleyi* reproduces both sexually and clonally. DNA analysis easily facilitated non-invasive identification of unique individuals. At one site, clones were found in discrete clumps up to 30 meters apart. A number of conservation management

Documentation of a *Quercus hinckleyi* sample (Janet Backs)

pitfalls are avoided when individuals can be identified. Population counts are more accurate, and therefore allow more precise determination of the level of endangerment. Also, if plants or plant material such as acorns or shoots are used for regeneration either *in situ* or *ex situ*, using unique individuals is critically important to capture maximum genetic variability and continued fertility.

Secondly, the study grouped *Q. hinckleyi* individuals at widely separated sites into genetically related clusters. One of the clusters consisted of individuals separated by approximately 60 kilometers of desert. It is felt that these are out-lying remnants of the much larger population that once occupied this area. Again, the ability to identify related groups gives conservationists the information needed to maintain genetic diversity when introducing individuals *in situ* as well as selecting for *ex situ* sites.

Thirdly, a stand of *Quercus pungens*—another oak in the white oak group—growing near *Q. hinckleyi* at one of the study sites was found to have a high percentage of *Q. hinckleyi* inferred ancestry, even though they bore no visible *Q. hinckleyi* traits. Plants that show no outward resemblance to an endangered species may in fact be acting as repositories for some of its genetic material. Introgression, known to be common among oak species, can be viewed as a method in which oaks preserve their genetic variation and potential survival traits. This highlights the importance of preserving habitats not just individual species.

These species include *Q. arkansana, Q. austrina, Q. chapmanii, Q. inopina, Q. laceyi*, and *Q. oglethorpensis* in the East, and *Q. ajoensis, Q. carmenensis, Q. cedrosensis, Q. dumosa, Q. hinckleyi, Q. pacifica, Q. palmeri, Q. robusta*, and *Q. tomentella* in the West. Eleven species of concern (39%) are recommended for further wild collecting.

Land protection is recommended for 14 (50%) species of concern (Table 6). The majority of these species are distributed in the eastern U.S. (9 of 14; 64%) and only two species in the East do not have a significant need for land protection (*Q. chapmanii, Q. pumila*), both of which are mainly distributed in Florida. This reflects the pattern of protected areas in the U.S.; much more land area in the West is protected compared to the Southeast, but Florida is an exception, having a large proportion of protected area. Species of concern in the eastern U.S. occupy a variety of habitats, but the southern portion of the Piedmont, which extends through Alabama, Georgia, and South Carolina, is a hotspot for oak species of concern and should be a priority for further protection. Only five (18%) species are a high priority for further land protection, either because a key population is not currently protected (*Q. acerifolia, Q. hinckleyi*) or the species is present in very few protected areas (*Q. havardii, Q. laceyi, Q. similis*). These species with an urgent need for further overall protection have a significant distribution in and/or around Texas.

Further sustainable management of land is recommended for 21 (75%) species of concern and a priority activity for 11 (39%; Table 6). This conservation activity mitigates or prevents negative impacts from a variety of threats, including agriculture, silviculture, and/or ranching, tourism and/or recreation, disturbance regime modification, and invasive species competition. Of these, disturbance regime modification and agriculture and/or ranching are significantly more common and higher impact among oak species of concern. Therefore, conservation activities addressing these threats should be a first priority. Management of fire is particularly important for oaks, and is a main issue for the majority of species of concern with sustainable management of land as a priority conservation recommendation. Some species need relatively frequent fire to maintain an open canopy, which allows for regeneration (e.g., *Q. boyntonii*), while others take many years to

Fifteen-year-old planting of *Quercus tomentella* established by the Navy on San Clemente Island, using locally-collected seed (Julie Lambert)

Quercus austrina (Ron Lance)

reproduce after fire, needing long intervals between burns (e.g., *Q. dumosa*). Slightly less than half of the species of concern requiring sustainable management of land are found in the East (9 of 21; 43%), but these make up eight of the ten (80%) species with sustainable management of land as a highest priority action; exceptions include two species (*Q. parvula, Q. sadleriana*), which are fairly common in the wildlands of California and/or Oregon where intense fires are a threat. Because the majority of land in the East is privately owned, the high need for sustainable management of land in the eastern U.S. should be addressed through further engagement of private landowners.

Education, outreach, and/or training is another vital activity for the conservation of species of concern. Seven (25%) species are a high priority for further education, outreach, and/or training activities, and 11 (39%) species are recommended for the activity (Table 6). Multiple audiences should be the focus of educational engagement, depending on threats facing the species, stakeholders, and available resources. *Quercus havardii* and *Q. lacey*—high priorities for education, outreach, and/or training—are distributed in the south-central U.S. (Texas, Oklahoma) and found primarily on private land used for grazing or agriculture; recreational use of all-terrain vehicles sometimes causes damage as well. High priority species distributed across the Southeast (*Q. arkansana, Q. austrina, Q. boyntonii, Q. georgiana*) also inhabit mostly privately owned land, which is used for activities such as agriculture, silviculture, or recreation, and can be at risk of being sold for development. There are also two species located in southern California, which are a high priority for further education, outreach, and/or training (*Q. dumosa, Q. engelmannii*). There is an urgent need to engage private landowners through education, outreach, and/or training regarding best practices for management of land in ecosystems to which rare oaks are especially and uniquely adapted, such as the the southern Piedmonts, scrub habitat in Florida and southern California, and Sand Shinnery communities in Texas and Oklahoma.

Table 6. Conservation recommendations for U.S. oak species of conservation concern. Species are listed by average vulnerability score from highest (*Q. tardifolia*) to lowest (*Q. sadleriana*). See Appendix E for detailed descriptions of conservation priorities and recommendations for each species of concern.

Species of concern (Average vulnerability score)	**Land protection**	**Sustainable management of land**	**Population monitoring/ occurrence surveys**	**Wild collecting/ *ex situ* curation**	**Propagation/breeding programs**	**Reintroduction/ reinforcement/ translocation**	**Research**	**Education/ outreach/ training**
Q. tardifolia (25.0)			Highest priority				Highest priority	
Q. robusta (24.0)			Highest priority	Highest priority	Highest priority	Recommended	Highest priority	Recommended
Q. graciliformis (14.2)			Highest priority	Recommended	Recommended	Highest priority	Highest priority	Recommended
Q. hinckleyi (14.2)	Highest priority		Recommended	Highest priority	Highest priority	Recommended	Recommended	Recommended
Q. ajoensis (13.3)		Recommended	Highest priority	Highest priority	Recommended	Highest priority	Highest priority	
Q. boyntonii (13.3)	Recommended	Highest priority	Highest priority	Recommended		Recommended	Highest priority	Highest priority
Q. acerifolia (12.5)	Highest priority	Highest priority	Highest priority	Recommended		Recommended	Highest priority	Recommended
Q. carmenensis (12.0)			Highest priority	Highest priority	Recommended	Recommended	Highest priority	
Q. georgiana (11.7)	Recommended	Highest priority	Highest priority	Recommended	Recommended	Recommended	Highest priority	Highest priority
Q. oglethorpensis (11.7)	Recommended	Highest priority	Highest priority	Highest priority		Recommended	Recommended	Recommended
Q. dumosa (10.8)	Recommended	Recommended	Recommended	Highest priority		Recommended	Recommended	Highest priority
Q. austrina (10.0)	Recommended	Highest priority	Highest priority	Highest priority			Highest priority	Recommended
Q. engelmannii (10.0)		Recommended	Recommended	Recommended		Highest priority	Recommended	Highest priority
Q. arkansana (9.2)	Recommended	Highest priority	Highest priority	Highest priority		Recommended	Recommended	Highest priority
Q. lobata (8.3)		Recommended	Recommended			Highest priority	Highest priority	Recommended
Q. pacifica (8.3)		Recommended	Highest priority	Highest priority	Recommended	Recommended	Highest priority	
Q. tomentella (8.3)		Recommended	Highest priority	Highest priority	Highest priority	Highest priority	Recommended	
Q. cedrosensis (8.0)	Recommended	Recommended	Highest priority	Highest priority	Recommended	Recommended	Recommended	
Q. inopina (6.0)	Recommended	Highest priority	Recommended	Highest priority		Recommended	Recommended	Recommended
Q. havardii (5.8)	Highest priority	Recommended	Recommended	Recommended		Recommended	Highest priority	Highest priority
Q. palmeri (5.0)		Recommended	Recommended	Highest priority		Highest priority	Highest priority	
Q. parvula (5.0)	Recommended	Highest priority	Highest priority	Recommended			Highest priority	Recommended
Q. similis (5.0)	Highest priority		Highest priority	Recommended			Highest priority	
Q. toumeyi (4.2)		Recommended	Highest priority	Recommended			Recommended	
Q. pumila (4.0)		Highest priority	Recommended	Recommended		Recommended	Highest priority	Recommended
Q. laceyi (3.8)	Highest priority		Recommended	Highest priority			Recommended	Highest priority
Q. chapmanii (3.0)		Highest priority	Recommended	Highest priority		Recommended	Recommended	Recommended
Q. sadleriana (3.0)		Highest priority	Recommended	Recommended			Recommended	

Quercus inopina (Ron Lance)

KEY

- Highest priority conservation actions
- Recommended activities

Table 7. Types of research needed to better understand and protect U.S. oak species of conservation concern and examples of species that fall into these categories. See Appendix E for descriptions of specific research needs for each species of conservation concern.

Research category	Examples
Climate change modeling	Predicted impacts; determining future suitable habitat areas (e.g., *Q. ajoensis*)
Demographic studies/ ecological niche modeling	Population trends; age distributions; refinement of known native distribution (e.g., *Q. boyntonii, Q. georgiana, Q. similis*)
Land management/ disturbance regime needs	Prescribed burns; removal of invasive species; canopy thinning (e.g., *Q. inopina*)
Pests/pathogens	Control; modeling climate-induced range shifts; predicting new invasive pests (e.g., *Q. parvula*)
Population genetics	Levels of genetic diversity; inbreeding; gene flow; introgression (e.g., *Q. acerifolia, Q. carmenensis, Q. palmeri, Q. pumila*)
Reproductive biology/regeneration	Masting patterns; seed viability; clonal vs. sexual reproduction (e.g., *Q. havardii*); patterns of regeneration successes and failures (e.g., *Q. lobata*)
Restoration protocols/guidelines	Propagation; population reinforcement; reintroduction; translocation (e.g., *Q. georgiana, Q. pacifica*)
Taxonomy/phylogenetics	Distinguishing spontaneous hybrids from historic hybrids that have evolved into true species (e.g., *Q. robusta, Q. tardifolia*); clarifying species from varieties, ecotypes, formas, and subspecies (e.g., *Q. havardi*i var. *tuckeri/Q.welshii*); identifying 'mistaken' records of the species due to morphologic similarity to other species (e.g., *Q. austrina*)

In total, 11 (39%) species of concern are recommended for propagation and/or breeding programs and 21 (75%) for reintroduction, reinforcement, and/or translocation (Table 6). Generally, the need for propagation and/or breeding programs for species of concern corresponds with a need for reintroduction, reinforcement, and/or translocation; exceptions usually occur when robust propagation programs already exist (e.g., *Q. boyntonii, Q. oglethorpensis*), or seed is reliably produced in the wild (e.g., *Q. chapmanii, Q. palmeri*). There are several common reasons for reintroduction, reinforcement, and/or translocation to be a priority: small population size and/or limited distribution leaves a species vulnerable to one extreme event such as a wildfire (e.g., *Q. graciliformis*); populations have been severely diminished by human use of land such as agriculture and/or commercial development (e.g., *Q. lobata*); populations are relatively small or vastly clonal and highly fragmented, such that they are unlikely to exchange genes (e.g., *Q. georgiana, Q. palmeri*); small population size and/or range, combined with insufficient regeneration in the wild (e.g., *Q. tomentella*). Reintroduction, reinforcement, and/or translocation is a priority for the majority of rare species, but often other conservation activities must be completed first and therefore take priority. For example, *Q. robusta* has a very limited native distribution and only two known subpopulations; reinforcement would be a high priority for the species, but occurrence surveys, *ex situ* representation, and taxonomic research take precedent. It is often most feasible to carry out reintroduction, reinforcement, and/or translocation activities for species that have already been the focus of extensive conservation efforts (e.g., *Q. engelmannii*).

Two other categories of conservation recommendations—sustainable management of species and species protection policies—are not specifically considered in this report. Conservation activities focused on the sustainable management of species are not priority for U.S. oak species of concern because wild harvesting is an uncommon and low-threat activity. Only one species of concern, *Q. hinckleyi*, is currently protected under the federal Endangered Species Act (ESA), though at least three other species (*Q. boyntonii, Q. robusta, Q. tardifolia*) have been petitioned for listing within the ESA in the last few decades; all were rejected due to insufficient data (Rosmarino, 2008; U.S. Fish and Wildlife Service, 2009). Many species of concern are listed on state-specific lists of at-risk species, with each state using its own set of labels such as "rare," "endangered," "vulnerable", "threatened," and "species of conservation concern;" some of these policies provide protection and others simply require distribution records to be kept for the species. Counties, cities, and residential associations occasionally provide legal protections for specific species of concern as well. Some U.S. oak species of concern may benefit from these various levels of protection policies, and this option should be considered on a case-by-case basis.

Possibly *Quercus carmenensis* (Shannon Still)

CONCLUSIONS

This gap analysis included extensive literature review, a global survey of *ex situ* collections, a conservation action questionnaire distributed to over 1,000 individuals, spatial data analyses, a vulnerability assessment, and one-on-one consultation with dozens of oak experts, botanists, land managers, and conservationists across the country. We identified 28 of the 91 native U.S. oak species to be of conservation concern, threatened by a range of factors including climate change and human modification of ecosystems and landscapes. Prioritizing conservation actions for these species and populations requires the integration of a wide range of data types—vulnerability, threats, current conservation activities—from many sources, but some fundamental knowledge about many species of concern is currently lacking.

Accurate knowledge of species' native distributions is a key area lacking data, either because the data are nonexistent or are not published or accessible. Biodiversity databases (e.g., GBIF, online herbaria records) provide a valuable set of spatial data as a strong starting point. However, these databases are often missing populations, taxonomic changes are updated slowly, specimens can be misidentified, and there is no mechanism to record extirpation of wild populations. Ground-truthing of old occurrence records, ecological niche modeling to predict other potential locations, and additional field surveys and population monitoring are all high priority activities needed to understand the true distribution of many species of concern.

While many native oak species are well represented in *ex situ* collections nationally and globally, species of conservation concern are generally very poorly represented. This is especially worrying because oaks are exceptional species—their acorns cannot be seed banked through conventional methods. As such, genetically diverse and representative living collections are critical to ensuring these species do not go extinct in the wild. Equally important is the need for those institutions holding *ex situ* collections to maintain precise and accurate plant record data, facilitate standardization and sharing of data, and coordinate efforts to expand and improve the conservation quality of those collections.

Research is also a fundamental need for many species of concern, to inform the creation of effective conservation strategies. Climate change modeling, demographic studies, ecological niche modeling, pest and pathogen control methods, population genetic studies, taxonomy, and phylogenetics research are all necessary to better understand and predict the current and future health of wild populations under threat. Practical and applied research is needed too. Scientifically informed guidelines for propagation, conservation horticulture, population reinforcement, reintroduction, and translocation, as well as understanding the best land management practices would greatly improve the chances of recovery for threatened oak populations.

These analyses and recommendations are intended to inform the conservation strategies of many sectors including federal agencies, state and local land managers, non-governmental organizations, botanical gardens and arboreta, policy makers, and others. Stakeholders are encouraged to interpret these results through their own lens, considering their goals, expertise, and available resources when deciding which species and conservation recommendations to undertake first. More important still is the need for conservation practitioners to work collaboratively, especially across sectors, to fill the gaps identified here. The conservation actions recommended in this gap analysis are much more than one institution can do alone. Effective and efficient tree conservation is greatly hindered by a lack of awareness of activities underway in different sectors, or even in different institutions within the same sector. Conservation successes and (perhaps more importantly) failures, are rarely published. Communication among parties engaging in oak conservation is vital to addressing a challenge of this scale. We hope this study facilitates the identification of potential partners, promotes cross-sector networking, and contributes to the advancement of effective conservation of at-risk oaks in the U.S.


Quercus palmeri (Paul Manos)

REFERENCES

Quercus boyntonii (Sean Hoban)

Ashley, M. V., Abraham, S. T., Backs, J. R., & Koenig, W. D. (2015). Landscape genetics and population structure in Valley oak (Quercus lobata Née). *American Journal of Botany*, 102(12), 2124-2131. doi:10.3732/ajb.1500182

Backs, J. R., Terry, M., Klein, M., & Ashley, M. V. (2015). Genetic analysis of a rare isolated species: A tough little West Texas oak, *Quercus hinckleyi* C.H. Mull. *The Journal of the Torrey Botanical Society*, 142(4), 302-313. doi:10.3159/torrey-d-14-00091.1

Bendixsen, D. P., Hallgren, S. W., & Frazier, A. E. (2015). Stress factors associated with forest decline in xeric oak forests of south-central United States. *Forest Ecology and Management*, 347, 40-48. Retrieved from https://doi.org/10.1016/j.foreco.2015.03.015

BGCI. (2009, March). *Global survey of* ex situ *oak collections*. Retrieved from https://www.bgci.org/files/Worldwide/Publications/global_survey_of_ex_situ_oak_collections.pdf

BGCI. (2016). *North American botanic garden strategy for plant conservation, 2016-2020*. IL: Botanic Gardens Conservation International, U.S. Retrieved from http://northamericanplants.org/

Coder, K. D. (2003, December). *Oglethorpe oak: Sunset of a species*. Athens, GA: University of Georgia Warnell School of Forest Resources.

Quercus cedrosensis (Jon Rebman)

Conference of the Parties to the Convention on Biological Diversity. (2011). *Global strategy for plant conservation 2011-2020*. Retrieved from https://www.cbd.int/gspc/strategy.shtml

Conservation Measures Partnership. (2016). Classification of conservation actions and threats (Version 2.0).

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

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

Gratzfeld, J. (Ed.). (2016). *From Idea to realisation – BGCI's manual on planning, developing and managing botanic gardens*. Richmond, United Kingdom: Botanic Gardens Conservation International.

Hipp, A. L., Manos, P. S., González-Rodríguez, A., Hahn, M., Kaproth, M., Mcvay, J. D., Valencia Avalos, S., & Cavender-Bares, J. (2017). Sympatric parallel diversification of major oak clades in the Americas and the origins of Mexican species diversity. *New Phytologist*, 217(1), 439-452. doi:10.1111/nph.14773

IUCN. (2012). *IUCN Red List categories and criteria* (Version 3.1, 2nd ed.). Gland, Switzerland and Cambridge, UK: International Union for Conservation of Nature and Natural Resources. iv + 32pp. Retrieved from https://www.iucnredlist.org/resources/categories-and-criteria

IUCN. (2018). The IUCN Red List of Threatened Species. Version 2018-1. Retrieved from https://www.iucnredlist.org/

IUCN Standards and Petitions Subcommittee. (2017). *Guidelines for using the IUCN Red List categories and criteria* (Version 13). Prepared by the Standards and Petitions Subcommittee. Retrieved from https://www.iucnredlist.org/resources/redlistguidelines

Jepson Flora Project (Eds.). (2018). *Jepson eFlora*. Retrieved from http://ucjeps.berkeley.edu/eflora/

Jerome, D., Beckman, E., Kenny, L., Wenzell, K., Kua, C., & Westwood, M. (2017). *The Red List of US oaks*. Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/Westwood_2017_Red%20List%20of%20Oaks.pdf

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., Heider, B., Castañeda-Álvarez, N. P., Achicanoy, H. A., Sosa, C. C., Miller, R. E., Scotland, R. W., Wood, J. R. I., Rossel, G., Eserman, L. A., Jarret, R. L., Yencho, G. C., Bernau, V., Juarez, H., Sotelo, S., de Hann, S., & 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

NatureServe. (2017). NatureServe explorer (Version 7.1). Retrieved from http://explorer.natureserve.org/

Oldfield, S. & Newton, A. C. (2012). *Integrated conservation of tree species by botanic gardens: A reference manual*. Richmond, UK: Botanic Gardens Conservation International.

Petrides, G. A. (2005). *Trees of the American Southwest*. Mechanicsburg, PA: Stackpole Books.

Polle, J. M. (2007). *Rare plants of Texas: A field guide*. College Station, TX: Texas A&M University Press.

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

Rizzo, D. M., Garbelotto, M., Davidson, J. M., Slaughter, G. W., & Koike, S. T. (2002). *Phytophthora ramorum* as the cause of extensive mortality of *Quercus* spp. and *Lithocarpus densiflorus* in California. *Plant Disease*, 86(3), 205-214. doi:10.1094/pdis.2002.86.3.205

Rosmarino, N. J. (2008, June 12). *A petition requesting emergency listing of 32 species under the Endangered Species Act*. WildEarth Guardians. Retrieved from https://pdf.wildearthguardians.org/support_docs/petition_emergency-listing_6-12-08.pdf

Schueler, S., & Schlünzen, K. H. (2006). Modeling of oak pollen dispersal on the landscape level with a mesoscale atmospheric model. *Environmental Modeling & Assessment*, 11(3), 179-194. doi:10.1007/s10666-006-9044-8

Standiford, R. B. (2015). Valley oak conservation. University of California Oak Woodland Management. Retrieved from http://ucanr.edu/

Stouthamer, R., Rugman-Jones, P., Eskalen, A., Kabashima, J., Dimson, M., Gonzalez, A., Arakelian, G., Hodel, & D., Drill, S. (2017). Polyphagous shot hole borer. CA: Department of Entomology & Department of Plant Pathology and Microbiology, University of California. Retrieved from http://ucanr.edu/

The Morton Arboretum. (2017). ArbNet arboretum accreditation application form. Retrieved from http://www.arbnet.org/

U.S. EPA Office of Research & Development. (2013, April). 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

U.S. Fish and Wildlife Service. (2009). Endangered and threatened wildlife and plants; Partial 90 day finding on a petition to list 475 species in the southwestern United States as threatened or endangered with critical habitat; proposed rule. *Federal Register*, 74(240), 66866-66905.

U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May). Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/

Mature *Quercus agrifolia* specimen at Rancho Santa Ana Botanic Garden, California (Emily Beckman)

APPENDICES

Oak grove at The Morton Arboretum, Illinois (Emily Beckman)

APPENDIX A. LIST OF CONTRIBUTORS

Individual contributors to species profiles and/or natural occurrence data:

Aiello, Tony | Allenstein, Pam | Amos, Lee | Anderson, Patti | Ashley, Mary | Bachtel, Kris | Backs, Janet R. | Baker, Brent | Barger, Wayne T. | Barnett, LoriAnne | Bartig, Jarel | Bell, Duncan | Berrang, Paul | Birker, Cheryl | Black, Adam | Blush, Thomas | Boland, Tim | Bower, Andrew | Brown, Herrick | Burrill, Elizabeth | Cannon, Chuck | Chassé, Béatrice | Chauncey, Jared | Coggeshall, Mark | Cox, Hilary | Crane, Barbara | Dagit, Rosi | Dunn, Jonathan | Ecker, Mike | Ellenwood, James | Emerson, Clint | Erickson, Vicky | Estes, Dwayne | Fallon, Beth | Frances, Anne | Franck, Alan | Gaman, Tom | Griffith, Patrick | Hamilton, Jill | Helenurm, Kaius | Henrich, Jim | Hille, Andrea | Hoban, Sean | Hoover, Lisa | Jenkins, Michael | Kartesz, John | Lance, Ron | Larson, Jan | Laughrin, Lyndal | Lobdell, Matt | MacRoberts, Michael | Mahalovich, Mary | Manos, Paul | McCauley, Ross | McNeil-Marshall, Andrew | Meyer, Abby | Meyer, Evan | Moore, Gerry | Morgan, Brian | O'Connor, Philip | Osbrack, Stuart | Pearse, Ian | Peet, Robert | Pesendorfer, Mario B. | Pivorunas, David | Potter, Kevin | Rebman, Jon | Rollinson, Christy | Russell, Ryan | Sachs, Elyse | Sax, Miles S. | Singhurst, Jason | Spence, Emma | Standiford, Richard | Still, Shannon | Taylor, Robin | Thibault, Tim | Thompson, Patrick | Tokarz, Elizabeth | Treher, Amanda | Underhill, Jeffrey | Westwood, Murphy | Wiens, John | Wilhelm, Gerould | Wright, Jessica | Young, Carol | Youtz, James | Zeleznik, Joseph

Institutional contributors to 2017 *ex situ* collections survey and/or conservation action questionnaire:

Adkins Arboretum | Alabama Department of Conservation and Natural Resources, State Lands | Alamo Area Master Naturalist | American Public Gardens Association | Arboretum at Flagstaff, The | Arboretum at Penn State, The | Arboretum de Chevreloup | Arboretum des Pouyouleix | Arboretum in Hørsholm, The | Arboretum Robert Lenoir | Arboretum Wespelaar | Arizona Game and Fish Department | Arizona State University | Arizona-Sonora Desert Museum | Arkansas Forestry Commission | Arkansas Natural Heritage Commission | Arnold Arboretum of Harvard University, The | Atlanta Botanical Garden | Auburn University | Auckland Botanic Gardens | Australian Botanic Garden, Mount Annan, The | Barnea Oak Nursery | Bartlett Tree Research Lab and Arboretum | Batumi Botanical Garden | Bayard Cutting Arboretum | BBI | Bedgebury National Pinetum & Forest | Belmonte Arboretum | Bendigo Botanic Gardens, White Hills | Bethune-Cookman University | Better Tree Care | Birmingham Botanical Gardens and Glasshouses | Boone County Arboretum | Botanic Garden Louise Wardle de Camacho | Botanic Garden Meise | Botanic Garden of Smith College, The | Botanic Garden, Delft University of Technology | Botanic Gardens of South Australia | Botanical Garden Lomonosov, Moscow State University | Botanical Garden of Moscow Palace of Pioneers | Botanischer Garten der Carl von Ossietzky-Universität Oldenburg | Botanischer Garten der Philipps-Universität Marburg | Botanischer Garten der Universität Zürich | Botanischer Garten der Universität Osnabrück | Botanischer Garten Frankfurt am Main | Bowman's Hill Wildflower Preserve | Boyce Thompson Arboretum | Brenton Arboretum, The | Brookgreen Gardens | Brooklyn Botanic Garden | Brookside Gardens | Bureau of Land Management | Butte County Environmental Council | California Department of Transportation | California Department of Water Resources | California Department of Fish and Wildlife | California State Parks | Cape Fear Botanical Garden | Capital Area Native Plant Society | Cherokee County (GA) Biodiversity Project | Cherry Hill Environmental Board | Chicago Botanic Garden | Cincinnati Zoo and Botanical Gardens | City of Boerne | City of Columbia | City of Philadelphia | City of Rochester Hills | City of San Antonio | Coastal Bend Bays and Estuaries Program | Coastside Land Trust | Conservation Foundation of the Gulf Coast | Cornell Botanic Gardens | Cornell University | Cowichan Lake Research Station | Cradle of Texas Conservancy | Dawes Arboretum, The | Dayton VA Medical Center Gardens & Grotto | Dendrologicka zahrada | Denver Botanic Gardens | Descanso Gardens | Desert Botanical Garden | Donald E. Davis Arboretum | Dunedin Botanic Garden | Dyck Arboretum of the Plains | Eastwoodhill Arboretum | Eddy Arboretum - Pacific Southwest Research Station | Eglin Air Force Base | Elisabeth C. Miller Botanical Garden | Elmhurst Arboretum, The | Estancia San Miguel | Etter Tree Care | Fernwood Botanical Garden and Nature Preserve | Finnish Museum of Natural History / Helsinki University Botanic Garden | Florida Department of Agriculture and Consumer Services | Florida Fish and Wildlife Conservation Commision | Florida Forest Service | Florida Native Plant Society | Florida Natural Areas Inventory | For-Mar Nature Preserve & Arboretum | Forstbotanischer Garten der Technischen Universität Dresden | Forstbotanischer Garten Universität Göttingen | Foundation for Environmental Research | Frederik Meijer Gardens and Sculpture Park | Friends of Lost Creek Forest | Gainesway Farm | Garvan Woodland Gardens | Geografisch Arboretum Tervuren | George G. Willis Jr. Arboretum | George Landis Arboretum | Georgia Department of Natural Resources | Georgia Native Plant Society | Georgia Tech Arboretum | Gradina

Quercus pacifica (Bart O'Brien)

Agrobotanica din Cluj-Napoca | Green Bay Botanical Garden | Greenbelt Native Plant Center | Grigadale Arboretum | Growild, Inc. | Hackfalls Arboretum | Harmas de Fabre | Harris County Flood Control District | Heritage Seedlings and Liners Inc. | Hof ter Saksen Arboretum | Holden Arboretum, The | Hollard Garden | Honolulu Botanical Gardens | Hoyt Arboretum | Hungry Valley State Vehicular Recreation Area | Huntington Botanical Gardens | Huntington, The | Huntsville Botanical Garden | Indiana Division of Forestry | Institute for Regional Conservation, The | Iowa Arboretum | Iturraran Botanical Garden | Jardi Botanic de Soller | Jardin alpin La Jaÿsinia | Jardín Botánico "Carlos Thays" | Jardín Botánico de la Universidad Autónoma de Puebla | Jardín Botánico del Instituto de Biología (UNAM) | Jardín Botánico Francisco Javier Clavijero | Jardin Botanique de la Villa Thuret | Jardin botanique exotique de Menton | Jardin Botanique De Lyon | Jardin des Plantes de Paris | JC Raulston Arboretum | Jerusalem Botanical Gardens | Jerusalem University | Jim Martinez & Associates | Kruckeberg Botanic Garden | l'Arboretum de La Bergerette | Lady Bird Johnson Wildflower Center | Lake County Parks and Trails | Land Conservancy of San Luis Obispo County, The | Land Trust for Central North Carolina, The | Land Trust of Santa Cruz County | Lane County Parks | Lauritzen Gardens | Les Jardins Suspendus | Lewis Ginter Botanical Garden | Lewis W. Barton Arboretum & Nature Preserve at Medford Leas | Ling Island Botanical Society | Linnaean Gardens of Uppsala (Uppsala University), The | Living Desert Zoo and Botanical Garden State Park | Living Desert Zoo and Gardens | Lomakatsi Restoration Project | Long Tom Watershed Council | Longwood Gardens | Los Angeles County Arboretum and Botanic Garden | Louis Berger US, Inc. | Louisiana Department of Wildlife and Fisheries | Louisiana Natural Heritage Program | Madronia Cemetery and Arboretum | Main Botanical Garden, Russian Academy of Sciences | Marie Selby Botanical Gardens | Matthaei Botanical Gardens and Nichols Arboretum | Maymont Foundation | Meijer Garden and Sculpture Park | Memphis Botanic Garden | Mereweather Arboretum | Metro | Michigan State University | Michigan State University Plant Sciences Greenhouse | Millpond Plants | Minnesota State University, Mankato | Mississippi State University Extension | Missouri Botanical Garden | Missouri Department of Conservation | Mobile Botanical Gardens | Montgomery Botanical Center | Montreal Botanical Garden / Jardin botanique de Montréal | Moore Farms Botanical Garden | Morris Arboretum, The | Morton Arboretum, The | Mount Auburn Cemetery | Mountains Restoration Trust | Mt. Cuba Center | Naples Botanical Garden | National Botanic Gardens of Ireland | National Botanic Gardens, Glasnevin | National Plant Germplasm System - USDA-ARS-NGRL | National Tropical Botanical Garden | Native Plant Society of Texas | Nature Conservancy, The | New England Wild Flower Society | New Jersey Forest Service | New Mexico State University | New Plymouth Reserves / Parklands | New York Botanical Garden, The | Niagara Parks Botanical Gardens and School of Horticulture, The | Norfolk Botanical Garden | North American Land Trust | North American Native Plant Society | North Carolina Arboretum, The | North Carolina Botanical Garden | North Central Regional Plant Introduction Station | North Dakota State University | Oaks of Chevithorne Barton | Oconee River Land Trust | Ohio Department of Natural Resources Park | Oklahoma City Zoo and Botanical Garden | Oklahoma Natural Heritage Inventory | Orange County Environmental Protection Division | Orto Botanico dell'Università degli studi di Siena | Paignton Zoo Environmental Park | Palacký University Botanical Garden | Patterson Garden Arboretum | Peckerwood Garden Conservation Foundation | Penn State University | Pennsylvania of Conservation and Natural Resources, Bureau of Forestry | Pines and Prairies Land Trust | Polly Hill Arboretum, The | Pukeiti Garden | Pukekura Park | Quarryhill Botanical Garden | Queens Botanical Garden | R.L. McGregor Herbarium | Rae Selling Berry Seed Bank | Rancho Santa Ana Botanic Garden | Real Jardín Botánico Juan Carlos I | Red Butte Garden and Arboretum, University of Utah | Redwood National Park | Reiman Gardens | Rogów Arboretum of Warsaw University of Life Sciences | Rose Woods | Royal Botanic Garden Edinburgh | Royal Botanic Gardens, Kew | Royal Botanic Gardens, Victoria | Royal Botanic Gardens, Victoria - Melbourne Gardens | Royal Botanical Gardens, Ontario | Royal Roads University | Royal Tasmanian Botanical Gardens | Sacramento Valley Conservancy | Saguaro National Park | San Antonio Water System | San Diego Botanic Garden | San Diego Zoo Safari Park | San Francisco Botanical Garden | San Juan County Land Bank | San Luis Obispo Botanical Garden | Santa Barbara Botanic Garden | Sarah P. Duke Gardens | Scott Arboretum of Swarthmore College | Shaw Nature Reserve of the Missouri Botanical Garden | Sheffield Botanical Gardens | Silva

Quercus laceyi (Adam Black)

Tarouca Research Institute for Landscape and Ornamental Gardening, The | Sir Harold Hillier Gardens, The | Sister Mary Grace Burns Arboretum of Georgian Court University | South Carolina Native Plant Society | Southeast Regional Land Conservancy | Southern Illinois University, Department of Forestry | Spring Grove Cemetery and Arboretum | Starhill Forest Arboretum | State Botanical Garden of Georgia, The | State Botanical Garden of Georgia at the University of Georgia | State of New Jersey | Stavanger Botanic Garden | Stephen's Lake Park Arboretum | Sul Ross State University | Sustainable Ecosystems International | SWCA, Inc. | Taltree Arboretum & Gardens | Tasmanian Arboretum, The | Texas Forest Service | Texas Master Naturalist | Texas Parks and Wildlife Department | Texas Tech University | Tharandt Botanic Garden and Arboretum | Timaru Botanic Garden | Trees Atlanta | Trinity County Resource Conservation District | Trompenburg Gardens & Arboretum | Tulsa Botanic Garden | Tupare Garden | Tyler Arboretum | UC Davis Arboretum and Public Garden | United States Botanic Garden | United States National Arboretum | Universidad de San Carlos de Guatemala | Universidad Nacional Autonoma de Mexico | University of British Columbia Botanical Garden | University of California Botanical Garden at Berkeley | University of California, Berkeley | University of Central Florida | University of Colorado | University of Copenhagen | University of Delaware | University of Exeter Grounds | University of Guelph Arboretum, The | University of Illinois at Chicago | University of Kentucky | University of Kentucky Arboretum and State Botanical Garden | University of Minnesota | University of Missouri | University of North Carolina | University of Oklahoma | University of Saskatchewan | University of Tennessee, The | | University of Texas at El Paso, The | University of Washington Botanic Gardens | U.S. Fish and Wildlife Service | USA National Phenology Network | USDA Forest Service | USDA Natural Resources Conservation Service | USDI National Arcata Field Office | VanDusen Botanical Garden | W. J. Beal Botanical Garden, Michigan State University | Watershed Research and Training Center | Wellington Botanic Garden | Wesleyan College Arboretum | West Chester University Arboretum | West Laurel Hill Cemetery | Western Carolina Botanical Society | Westonbirt, The National Arboretum | Wildland Management Services LLC | Wildlands Conservancy, The | Winthrop Department of Public Works | Wisconsin Department of Natural Resources | Xishuangbanna Tropical Botanical Garden, CAS | Zoological and Botanical Gardens of Plzen

APPENDIX B. SELECTION PROCESS FOR SPECIES OF CONSERVATION CONCERN

Four analyses or metrics were used to rank species: 1) IUCN Red List of Threatened Species, 2) NatureServe global conservation status rankings, 3) Project CAPTURE (a climate change vulnerability study conducted by Potter *et al*., 2017), 4) the *ex situ* collections survey conducted for this gap analysis. Species with an overall concern score of 3 or higher were deemed "species of conern."

SCORING 5 points | 4 points | 3 points | 2 points | 1 points | 0 points

Species name	Concern score	IUCN Red List	NatureServe	Potter *et al.*, 2017	*Ex situ* survey results	
		Threat category	Global conservation status ranking	Vulnerability class	Number of individuals in *ex situ*	Number of *ex situ* institutions
Quercus boyntonii	11	CR	G1	B	318	16
Quercus graciliformis	11	CR	G1	D	108	15
Quercus hinckleyi	10	CR	G2		10	6
Quercus acerifolia	9	EN	G1		79	21
Quercus carmenensis	9	EN	G2?		2	1
Quercus ajoensis	8	VU	G2G4		7	3
Quercus cedrosensis	8	VU	G2?		1	1
Quercus robusta	8	DD	G1Q		2	2
Quercus tardifolia	8	DD	G1		0	0
Quercus arkansana	7	VU	G3	A	129	28
Quercus dumosa	7	EN	G2		215	16
Quercus engelmannii	7	EN	G3	D	563	19
Quercus georgiana	6	EN	G3		208	24
Quercus oglethorpensis	6	EN	G3		390	30
Quercus pacifica	6	EN	G3		73	11
Quercus tomentella	6	EN	G3		64	18
Quercus havardii	5	EN	G4		415	13
Quercus austrina	4	VU	G4?		47	16
*Quercus depressipes**	4	LC	G3		2	1
Quercus palmeri	4	NT	G3G5		42	18
Quercus pumila	4	LC	G3G5		20	9
Quercus similis	4	LC	G4	C	4	2
Quercus toumeyi	4	DD	G4		10	3
Quercus chapmanii	3	LC	G4G5		16	8
Quercus inopina	3	LC	G4		14	5
Quercus laceyi	3	LC	G4	A	45	16
Quercus lobata	3	NT	G4	E	1218	41
Quercus parvula	3	NT	G4Q		61	15
Quercus sadleriana	3	NT	GNR		74	14
*Quercus viminea**	3	LC	G4G5		8	3
Quercus bicolor	2	LC	G5	A	2357	97
Quercus chihuahuensis	2	LC	G3G5		3	2
Quercus intricata	2	LC	G5		3	2
Quercus john-tuckeri	2	LC	G4?		65	9
Quercus margarettae	2	LC	G5	C	141	10
Quercus rugosa	2	LC	G4G5	B	106	36
Quercus sinuata	2	LC	G4G5	C	118	23
Quercus texana	2	LC	G4G5	B	161	51
Quercus arizonica	1	LC	G5	D	97	21
Quercus cornelius-mulleri	1	LC	G4		25	12
Quercus douglasii	1	LC	G4?	E	812	36
Quercus durata	1	LC	G4		77	22
Quercus ellipsoidalis	1	LC	G5	C	317	54
Quercus emoryi	1	LC	G5	C	66	22
Quercus gravesii	1	LC	G5	D	37	20
Quercus grisea	1	LC	G5	B	70	21
Quercus ilicifolia	1	LC	G5	C	154	53

Species name	Concern score	IUCN Red List	NatureServe	Potter *et al.*, 2017	2017 *ex situ* survey results	
		Threat category	Global conservation status ranking	Vulnerability class	Number of individuals in *ex situ*	Number of *ex situ* institutions
Quercus imbricaria	1	LC	G5	C	595	73
Quercus incana	1	LC	G5	B	126	22
Quercus laevis	1	LC	G5	B	80	14
Quercus lyrata	1	LC	G5	C	372	61
Quercus michauxii	1	LC	G5	D	295	61
Quercus mohriana	1	LC	G4		24	11
Quercus montana (prinus)	1	LC	G5	B	702	75
Quercus muehlenbergii	1	LC	G5	C	733	76
Quercus oblongifolia	1	LC	G5	D	31	13
Quercus pagoda	1	LC	G5	C	123	32
Quercus palustris	1	LC	G5	C	5758	97
Quercus polymorpha	1	LC	G5	B	120	28
Quercus prinoides	1	LC	G5	C	335	44
Quercus pungens	1	LC	GNR		54	17
Quercus shumardii	1	LC	G5	C	745	85
Quercus vacciniifolia	1	LC	G4G5		35	16
Quercus vaseyana	1	LC	G4G5		23	14
Quercus virginiana	1	LC	G5	D	420	60
Quercus agrifolia	0	LC	G5	E	1760	43
Quercus alba	0	LC	G5	E	3180	101
Quercus berberidifolia	0	LC	G5		246	20
Quercus buckleyi	0	LC	G5		73	26
Quercus chrysolepis	0	LC	G5	E	228	39
Quercus coccinea	0	LC	G5	E	976	88
Quercus falcata	0	LC	G5	E	489	56
Quercus fusiformis	0	LC	G5		61	19
Quercus gambelii	0	LC	G5	E	262	32
Quercus garryana	0	LC	G5	E	350	36
Quercus geminata	0	LC	G5		124	19
Quercus hemisphaerica	0	LC	G5		100	28
Quercus hypoleucoides	0	LC	G5	E	65	22
Quercus kelloggii	0	LC	G5	E	158	30
Quercus laurifolia	0	LC	G5	E	125	38
Quercus macrocarpa	0	LC	G5	E	2472	108
Quercus marilandica	0	LC	G5	E	208	56
Quercus minima	0	LC	G5	E	43	12
Quercus myrtifolia	0	LC	G5		56	17
Quercus nigra	0	LC	G5	E	211	57
Quercus phellos	0	LC	G5	E	743	81
Quercus rubra	0	LC	G5	E	4003	115
Quercus stellata	0	LC	G5	E	727	65
Quercus turbinella	0	LC	G5		214	34
Quercus velutina	0	LC	G5	E	1323	83
Quercus wislizeni	0	LC	G5	E	239	22

*Not included in final species of concern list because less than 10% of the species' distribution is within the U.S.

Explanation of metrics used for scoring

IUCN Red List	CR = 5 points, EN = 4 points, VU = 3 points, NT = 2 points, DD = 1 point, LC = 0 points
NatureServe	G1 = 5 points, G2 = 3 points, G3 = 2 points, G4 = 1 point, G5 = 0 points; if two ranks are given (e.g. G3G5) the score reflects the more severe threat level; other indicators (i.e., Q = Questionable Taxonomy, ? = Inexact Numeric Rank) are not taken into account for scoring
Potter *et al.*, 2017	A = high vulnerability, little adaptation or persistence potential (2 points), B = high vulnerabiliy, potential adaptation (1 point), C = high vulnerability, potential persistence (1 point), D = Potential high future vulnerability (1 point), E = Low current vulnerability (0 points); blank cells represent species that were not included in the study
***Ex situ* survey**	Number of individuals in *ex situ* collections ≤ 20 = 1 point; number of *ex situ* institutions ≤ 10 = 1 point; values outside these thresholds = 0 points

APPENDIX C. *EX SITU* COLLECTIONS SURVEY OF NATIVE U.S. OAKS

Data were gathered May-July, 2017. A total of 162 respondent institutions from 26 countries reported 34,167 native U.S. oak plants. Species of conservation concern are highlighted in red.

Native U.S. oak species	Number of *ex situ* institutions	Number of plants in *ex situ* collections	Number of plants marked as wild origin	Number of plants geolocated to their wild origin*
Quercus acerifolia	21	79	40	44
Quercus agrifolia	43	1760	1503	
Quercus ajoensis	3	7	7	7
Quercus alba	101	3180	1553	
Quercus arizonica	21	97	58	
Quercus arkansana	28	129	82	99
Quercus austrina	16	47	29	28
Quercus berberidifolia	20	246	115	
Quercus bicolor	97	2357	464	
Quercus boyntonii	16	318	213	311
Quercus buckleyi	26	73	27	
Quercus carmenensis	1	2	2	2
Quercus cedrosensis	1	1	1	1
Quercus chapmanii	8	16	11	9
Quercus chihuahuensis	2	3	3	
Quercus chrysolepis	39	228	148	
Quercus coccinea	88	976	73	
Quercus cornelius-mulleri	12	25	14	
Quercus depressipes	1	2	2	
Quercus douglasii	36	812	747	
Quercus dumosa	16	215	180	183
Quercus durata	22	77	49	
Quercus ellipsoidalis	54	317	126	
Quercus emoryi	22	66	34	
Quercus engelmannii	19	563	434	506
Quercus falcata	56	489	108	
Quercus fusiformis	19	61	37	
Quercus gambelii	32	262	74	
Quercus garryana	36	350	212	
Quercus geminata	19	124	42	
Quercus georgiana	24	208	143	165
Quercus graciliformis	15	108	91	91
Quercus gravesii	20	37	17	
Quercus grisea	21	70	53	
Quercus havardii	13	415	273	381
Quercus hemisphaerica	28	100	47	
Quercus hinckleyi	6	10	2	1
Quercus hypoleucoides	22	65	32	
Quercus ilicifolia	53	154	50	
Quercus imbricaria	73	595	119	
Quercus incana	22	126	97	
Quercus inopina	5	14	11	11
Quercus intricata	2	3	3	
Quercus john-tuckeri	9	65	58	
Quercus kelloggii	30	158	80	
Quercus laceyi	16	45	28	8

Native U.S. oak species	Number of *ex situ* institutions	Number of plants in *ex situ* collections	Number of plants marked as wild origin	Number of plants geolocated to their wild origin*
Quercus laevis	14	80	39	
Quercus laurifolia	38	125	50	
Quercus lobata	41	1218	482	1087
Quercus lyrata	61	372	101	
Quercus macrocarpa	108	2472	1059	
Quercus margarettae	10	141	129	
Quercus marilandica	56	208	121	
Quercus michauxii	61	295	108	
Quercus minima	12	43	27	
Quercus mohriana	11	24	16	
Quercus montana	75	702	278	
Quercus muehlenbergii	76	733	353	
Quercus myrtifolia	17	56	40	
Quercus nigra	57	211	66	
Quercus oblongifolia	13	31	17	
Quercus oglethorpensis	30	390	271	354
Quercus pacifica	11	73	50	61
Quercus pagoda	32	123	59	
Quercus palmeri	18	42	27	26
Quercus palustris	97	5758	261	
Quercus parvula	15	61	38	40
Quercus phellos	81	743	210	
Quercus polymorpha	28	120	32	
Quercus prinoides	44	335	238	
Quercus pumila	9	20	8	8
Quercus pungens	17	54	36	
Quercus robusta	2	2	1	1
Quercus rubra	115	4003	708	
Quercus rugosa	36	106	51	
Quercus sadleriana	14	74	61	43
Quercus shumardii	85	745	248	
Quercus similis	2	4	4	4
Quercus sinuata	23	118	92	
Quercus stellata	65	727	588	
Quercus tardifolia	0	0	0	0
Quercus texana	51	161	44	
Quercus tomentella	18	64	18	24
Quercus toumeyi	3	10	8	8
Quercus turbinella	34	214	119	
Quercus vacciniifolia	16	35	24	
Quercus vaseyana	14	23	21	
Quercus velutina	83	1323	343	
Quercus viminea	3	8	7	
Quercus virginiana	60	420	57	
Quercus wislizeni	22	239	193	

*Geolocation was attempted only for accession records for species of concern.

APPENDIX D. RESULTS OF CONSERVATION ACTION QUESTIONNAIRE FOR U.S. OAK SPECIES OF CONSERVATION CONCERN

Data were gathered April-May, 2017. A total of 328 individuals from 252 institutions responded, including 78 institutions that provided input on species of concern. Institutions reporting efforts in any of the conservation action categories for a species of concern are listed. See Table 8 for a list of state abbreviations.

Species name	Institution	State	Category	Interested in further oak conservation efforts?
Quercus acerifolia	Arkansas Natural Heritage Commission	AR	Natural heritage	*Ex situ* & *in situ*
	Arnold Arboretum of Harvard University, The	MA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Chicago Botanic Garden	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	City of Columbia	MO	City government	*Ex situ* & *in situ*
	Dawes Arboretum, The	OH	Arboretum/botanic garden	*Ex situ* & *in situ*
	Georgia Department of Natural Resources	GA	State government	*In situ*
	Morris Arboretum, The	PA	Arboretum/botanic garden	*Ex situ*
	Morton Arboretum, The	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	North American Land Trust	PA	National NGO	*Ex situ* & *in situ*
	Polly Hill Arboretum, The	MA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Taltree Arboretum & Gardens	IN	Arboretum/botanic garden	*Ex situ* & *in situ*
	USDA Forest Service	AR	National government	*Ex situ* & *in situ*
	Zoological and Botanical Gardens of Plzen	Non-U.S.	Arboretum/botanic garden	*Ex situ*
Quercus arkansana	Arkansas Natural Heritage Commission	AR	Natural heritage	*Ex situ* & *in situ*
	Arnold Arboretum of Harvard University, The	MA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Auburn University	AL	University	*Ex situ* & *in situ*
	BBI	GA	Private	*Ex situ* & *in situ*
	Chicago Botanic Garden	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	City of Columbia	MO	City government	*Ex situ* & *in situ*
	Cornell University	NY	University	*Ex situ* & *in situ*
	Dawes Arboretum, The	OH	Arboretum/botanic garden	*Ex situ* & *in situ*
	Donald E. Davis Arboretum	AL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Eglin Air Force Base	FL	National government	*In situ*
	Florida Department of Agriculture and Consumer Services	FL	State government	*In situ*
	Florida Forest Service	FL	State government	*In situ*
	Gainesway Farm	KY	Arboretum/botanic garden	*In situ*
	Georgia Department of Natural Resources	GA	State government	*In situ*
	Louisiana Department of Wildlife and Fisheries	LA	State government	*In situ*
	Louisiana Natural Heritage Program	LA	Natural heritage	*Ex situ* & *in situ*
	Missouri Botanical Garden	MO	Arboretum/botanic garden	*Ex situ* & *in situ*
	Morris Arboretum, The	PA	Arboretum/botanic garden	*Ex situ*
	Morton Arboretum, The	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Nature Conservancy, The	National	National NGO	*Ex situ* & *in situ*
	North American Land Trust	PA	National NGO	*Ex situ* & *in situ*
	Taltree Arboretum & Gardens	IN	Arboretum/botanic garden	*Ex situ* & *in situ*
	Trees Atlanta	GA	Arboretum/botanic garden	*Ex situ*
	USDA Forest Service	GA	National government	*Ex situ* & *in situ*
Quercus austrina	Arkansas Natural Heritage Commission	AR	Natural heritage	*Ex situ* & *in situ*
	BBI	GA	Private	*Ex situ* & *in situ*
	Chicago Botanic Garden	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	City of Columbia	MO	City government	*Ex situ* & *in situ*
	Donald E. Davis Arboretum	AL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Florida Forest Service	FL	State government	*In situ*
	Gainesway Farm	KY	Arboretum/botanic garden	*In situ*
	Georgia Department of Natural Resources	GA	State government	*In situ*
	Morton Arboretum, The	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Nature Conservancy, The	National	National NGO	*Ex situ* & *in situ*
	North American Land Trust	PA	National NGO	*Ex situ* & *in situ*
	Taltree Arboretum & Gardens	IN	Arboretum/botanic garden	*Ex situ* & *in situ*
	Trees Atlanta	GA	Arboretum/botanic garden	*Ex situ*

Species name	Institution	State	Category	Interested in further oak conservation efforts?
Quercus austrina	U.S. Fish and Wildlife Service	FL	National government	*Ex situ* & *in situ*
	University of Minnesota	MN	University	*Ex situ* & *in situ*
	University of North Carolina	NC	University	*Ex situ*
	USDA Forest Service, Uwharrie/Croatan National Forest	NC	National government	*Ex situ* & *in situ*
Quercus boyntonii	Auburn University	AL	University	*Ex situ* & *in situ*
	Chicago Botanic Garden	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	City of Columbia	MO	City government	*Ex situ* & *in situ*
	Cornell University	NY	University	*Ex situ* & *in situ*
	Donald E. Davis Arboretum	AL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Morris Arboretum, The	PA	Arboretum/botanic garden	*Ex situ*
	Morton Arboretum, The	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Nature Conservancy, The	National	National NGO	*Ex situ* & *in situ*
	North American Land Trust	PA	National NGO	*Ex situ* & *in situ*
	Polly Hill Arboretum, The	MA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Taltree Arboretum & Gardens	IN	Arboretum/botanic garden	*Ex situ* & *in situ*
	USDA Forest Service, National Forests of Alabama	AL	National government	*Ex situ* & *in situ*
Quercus carmenensis	Sul Ross State University	TX	University	Unknown
Quercus cedrosensis	Rancho Santa Ana Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
Quercus chapmanii	Chicago Botanic Garden	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	City of Columbia	MO	City government	*Ex situ* & *in situ*
	Conservation Foundation of the Gulf Coast	FL	Regional NGO	*Ex situ* & *in situ*
	Donald E. Davis Arboretum	AL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Florida Department of Agriculture and Consumer Services	FL	State government	*In situ*
	Florida Fish and Wildlife Conservation Commision	FL	State government	No
	Florida Forest Service	FL	State government	*In situ*
	Florida Natural Areas Inventory	FL	Regional NGO	*Ex situ* & *in situ*
	Gainesway Farm	KY	Arboretum/botanic garden	*In situ*
	Georgia Department of Natural Resources	GA	State government	*In situ*
	Institute for Regional Conservation, The	FL	Regional NGO	*Ex situ* & *in situ*
	Lake County Parks and Trails	FL	County government	*Ex situ* & *in situ*
	Marie Selby Botanical Gardens	FL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Memphis Botanic Garden	TN	Arboretum/botanic garden	*Ex situ* & *in situ*
	Minnesota State University, Mankato	MN	University	*Ex situ* & *in situ*
	Naples Botanical Garden	FL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Nature Conservancy, The	National	National NGO	*Ex situ* & *in situ*
	North American Land Trust	PA	National NGO	*Ex situ* & *in situ*
	Orange County Environmental Protection Division	FL	County government	*In situ*
	Sustainable Ecosystems International	FL	International NGO	*In situ*
	Taltree Arboretum & Gardens	IN	Arboretum/botanic garden	*Ex situ* & *in situ*
	Trees Atlanta	GA	Arboretum/botanic garden	*Ex situ*
	U.S. Fish and Wildlife Service	FL	National government	*Ex situ* & *in situ*
	University of Central Florida	FL	University	*Ex situ* & *in situ*
	University of Minnesota	MN	University	*Ex situ* & *in situ*
	University of North Carolina	NC	University	*Ex situ*
	USDA Forest Service, National Forests of Alabama	AL	National government	*Ex situ* & *in situ*
Quercus dumosa	Hoyt Arboretum	OR	Arboretum/botanic garden	*Ex situ*
	Huntington, The	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Rancho Santa Ana Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	San Diego Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	San Luis Obispo Botanical Garden	CA	Arboretum/botanic garden	*In situ*
	Santa Barbara Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	University of California Botanical Garden at Berkeley	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	University of Illinois at Chicago	IL	University	*Ex situ* & *in situ*
	USDA Forest Service, Southwestern Region	Regional	National government	No
Quercus engelmannii	Huntington, The	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Rancho Santa Ana Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	San Diego Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	San Luis Obispo Botanical Garden	CA	Arboretum/botanic garden	*In situ*

Species name	Institution	State	Category	Interested in further oak conservation efforts?
Quercus engelmannii	Santa Barbara Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	University of California, Berkeley	CA	University	*Ex situ* & *in situ*
Quercus georgiana	Auburn University	AL	University	*Ex situ* & *in situ*
	BBI	GA	Private	*Ex situ* & *in situ*
	Chicago Botanic Garden	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	City of Columbia	MO	City government	*Ex situ* & *in situ*
	Cornell University	NY	University	*Ex situ* & *in situ*
	Donald E. Davis Arboretum	AL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Gainesway Farm	KY	Arboretum/botanic garden	*In situ*
	Georgia Department of Natural Resources	GA	State government	*In situ*
	Morton Arboretum, The	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Nature Conservancy, The	National	National NGO	*Ex situ* & *in situ*
	North American Land Trust	PA	National NGO	*Ex situ* & *in situ*
	Sarah P. Duke Gardens	NC	Arboretum/botanic garden	*Ex situ* & *in situ*
	Taltree Arboretum & Gardens	IN	Arboretum/botanic garden	*Ex situ* & *in situ*
	Trees Atlanta	GA	Arboretum/botanic garden	*Ex situ*
	University of North Carolina	NC	University	*Ex situ*
	USDA Forest Service	GA	National government	*Ex situ* & *in situ*
	Wildland Management Services LLC	GA	Private	*In situ*
Quercus graciliformis	Boyce Thompson Arboretum	AZ	Arboretum/botanic garden	*Ex situ* & *in situ*
	Denver Botanic Gardens	CO	Arboretum/botanic garden	*Ex situ*
	Living Desert Zoo and Botanical Garden State Park	NM	Arboretum/botanic garden	*Ex situ*
	San Francisco Botanical Garden	CA	Arboretum/botanic garden	*Ex situ*
	Sul Ross State University	TX	University	Unknown
	University of Texas at El Paso, The	TX	University	*Ex situ*
	VanDusen Botanical Garden	Non-U.S.	Arboretum/botanic garden	*Ex situ*
Quercus havardii	Boyce Thompson Arboretum	AZ	Arboretum/botanic garden	*Ex situ* & *in situ*
	Denver Botanic Gardens	CO	Arboretum/botanic garden	*Ex situ*
	Huntington, The	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Living Desert Zoo and Botanical Garden State Park	NM	Arboretum/botanic garden	*Ex situ*
	Red Butte Garden and Arboretum, University of Utah	UT	Arboretum/botanic garden	*Ex situ* & *in situ*
	Texas Tech University	TX	University	*Ex situ* & *in situ*
	University of Texas at El Paso, The	TX	University	*Ex situ*
Quercus hinckelyi	City of San Antonio	TX	City government	*In situ*
	Living Desert Zoo and Botanical Garden State Park	NM	Arboretum/botanic garden	*Ex situ*
	Sul Ross State University	TX	University	Unknown
	University of Illinois at Chicago	IL	University	*Ex situ* & *in situ*
	University of Texas at El Paso, The	TX	University	*Ex situ*
Quercus inopina	Chicago Botanic Garden	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Conservation Foundation of the Gulf Coast	FL	Regional NGO	*Ex situ* & *in situ*
	Florida Department of Agriculture and Consumer Services	FL	State government	*In situ*
	Florida Fish and Wildlife Conservation Commision	FL	State government	No
	Florida Forest Service	FL	State government	*In situ*
	Florida Natural Areas Inventory	FL	Regional NGO	*Ex situ* & *in situ*
	Institute for Regional Conservation, The	FL	Regional NGO	*Ex situ* & *in situ*
	Marie Selby Botanical Gardens	FL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Sustainable Ecosystems International	FL	International NGO	*In situ*
	Taltree Arboretum & Gardens	IN	Arboretum/botanic garden	*Ex situ* & *in situ*
	U.S. Fish and Wildlife Service	FL	National government	*Ex situ* & *in situ*
	University of Central Florida	FL	University	*Ex situ* & *in situ*
	University of North Carolina	NC	University	*Ex situ*
	USDA Forest Service, National Forests of Alabama	AL	National government	*Ex situ* & *in situ*
Quercus laceyi	City of San Antonio	TX	City government	*In situ*
	Denver Botanic Gardens	CO	Arboretum/botanic garden	*Ex situ*
	Etter Tree Care	TX	Private	*Ex situ* & *in situ*
	Native Plant Society of Texas, Lindheimer Chapter	TX	Native plant society	*Ex situ* & *in situ*
	Native Plant Society of Texas, San Antonio Chapter	TX	Native plant society	No
	University of Texas at El Paso, The	TX	University	*Ex situ*

Species name	Institution	State	Category	Interested in further oak conservation efforts?
Quercus lobata	Boyce Thompson Arboretum	AZ	Arboretum/botanic garden	*Ex situ* & *in situ*
	Bureau of Land Management, Redding Field Office	CA	National government	*Ex situ* & *in situ*
	Butte County Environmental Council	CA	County government	*Ex situ* & *in situ*
	California Department of Transportation	CA	State government	*Ex situ* & *in situ*
	California State Parks	CA	State government	*In situ*
	Denver Botanic Gardens	CO	Arboretum/botanic garden	*Ex situ*
	Elisabeth C. Miller Botanical Garden	WA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Heritage Seedlings and Liners Inc.	OR	Private	*Ex situ*
	Hungry Valley State Vehicular Recreation Area	CA	State government	*Ex situ*
	Mountains Restoration Trust	CA	Regional NGO	*Ex situ* & *in situ*
	Quarryhill Botanical Garden	CA	Arboretum/botanic garden	*In situ*
	Rancho Santa Ana Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Red Butte Garden and Arboretum, University of Utah	UT	Arboretum/botanic garden	*Ex situ* & *in situ*
	Sacramento Valley Conservancy	CA	Regional NGO	*Ex situ* & *in situ*
	San Diego Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	San Luis Obispo Botanical Garden	CA	Arboretum/botanic garden	*In situ*
	Santa Barbara Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	University of Illinois at Chicago	IL	University	*Ex situ* & *in situ*
	USDA Forest Service, Pacific Northwest Research Station	OR	National government	No
Quercus oglethorpensis	Auburn University	AL	University	*Ex situ* & *in situ*
	BBI	GA	Private	*Ex situ* & *in situ*
	Chicago Botanic Garden	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	City of Columbia	MO	City government	*Ex situ* & *in situ*
	Dawes Arboretum, The	OH	Arboretum/botanic garden	*Ex situ* & *in situ*
	Donald E. Davis Arboretum	AL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Gainesway Farm	KY	Arboretum/botanic garden	*In situ*
	Georgia Department of Natural Resources	GA	State government	*In situ*
	Louisiana Department of Wildlife and Fisheries	LA	State government	*In situ*
	Morton Arboretum, The	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	North American Land Trust	PA	National NGO	*Ex situ* & *in situ*
	Polly Hill Arboretum, The	MA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Sarah P. Duke Gardens	NC	Arboretum/botanic garden	*Ex situ* & *in situ*
	Southeast Regional Land Conservancy	Regional	Regional NGO	*In situ*
	Taltree Arboretum & Gardens	IN	Arboretum/botanic garden	*Ex situ* & *in situ*
	Trees Atlanta	GA	Arboretum/botanic garden	*Ex situ*
	University of North Carolina	NC	University	*Ex situ*
	USDA Forest Service	GA	National government	*Ex situ* & *in situ*
	Wildland Management Services LLC	GA	Private	*In situ*
Quercus pacifica	Cornell University	NY	University	*Ex situ* & *in situ*
	Mountains Restoration Trust	CA	Regional NGO	*Ex situ* & *in situ*
	Rancho Santa Ana Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Santa Barbara Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	University of California, Berkeley	CA	University	*Ex situ* & *in situ*
	University of Illinois at Chicago	IL	University	*Ex situ* & *in situ*
Quercus palmeri	Rancho Santa Ana Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Santa Barbara Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	University of California, Berkeley	CA	University	*Ex situ* & *in situ*
	USDA Forest Service, Southwestern Region	Regional	National government	No
Quercus parvula	Mountains Restoration Trust	CA	Regional NGO	*Ex situ* & *in situ*
	San Luis Obispo Botanical Garden	CA	Arboretum/botanic garden	*In situ*
	Santa Barbara Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
Quercus pumila	Chicago Botanic Garden	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	City of Columbia	MO	City government	*Ex situ* & *in situ*
	Conservation Foundation of the Gulf Coast	FL	Regional NGO	*Ex situ* & *in situ*
	Donald E. Davis Arboretum	AL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Eglin Air Force Base	FL	National government	*In situ*
	Florida Department of Agriculture and Consumer Services	FL	State government	*In situ*
	Florida Forest Service	FL	State government	*In situ*

Species name	Institution	State	Category	Interested in further oak conservation efforts?
Quercus pumila	Florida Natural Areas Inventory	FL	Regional NGO	*Ex situ* & *in situ*
	Gainesway Farm	KY	Arboretum/botanic garden	*In situ*
	Georgia Department of Natural Resources	GA	State government	*In situ*
	Institute for Regional Conservation, The	FL	Regional NGO	*Ex situ* & *in situ*
	Marie Selby Botanical Gardens	FL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Naples Botanical Garden	FL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Nature Conservancy, The	National	National NGO	*Ex situ* & *in situ*
	North American Land Trust	PA	National NGO	*Ex situ* & *in situ*
	Taltree Arboretum & Gardens	IN	Arboretum/botanic garden	*Ex situ* & *in situ*
	Trees Atlanta	GA	Arboretum/botanic garden	*Ex situ*
	U.S. Fish and Wildlife Service	FL	National government	*Ex situ* & *in situ*
	University of Minnesota	MN	University	*Ex situ* & *in situ*
	University of North Carolina	NC	University	*Ex situ*
	USDA Forest Service, National Forests of Alabama	AL	National government	*Ex situ* & *in situ*
Quercus robusta	Living Desert Zoo and Botanical Garden State Park	NM	Arboretum/botanic garden	*Ex situ*
	Sul Ross State University	TX	University	Unknown
Quercus sadleriana	Elisabeth C. Miller Botanical Garden	WA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Hoyt Arboretum	OR	Arboretum/botanic garden	*Ex situ*
	Santa Barbara Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	USDA Forest Service	OR	National government	*Ex situ* & *in situ*
Quercus similis	Arkansas Natural Heritage Commission	AR	Natural heritage	*Ex situ* & *in situ*
	Auburn University	AL	University	*Ex situ* & *in situ*
	Chicago Botanic Garden	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	City of Columbia	MO	City government	*Ex situ* & *in situ*
	Donald E. Davis Arboretum	AL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Georgia Department of Natural Resources	GA	State government	*In situ*
	Harris County Flood Control District	TX	County government	No
	Morton Arboretum, The	IL	Arboretum/botanic garden	*Ex situ* & *in situ*
	Nature Conservancy, The	National	National NGO	*Ex situ* & *in situ*
	North American Land Trust	PA	National NGO	*Ex situ* & *in situ*
	Taltree Arboretum & Gardens	IN	Arboretum/botanic garden	*Ex situ* & *in situ*
	Texas Parks and Wildlife Department	TX	State government	*Ex situ* & *in situ*
	Trees Atlanta	GA	Arboretum/botanic garden	*Ex situ*
	University of Minnesota	MN	University	*Ex situ* & *in situ*
	University of North Carolina	NC	University	*Ex situ*
Quercus tardifolia	Living Desert Zoo and Botanical Garden State Park	NM	Arboretum/botanic garden	*Ex situ*
	Sul Ross State University	TX	University	Unknown
	Texas Tech University	TX	University	*Ex situ* & *in situ*
Quercus tomentella	Mountains Restoration Trust	CA	Regional NGO	*Ex situ* & *in situ*
	Rancho Santa Ana Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	San Diego Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	San Luis Obispo Botanical Garden	CA	Arboretum/botanic garden	*In situ*
	Santa Barbara Botanic Garden	CA	Arboretum/botanic garden	*Ex situ* & *in situ*
	University of California, Berkeley	CA	University	*Ex situ* & *in situ*
	University of Illinois at Chicago	IL	University	*Ex situ* & *in situ*
Quercus toumeyi	Arizona Game and Fish Department	AZ	State government	No
	Boyce Thompson Arboretum	AZ	Arboretum/botanic garden	*Ex situ* & *in situ*
	Living Desert Zoo and Botanical Garden State Park	NM	Arboretum/botanic garden	*Ex situ*
	University of Texas at El Paso, The	TX	University	*Ex situ*
	USDA Forest Service, Southwestern Region	Regional	National government	No
Institutions that did not report conservation actions for U.S. oak species of concern, but would like to participate in further U.S. oak conservation efforts	Arboretum at Flagstaff, The	AZ	Arboretum/botanic garden	*Ex situ* & *in situ*
	Arizona-Sonora Desert Museum	AZ	Arboretum/botanic garden	*Ex situ*
	Arkansas Forestry Commission	AR	State government	*Ex situ* & *in situ*
	Bethune-Cookman University	FL	University	*Ex situ* & *in situ*
	Bowman's Hill Wildflower Preserve	PA	Arboretum/botanic garden	*Ex situ*
	Brenton Arboretum, The	IA	Arboretum/botanic garden	*Ex situ*
	Brookgreen Gardens	SC	Arboretum/botanic garden	*Ex situ* & *in situ*
	Brookside Gardens	MD	Arboretum/botanic garden	*Ex situ*

Species name	Institution	State	Category	Interested in further oak conservation efforts?
Institutions that did not report conservation actions for U.S. oak species of concern, but would like to participate in further U.S. oak conservation efforts	Cape Fear Botanical Garden	NC	Arboretum/botanic garden	*Ex situ* & *in situ*
	Cherry Hill Environmental Board	NJ	City government	*In situ*
	Cincinnati Zoo and Botanical Gardens	OH	Arboretum/botanic garden	*Ex situ*
	City of Philadelphia	PA	City government	*Ex situ* & *in situ*
	Cornell Botanic Gardens	NY	Arboretum/botanic garden	*Ex situ*
	Cowichan Lake Research Station	Non-U.S.	International NGO	*Ex situ*
	Dyck Arboretum of the Plains	KS	Arboretum/botanic garden	*Ex situ*
	Friends of Lost Creek Forest	GA	Regional NGO	*In situ*
	Garvan Woodland Gardens	AR	Arboretum/botanic garden	*Ex situ* & *in situ*
	George Landis Arboretum	NY	Arboretum/botanic garden	*Ex situ* & *in situ*
	Holden Arboretum, The	OH	Arboretum/botanic garden	*Ex situ*
	Huntsville Botanical Garden	AL	Arboretum/botanic garden	*In situ*
	JC Raulston Arboretum	NC	Arboretum/botanic garden	*Ex situ*
	Land Conservancy of San Luis Obispo County, The	CA	Regional NGO	*Ex situ* & *in situ*
	Land Trust of Santa Cruz County	CA	County government	*In situ*
	Lane County Parks	OR	County government	*In situ*
	Long Tom Watershed Council	OR	Regional NGO	*Ex situ* & *in situ*
	Matthaei Botanical Gardens and Nichols Arboretum	MI	Arboretum/botanic garden	*In situ*
	Millpond Plants	MO	Private	*Ex situ* & *in situ*
	Mobile Botanical Gardens	AL	Arboretum/botanic garden	*Ex situ* & *in situ*
	New Jersey Forest Service	NJ	State government	*Ex situ* & *in situ*
	North Dakota State University	ND	University	*Ex situ* & *in situ*
	Oklahoma City Zoo and Botanical Garden	OK	Arboretum/botanic garden	*Ex situ* & *in situ*
	Pennsylvania of Conservation and Natural Resources, Bureau of Forestry	PA	State government	*Ex situ* & *in situ*
	Queens Botanical Garden	NY	Arboretum/botanic garden	*Ex situ* & *in situ*
	Reiman Gardens	IA	Arboretum/botanic garden	*Ex situ*
	Royal Botanical Gardens, Ontario	Non-U.S.	Arboretum/botanic garden	*Ex situ* & *in situ*
	Scott Arboretum of Swarthmore College	PA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Sister Mary Grace Burns Arboretum of Georgian Court University	NJ	Arboretum/botanic garden	*In situ*
	Southern Illinois University, Department of Forestry	IL	University	*Ex situ* & *in situ*
	Spring Grove Cemetery and Arboretum	OH	Arboretum/botanic garden	*Ex situ* & *in situ*
	State Botanical Goarden of Georgia at the University of Georgia	GA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Tyler Arboretum	PA	Arboretum/botanic garden	*Ex situ* & *in situ*
	Universidad Nacional Autonoma de Mexico	Non-U.S.	University	*Ex situ*
	University of Copenhagen	Non-U.S.	University	*Ex situ*
	University of Guelph Arboretum, The	Non-U.S.	Arboretum/botanic garden	*Ex situ*
	University of Kentucky	KY	University	*Ex situ* & *in situ*
	University of Missouri	MO	University	*Ex situ* & *in situ*
	University of Oklahoma	OK	University	*Ex situ* & *in situ*
	University of Saskatchewan	Non-U.S.	University	*Ex situ*
	US Forest Service, Southern Research Station	Regional	National government	*Ex situ* & *in situ*
	USA National Phenology Network	National	National NGO	*In situ*
	USDA Forest Service, Huron-Manistee National Forest	MI	National government	*In situ*
	USDA Forest Service, Northern Research Station	MO	National government	*Ex situ* & *in situ*
	USDA Forest Service, Plumas National Forest	CA	National government	*In situ*
	USDA Forest Service, Shasta Trinity National Forest	CA	National government	*Ex situ* & *in situ*
	USDA Forest Service, Southern Research Station	AL	National government	*Ex situ* & *in situ*
	USDA Natural Resources Conservation Service	MS	National government	*In situ*

Table 8. List of state abbreviations used in Appendix D

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

APPENDIX E. SPECIES PROFILES

Individual profiles for species of conservation concern can be downloaded by following the links provided below. Page numbers for the species profiles within the full-length PDF (https://www.mortonarb.org/files/conservation-gap-analysis-of-native-US-oaks.pdf) are also given.

Species	Region	URL	Page numbers
Quercus acerifolia	Southeastern U.S.	https://www.mortonarb.org/files/species-profile-quercus-acerifolia.pdf	50-55
Quercus ajoensis	Southwestern U.S.	https://www.mortonarb.org/files/species-profile-quercus-ajoensis.pdf	56-61
Quercus arkansana	Southeastern U.S.	https://www.mortonarb.org/files/species-profile-quercus-arkansana.pdf	62-67
Quercus austrina	Southeastern U.S.	https://www.mortonarb.org/files/species-profile-quercus-austrina.pdf	68-73
Quercus boyntonii	Southeastern U.S.	https://www.mortonarb.org/files/species-profile-quercus-boyntonii.pdf	74-79
Quercus carmenensis	Southwestern U.S.	https://www.mortonarb.org/files/species-profile-quercus-carmenensis.pdf	80-85
Quercus cedrosensis	California	https://www.mortonarb.org/files/species-profile-quercus-cedrosensis.pdf	86-91
Quercus chapmanii	Southeastern U.S.	https://www.mortonarb.org/files/species-profile-quercus-chapmanii.pdf	92-97
Quercus dumosa	California	https://www.mortonarb.org/files/species-profile-quercus-dumosa.pdf	98-103
Quercus engelmannii	California	https://www.mortonarb.org/files/species-profile-quercus-engelmanii.pdf	104-109
Quercus georgiana	Southeastern U.S.	https://www.mortonarb.org/files/species-profile-quercus-georgiana.pdf	110-115
Quercus graciliformis	Southwestern U.S.	https://www.mortonarb.org/files/species-profile-quercus-graciliformis.pdf	116-121
Quercus havardii	Southwestern U.S.	https://www.mortonarb.org/files/species-profile-quercus-havardii.pdf	122-127
Quercus hinckleyi	Southwestern U.S.	https://www.mortonarb.org/files/species-profile-quercus-hinckleyi.pdf	128-133
Quercus inopina	Southeastern U.S.	https://www.mortonarb.org/files/species-profile-quercus-inopina.pdf	134-139
Quercus laceyi	Southwestern U.S.	https://www.mortonarb.org/files/species-profile-quercus-laceyi.pdf	140-145
Quercus lobata	California	https://www.mortonarb.org/files/species-profile-quercus-lobata.pdf	146-151
Quercus oglethorpensis	Southeastern U.S.	https://www.mortonarb.org/files/species-profile-quercus-oglethorpensis.pdf	152-157
Quercus pacifica	California	https://www.mortonarb.org/files/species-profile-quercus-pacifica.pdf	158-165
Quercus palmeri	Southwestern U.S.	https://www.mortonarb.org/files/species-profile-quercus-palmeri.pdf	166-171
Quercus parvula	California	https://www.mortonarb.org/files/species-profile-quercus-parvula.pdf	172-177
Quercus pumila	Southeastern U.S.	https://www.mortonarb.org/files/species-profile-quercus-pumila.pdf	178-183
Quercus robusta	Southwestern U.S.	https://www.mortonarb.org/files/species-profile-quercus-robusta.pdf	184-189
Quercus sadleriana	California	https://www.mortonarb.org/files/species-profile-quercus-sadleriana.pdf	190-195
Quercus similis	Southeastern U.S.	https://www.mortonarb.org/files/species-profile-quercus-similis.pdf	196-201
Quercus tardifolia	Southwestern U.S.	https://www.mortonarb.org/files/species-profile-quercus-tardifolia.pdf	202-207
Quercus tomentella	California	https://www.mortonarb.org/files/species-profile-quercus-tomentella.pdf	208-215
Quercus toumeyi	Southwestern U.S.	https://www.mortonarb.org/files/species-profile-quercus-toumeyi.pdf	216-221

Conservation Gap Analysis of Native

U.S. Oaks

Species profile: ***Quercus acerifolia***

Emily Beckman, Brent Baker, Matt Lobdell, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, *Quercus boyntonii*

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum®
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U S DEPARTMENT AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus acerifolia (E.J.Palmer) Stoynoff & Hess

Synonyms: *Quercus shumardii var. acerifolia* E.J.Palmer **Common Names:** Maple-leaved oak, Maple-leaf oak, Mapleleaf oak

Species profile co-authors: **Brent Baker,** Arkansas Natural Heritage Commission; **Matt Lobdell,** The Morton Arboretum

Contributors: **Kris Bachtell,** The Morton Arboretum; **Tim Boland,** The Polly Hill Arboretum; **Mike Ecker,** The Dawes Arboretum; **Dwayne Estes,** Department of Biology, Austin Peay State University; **Ryan Russell,** City of Columbia, Missouri

Suggested citation: Beckman, E., Baker, B., Lobdell, M., Meyer, A., & Westwood, M. (2019). *Quercus acerifolia* (E.J.Palmer) Stoynoff & Hess. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 50-55). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-acerifolia.pdf

DISTRIBUTION AND ECOLOGY

Endemic to the Interior Highlands of the Ouachita Mountains region in west-central Arkansas, U.S., *Quercus acerifolia* is restricted to four counties within the state. Also known as Maple-leaved oak, occurrences of the species are known from Magazine Mountain (Logan County), Sugarloaf Mountain (Sebastian County), Pryor Mountain (Montgomery County), and Porter Mountain (Polk County). Quercus acerifolia has an extremely restricted range, occupying a total of seven to 24 kilometers squared.[1] There have also been a few reports of the species in Oklahoma, Georgia, Alabama, and Tennessee, though all cases have appeared to be anomalous individuals not associated with a greater population (M. Lobdell pers. comm., 2018). Within its natural habitat, *Q. acerifolia* grows as a small tree or large shrub, typically three to nine meters tall, and is distinctive due to its palmately lobed leaves resembling those of the Norway maple. Early successional woodland habitats are preferred, especially those with open canopies, dry, rocky ledges, steep slopes, bluff lines, and open glades. Maple-leaved oak occurs most often on xeric sites with thin and rocky soils, but is known to exist in a few mesic, rich soils that have been altered by humans. Co-occurring species include *Q. stellata*, *Juniperus virginiana*, *Carya* spp. and *Fraxinus americana*.[2,3]

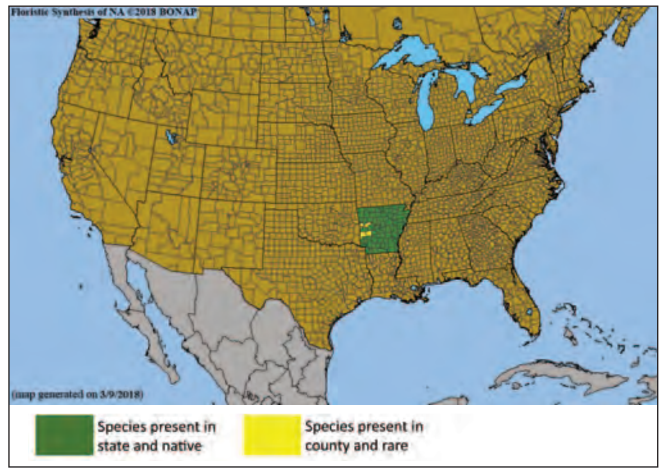


Figure 1. County-level distribution map for *Quercus acerifolia*. Source: Biota of North America Program (BONAP).[3]

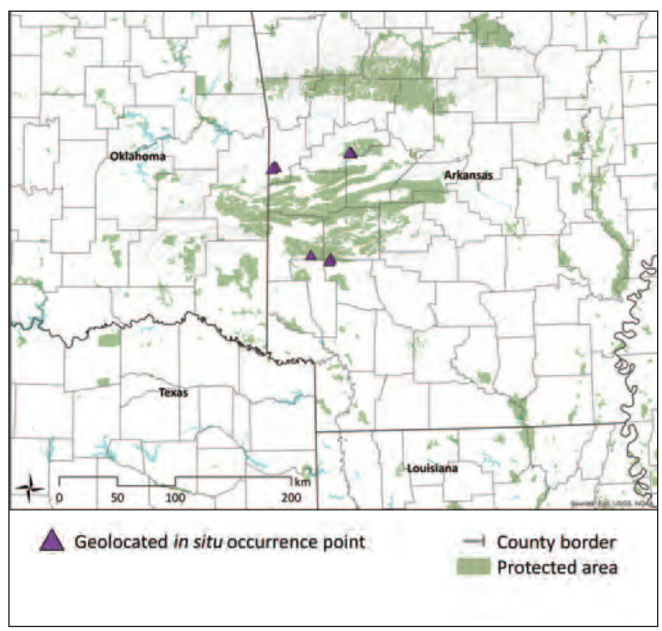


Figure 2. Documented *in situ* occurrence points for *Quercus acerifolia*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus acerifolia*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	Score
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	10
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	20
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
Average vulnerability score							12.5
Rank relative to all U.S. oak species of concern (out of 19)							5

THREATS TO WILD POPULATIONS

High Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: The subpopulation at Sugarloaf Mountain in Sebastian County, which holds more than half of the total number of individuals, lies on privately owned land where no protective status or conservation agreement exists, as of 2003. Unrestricted access and recreational use of the site (camping, all-terrain vehicles, deposition of refuse), as well as shale mining activity and electric tower construction, pose moderate threats. The land is also vulnerable to development by future landowners.[6]

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Human settlement has suppressed the natural fire regime on Magazine Mountain, resulting in a decline of the early successional open-canopy woodland in which *Q. acerifolia* thrives.[2]

Moderate Impact Threats

Genetic material loss — inbreeding and/or introgression: The subpopulation on Magazine Mountain seems to be in a bottleneck, perhaps due to low levels of outcrossing.[1]

Pests and/or pathogens: Cynipid wasps have recently been reported at the Magazine Mountain subpopulation, and may be impacting acorn production.[1] Because *Q. acerifolia* is a member of the red oak clade (Sect. Lobatae), it also has the potential to be affected by oak wilt, Sudden oak death (SOD), and Goldspotted oak borer.[7,8,9] No serious damage has been reported to-date, though continued monitoring is necessary. Based on SOD's current distribution in California and the environmental conditions at these locations, models "indicated highest potential for establishment [of SOD] in the southeastern USA;" therefore, Maple-leaved oak is at particular risk should the pathogen spread throughout the Southeast.[8]

Extremely small and/or restricted population: Simply the small range and relatively small population size of *Q. acerifolia* pose moderate threat.

Low Impact Threats

Human use of landscape — tourism and/or recreation: Magazine Mountain has close proximity to recreation areas and campgrounds, but the likelihood of disturbance to *Q. acerifolia* is low due to protection within a state park, which strictly enforces rules regarding threatened and endangered plants.[6]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: No specific research exists regarding predicted climate impacts on Maple-leaved oak, but its small range and habitat specificity could pose significant challenges in a changing climate.

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	21
Number of plants in *ex situ* collections:	79
Average number of plants per institution:	4
Percent of *ex situ* plants of wild origin:	65%
Percent of wild origin plants with known locality:	84%

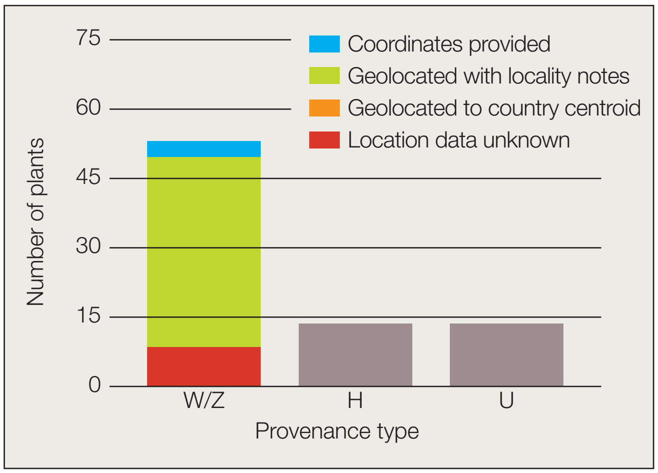


Figure 3. Number and origin of *Quercus acerifolia* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

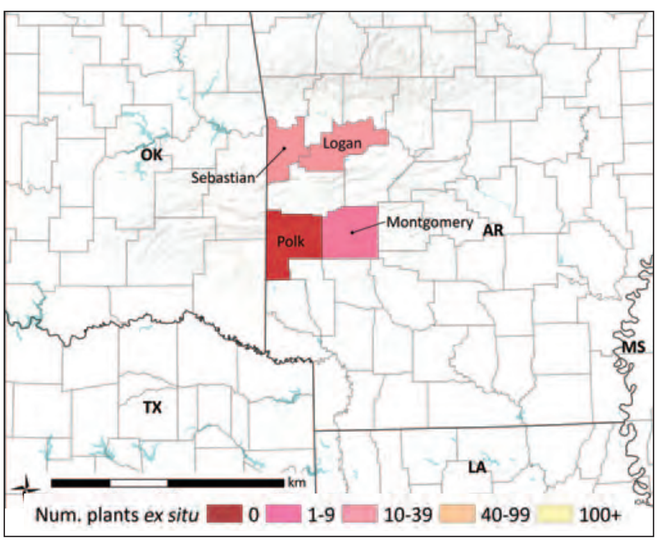


Figure 4. *Quercus acerifolia* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	94%
Ecological coverage:	100%

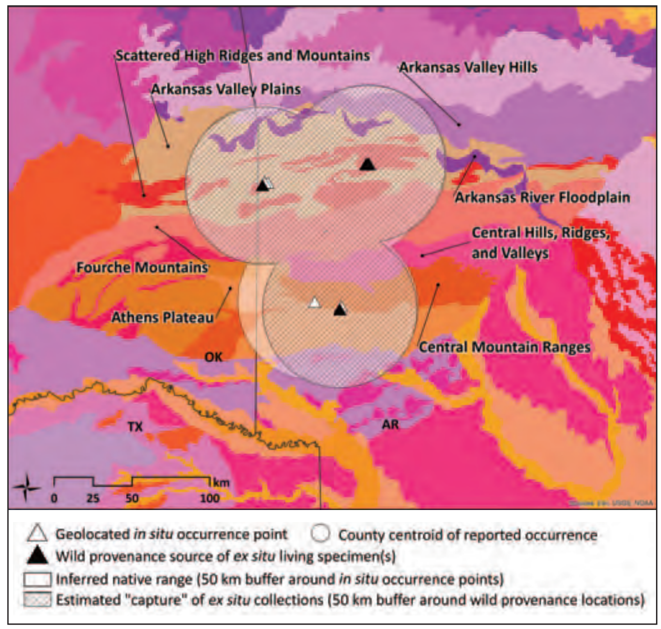


Figure 5. *Quercus acerifolia in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level IV Ecoregions are colored and labelled.[10] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

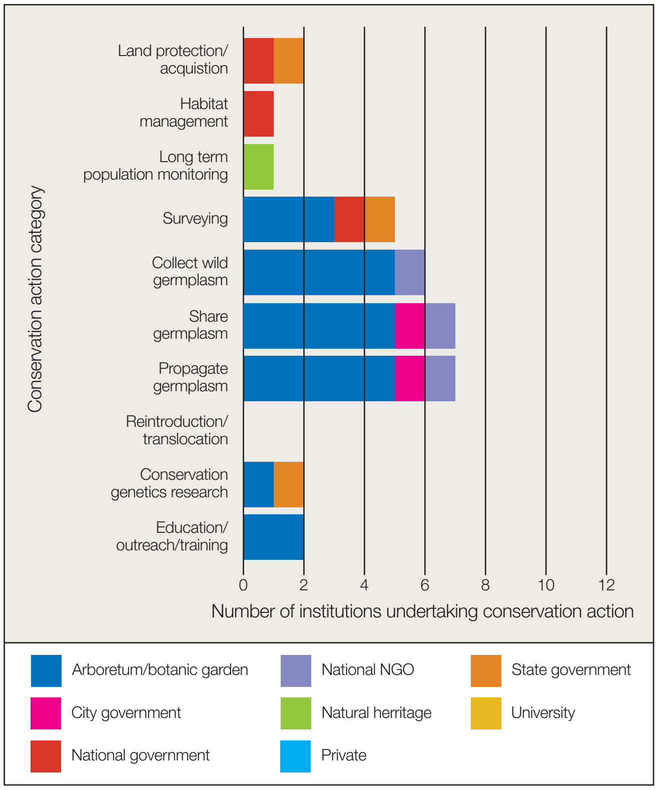


Figure 6. Number of institutions reporting conservation activities for *Quercus acerifolia* grouped by organization type. Thirteen of 252 institutions reported activities focused on *Q. acerifolia* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. acerifolia*, 32% of the land is covered by protected areas (Figure 7). However, it is known that three of the four well-documented localities of Maple-leaved oak are within protected areas; although about half of the known number of individuals are located on unprotected land.

Protected areas include Ozark-St. Francis National Forest and Mount Magazine State Park, Ouachita National Forest (Porter Mountain and Pryor Mountain), and Caney Creek National Game Refuge (Porter Mountain); Caney Creek has National Wilderness status. The occurrences within Ouachita National Forest are situated in remote areas with difficult terrain, which further protects them from any kind of human disturbance.[1] Based on USFS spatial data, *Q. acerifolia* could also be represented in other nearby protected areas, including Brush Heap, National Wild and Scenic Cossatot River, National Wild and Scenic Little Missouri River, and Roaring Branch Research Natural Area, which are all federally managed.[11]

Sustainable management of land: As part of the USDA Forest Service Silviculture Reforestation program, parts of Ouachita National Forest that may overlap with the distribution of *Q. acerifolia* have been burned at least once, in 2006. The Silviculture Reforestation program works to optimize forest vegetation establishment, including planting, seeding, site preparation for natural regeneration, and certification of natural regeneration without site preparation.[11]

Population monitoring and/or occurrence surveys: The Arkansas Natural Heritage Commission considers *Q. acerifolia* extremely rare in the state based on NatureServe's vulnerability assessment guidelines. This designation requires the Commission to track the species' distribution within their biodiversity database.[12] Lead by The Dawes Arboretum, with funding from an APGA-USFS Tree Gene Conservation Partnership grant, three of the four known sites were visited for seed collection in 2017. Due to "unusually heavy rains and more moderate weather than normal," they found that "trees from all sites displayed excellent vigor judging by recent growth increments." However, some individuals on Mount Magazine did show "considerable dieback in the upper crowns, [which was] attributed...to heavy shade from overtopping vegetation."[13]

Wild collecting and/or *ex situ* curation: With funding from a 2017 APGA-USFS Tree Gene Conservation Partnership grant, The Dawes Arboretum lead an expedition to collect seed from as many individuals as possible within three of the four known Maple-leaved oak sites. Low reproductivity has been documented in the past, so all individuals were examined for possible acorn collection. Six unique accessions were collected, with a total of 2,251 total acorns: Mount Magazine (902 acorns), Porter Mountain (857 acorns), Pryor Mountain (492 acorns; K. Bachtell & M. Ecker pers. comm., 2018). By the end of 2017, 22 gardens had received surplus seeds from one or more of these sites. Living material from Maple-leaved oak was also provided to Dr. Valerie Pence at the Center for Conservation and Research of Endangered Wildlife, Cincinnati Zoo and Botanical Garden. Using cutting-edge techniques to preserve oak germplasm, which cannot be successfully stored in normal seed bank conditions, Pence has preserved germinated seedlings of *Q. acerifolia* through in vitro culture of shoot tips and subsequent long-term liquid nitrogen storage.[13]

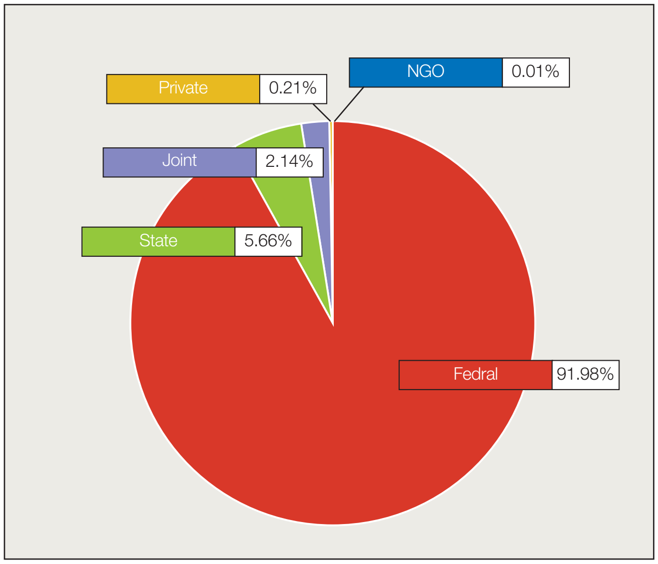


Figure 7. Management type of protected areas within the inferred native range of *Quercus acerifolia*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

Propagation and/or breeding programs: After completing wild collecting efforts funded by a 2017 APGA-USFS Tree Gene Conservation Partnership grant, The Dawes Arboretum kept at least five seedlings for their collections, and depending on the number of seedlings produced, remaining seedlings were distributed to other participating institutions when plants reached an appropriate size for shipping. Receiving institutions include: Holden Forest and Gardens, OH; Morris Arboretum of the University of Pennsylvania, PA; The Morton Arboretum, IL; Chicago Botanic Garden, IL; Starhill Forest Arboretum of Illinois College, IL (K. Bachtell pers comm., 2017).[13]

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: Through cutting-edge techniques that utilize in vitro culture of shoot tips and subsequent long-term liquid nitrogen storage, Dr. Valerie Pence is working towards long-term preservation of germinated seedlings of *Q. acerifolia* at the Center for Conservation and Research of Endangered Wildlife, Cincinnati Zoo and Botanical Garden.[13]

Education, outreach, and/or training: The Oklahoma City Zoo and Botanical Gardens held an event in conjunction with Endangered Species Day on May 18th, 2008, which included a plant sale with Q. acerifolia as a featured species.[14]

Species protection policies: The Arkansas Natural Heritage Commission considers *Q. acerifolia* threatened in the state, although no specific protection policies are attached to this designation. Distribution data are used to inform land management planning and the environmental review processes of private developers and public landowners, however the state of Arkansas does not have conservation requirements for land development.[15]

Deb Brown

PRIORITY CONSERVATION ACTIONS

Of greatest need with regard to conservation of Maple-leaved oak is a broad and thorough genetic analysis. An understanding of diversity between and within the four traditionally recognized mountaintop populations would be useful to prioritize investigation of protection of the privately owned Sugarloaf Mountain site, as well as to guide further *ex situ* preservation efforts. Furthermore, a genetic study is necessary to answer lingering debate and disagreement on the taxonomic disposition of the species in general. In recent years, oak populations have been documented elsewhere in Arkansas, as well as in Alabama, Georgia, Missouri, Oklahoma, and Tennessee, that are morphologically similar to *Q. acerifolia*, usually in association with rocky woodlands and glades of various geologic substrates and elevations (D. Estes pers. comm., 2018).[16,17] A thorough assessment of these populations and comparison to the four traditional populations is necessary to determine the true conservation status of the species.

Recognition of *Q. acerifolia* as a threatened species by the Arkansas Natural Heritage Commission is positive for awareness of the species, though the lack of legal protection or status attached to this designation will likely require supplementation with other means in order to ensure long-term viability of the species. The lack of land protection or extensive *in situ* conservation efforts are also problematic. All wild populations should continue to be closely monitored long-term, and land management should be discussed with the respective stakeholders to identify if disturbances such as burning or culling are necessary for the species' successful reproduction. If possible, landowners of the Sugarloaf Mountain site should be engaged to determine if land protection can be pursued; this could include options like conservation easements. Reinforcement and/or translocation should also be considered, especially if specific subpopulations are found to have very low genetic variation. Furthering the *ex situ* conservation of this species through cultivation in botanical gardens, arboreta, or seed orchards should be a priority as well.

Conservation recommendations for *Quercus acerifolia*

Highest Priority

- Research (climate change modeling; demographic studies/ecological niche modeling; pests/pathogens; population genetics; restoration protocols/guidelines; taxonomy/phylogenetics)
- Population monitoring and/or occurrence surveys
- Land protection
- Sustainable management of land

Recommended

- Wild collecting and/or *ex situ* curation
- Reintroduction, reinforcement, and/or translocation
- Education, outreach, and/or training

REFERENCES

1. **Wenzell, K., Kenny, L., & Beckman, E. (2016).** *Quercus acerifolia*. The IUCN Red List of Threatened Species 2016:e.T35039A2858212. Retrieved from http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T35039A2858212.en
2. **Rouw, D.W., & Johnson, G.P. (1994).** The vegetation of Maple-leaved oak sites on Sugarloaf and Magazine Mountains, Arkansas. *Proceedings Arkansas Academy of Science, 48*, 154-157. Retrieved from http://scholarworks.uark.edu/jaas/vol48/iss1/32
3. **USDA Forest Service. (n.d.).** *Ozark-St. Francis National Forest: Draft environmental impact statement*. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5212750.pdf
4. **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
5. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
6. **Williams, D.X. (2003).** *Molecular systematics of selected members of* Quercus *section Lobatae and ecology and conservation of* Quercus acerifolia *(maple-leaf oak)*. Fayetteville, AR: University of Arkansas.
7. **Canadian Food Inspection Agency (2019).** *Bretziella fagacearum* (previously known as *Ceratocystis fagacearum* (Oak Wilt) - Fact Sheet. Retrieved from http://www.inspection.gc.ca/plants/plant-pests-invasive-species/diseases/oak-wilt/fact-sheet/eng/1325629194844/1325632464641
8. **Kluza, D. A., Vieglais, D. A., Andreasen, J. K., & Peterson, A. T. (2007).** Sudden oak death: geographic risk estimates and predictions of origins. Plant Pathology, 56(4), 580-587. doi:10.1111/j.1365-3059.2007.01602.x
9. **Colman, T. W., Jones, M. I., Smith, S. L., Venette, R. C., Flint, M. L., & Seybold, S. J. (2017).** Goldspotted Oak Borer. Forest Insect & Disease Leaflet 183. U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf
10. **U.S. EPA Office of Research & Development. (2013, April).** 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
11. **USDA Forest Service. (2017).** FSGeodata clearinghouse. Retrieved from https://data.fs.usda.gov/geodata/edw/datasets.php
12. **Arkansas Natural Heritage Commission. (2015).** Rare species search engine: Find Arkansas species of conservation interest. Retrieved from http://www.naturalheritage.com/Research-and-Data/rare-species-search
13. **Larson, R. A. (2017).** *A summary report detailing the results of the 2017 Arkansas collection trip for procurement of seed of* Quercus acerifolia *(maple-leaf oak)*. Newark, Ohio: The Dawes Arboretum. Retrieved from https://www.publicgardens.org/sites/default/files/2017%20Quercus%20acerifolia%20Final%20Report.pdf
14. **Botanic Gardens Conservation International. (2008).** Plant conservation day: Celebration stories in North America.
15. **Arkansas Natural Heritage Commission. (n.d.).** American Recovery and Reinvestment Act and environmental review. Retrieved from http://www.naturalheritage.com/Research-and-Data/recovery-act
16. **Ladd, D., & J.R. Thomas. (2015).** Ecological checklist of the Missouri flora for floristic quality assessment. *Phytoneuron*, 12, 1-274. Retrieved from https://biodiversitylibrary.org/page/47862644
17. **Witsell, T. (2015, February).** *A rapid terrestrial ecological assessment of Kessler Mountain Reserve: City of Fayetteville, Washington County, Arkansas*. Arkansas Natural Heritage Commission & Fayetteville Natural Heritage Association. Retrieved from http://www.fayettevillenatural.org/wp-content/uploads/2015/03/Kessler-Mountain-Ecological-Assessment_PRINT_QUALITY.pdf


Kris Bachtell

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus ajoensis***

Emily Beckman, Beth Fallon, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis*, Quercus palmeri, Quercus toumeyi*

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum · Botanic Gardens Conservation International · Forest Service, U.S. Department of Agriculture · Fauna & Flora International

Quercus ajoensis C.H.Müll.

Synonyms: *Quercus turbinella* subsp. *ajoensis* (C.H.Müller) Felger & C.H.Lowe, *Q. turbinella* var. *ajoensis* (C.H.Müller) Little
Common Names: Ajo mountain scrub oak

Species profile co-author: Beth Fallon, Department of Plant Biology, University of Minnesota Twin Cities
Contributors: Tim Thibault, The Huntington

Suggested citation: Beckman, E., Fallon, B., Meyer, A., & Westwood, M. (2019). *Quercus ajoensis* C.H.Müll. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 56-61). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-ajoensis.pdf

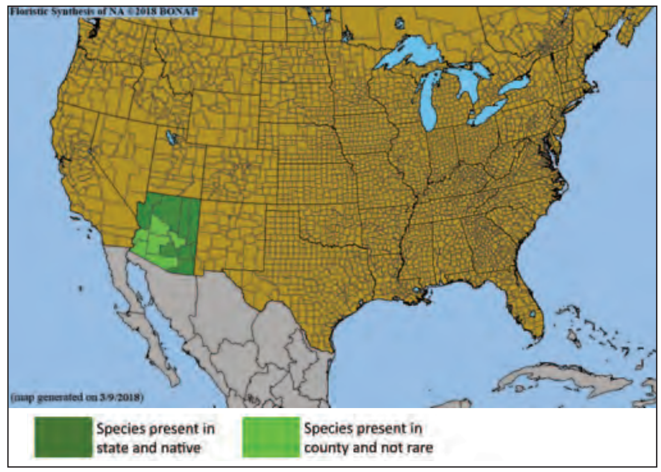


Figure 1. County-level distribution map for *Quercus ajoensis*. Source: Biota of North America Program (BONAP).[4]

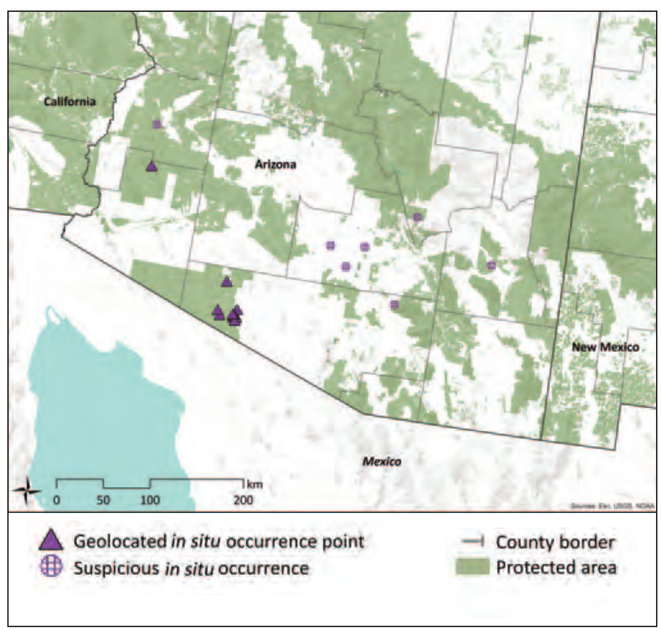


Figure 2. Documented *in situ* occurrence points for *Quercus ajoensis*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

DISTRIBUTION AND ECOLOGY

Quercus ajoensis, or Ajo mountain scrub oak, is known from a few isolated populations in south-southwestern Arizona, U.S., and likely Sonora, Mexico. This species is thought to be rare and limited to the canyons of the upland Sonoran Desert Scrub near the international border. However, it has been reported to occur as far south as Baja California and Baja California Sur, Mexico. In the past, the species has also been considered a variety of *Q. turbinella*, but acceptance as a unique species has been confirmed. Introgressed individuals have been reported stretching into central Arizona and New Mexico. Some records from as far north as Colorado are likely the result of hybridization and confusion with *Q. turbinella*. Populations outside of Pima and Yuma counties in Arizona have been identified as hybrids in initial treatments and morphological studies.[1,2] In general, any U.S. populations outside the species' confirmed range in the Ajo and Kofa Mountains of Arizona (Pima and Yuma counties) may be viewed with suspicion until tested genetically (B. Fallon pers. Comm. 2018). A recent collecting trip only located *Q. ajoensis* in the U.S. within three canyons of the Ajo Mountains.[3] Collections from Mexican populations have not been made recently and need to be revisited. Volcanic canyon bottoms and north-facing slopes between 500 and 1,500 meters in the Ajo Mountains are ideal habitats for this spreading, evergreen shrub, which reaches up to three meters tall.[1,2]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus ajoensis*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						Score
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	10
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	10
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	40
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	5
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
						Average vulnerability score	13.3
						Rank relative to all U.S. oak species of concern (out of 19)	4

THREATS TO WILD POPULATIONS

High Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: *Quercus ajoensis* is likely a drought tolerant species because of its distribution in the Sonoran Desert. However, it is limited to canyons, where it would usually experience seasonal flooding. Arizona is currently in its 21st year of a long-term drought.[6] Shifts in the seasonality of rainfall could adversely affect this species that may rely heavily on rain during the high temperature months (B. Fallon pers. comm., 2018).

Extremely small and/or restricted population: Ajo mountain scrub oak is likely very rare within the landscape and genetic exchange among mountain ranges is restricted (B. Fallon pers. comm., 2018). Wildfires and other disasters also present a serious threat; one event could wipe out a large portion of the population.[3]

Moderate Impact Threats

Human use of landscape — tourism and/or recreation: The best known, and likely largest, subpopulations of *Q. ajoensis* are located within Organ Pipe Cactus National Monument adjacent to the U.S.-Mexico border. Impact from recreation is minimal but degradation has occurred due to border patrol and illegal immigration impacts. The Department of Homeland Security is authorized to construct barriers along the border without compliance to federal, state or local environmental laws. Thousands of miles of new roads were constructed in 2010.[7] Border-related and recreational hiking traffic within the canyons may not directly impact tree populations, but likely increase other threats such as the spread of invasive plants and human-induced fire.

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Altered fire regimes in the region, with less frequent but more severe fires, allowed for rapid spread of the invasive buffelgrass (*Pennisetum ciliare*). This invasion has created a downward spiral in ecosystem health in some areas of southern Arizona.[8]

Human modification of natural systems — invasive species competition: Rapid spread of buffelgrass (Pennisetum ciliare) threatens the vitality of native plants in southern Arizona; it is facilitated by an increase in severe fires that create space for vigorous invaders.[8]

Genetic material loss — inbreeding and/or introgression: Ajo mountain scrub oak frequently hybridizes with *Q. turbinella*.[1,2]

Low Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: The National Park Service noted "a considerable increase in the number of fence breaks associated with border activities" in 2013, which "in turn has caused an increase in the frequency of cattle, horses, and feral burros entering [Organ Pipe Cactus National Monument], resulting in resource damage."[9]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern. *Quercus ajoensis* was the only species of concern with no conservation activities reported in the questionnaire.

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	3
Number of plants in *ex situ* collections:	7
Average number of plants per institution:	2
Percent of *ex situ* plants of wild origin:	100%
Percent of wild origin plants with known locality:	100%

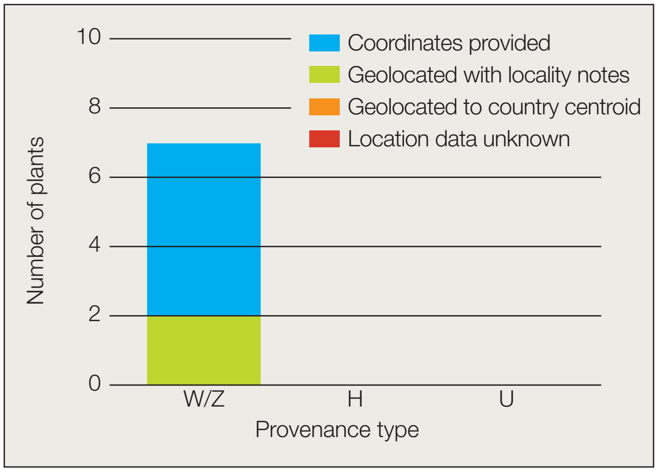


Figure 3. Number and origin of *Quercus ajoensis* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

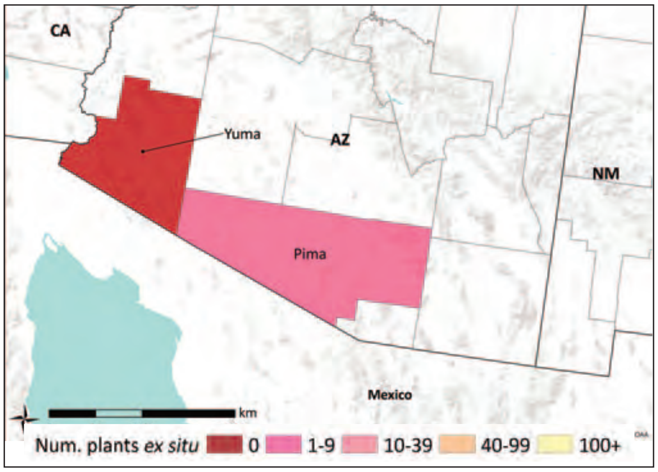


Figure 4. *Quercus ajoensis* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	40%
Ecological coverage:	83%

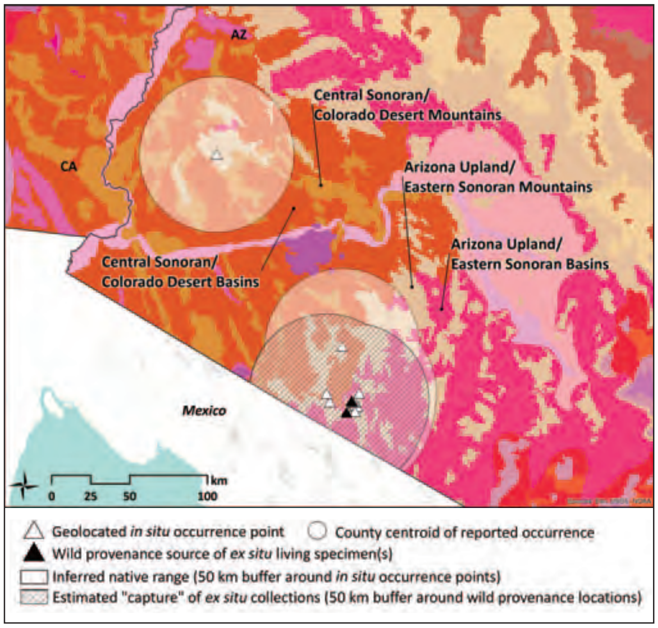


Figure 5. *Quercus ajoensis in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level IV Ecoregions are colored and labelled.[10] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

Land protection: Within the inferred native range of *Q. ajoensis* in the U.S., 99% of the land is covered by protected areas (Figure 7). All verified populations of Ajo mountain scrub oak are within the Organ Pipe Cactus National Monument, (managed by the U.S. National Park Service), and other locations with possible *Q. ajoensis* hybrids are located within the Kofa National Wildlife Refuge (managed by the U.S. Fish and Wildlife Service.[3]

Organ Pipe Cactus National Monument, including the western slopes of the Ajo Mountain range containing the primary populations of *Q. ajoensis*, is 95% designated as a wilderness area, which is the highest level of protection for federal lands. The Wilderness Act of 1964 lays down guidelines for "an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain...land retaining its primeval character and influence without permanent improvements or human habitation."[11] However, due to national security concerns, motorized equipment and vehicles, temporary roads, and permanent structures may be constructed within the wilderness area.[7] Organ Pipe Cactus National Monument has also been designated a UNESCO International Biosphere Reserve.[9]

Sustainable management of land: As a designated wilderness area, land management agencies working within Organ Pipe National Monument are directed to manage areas "so as to preserve, and where possible, to restore their wilderness character." The National Park Service describes management standards and progress within their 2013 State of the Park Report for Organ Pipe Cactus National Monument. They note that invasive buffelgrass and fountaingrass have been declining in managed areas, but "where management is more difficult due to border related access restrictions, buffelgrass has been increasing."[9]

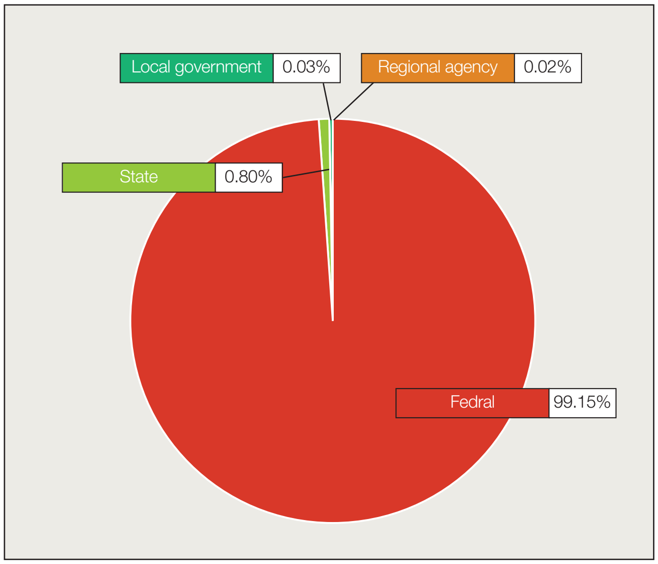


Figure 7. Management type of protected areas within the inferred native range of *Quercus ajoensis*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

Population monitoring and/or occurrence surveys: The Huntington lead a 2018 collecting trip for *Q. ajoensis* in collaboration with Arizona-Sonora Desert Museum, with funding from the APGA-USFS Tree Gene Conservation Partnership. The expedition visited the Ajo Mountains in Organ Pipe Cactus National Monument, including Arch, Alamo, and Estes canyons, Kofa Mountains in the Kofa National Wildlife Refuge, Pinal Mountains, White Tank Mountains, and Sand Tank Mountains and Javelina Mountains in the Sonoran Desert National Monument. *Quercus ajoensis* was only positively identified in the Ajo Mountains; likely hybrids or *Q. turbinella* individuals were found in the Kofa and Pinal mountains, while other locations did not show signs of any individuals resembling *Q. ajoensis*.[3]

Wild collecting and/or *ex situ* curation: With funding from a 2018 APGA-USFS Tree Gene Conservation Partnership grant, The Huntington lead an expedition to collect *Q. ajoensis* for *ex situ* preservation. Partner institutions in the collecting effort include Arizona-Sonora Desert Museum and Green Diamond Resource Company.[3,12]

Propagation and/or breeding programs: Germplasm gathered during the 2018 expedition is now being grown at The Huntington (in vitro buds from three individuals in Estes Canyon) and Arizona-Sonora Desert Museum (173 acorns from Alamo Canyon; T. Thibault pers. comm., 2018).

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: No known initiatives at the time of publication.

Education, outreach, and/or training: No known initiatives at the time of publication.

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

Ajo mountain scrub oak is a rare plant within the desert landscape, due to its native habitat in seasonally flooded canyons in the Sonoran Upland. Its local range is limited by canyon walls and desert expanses surrounding the small mountain ranges to which the species is endemic. The best known population of *Q. ajoensis* occurs on federally protected land within Organ Pipe Cactus National Monument, where it still produces abundant and viable acorn crops in fertile years. However the wilderness quality within the monument has been compromised due to law enforcement and border-related trade activities, which may especially impact the canyon habitat of this species. Climate change is likely the greatest long-term threat, as prolonged drought or irregularities in seasonality can reduce precipitation during the summer monsoons and winter rains that sustain the population.

Species conservation should take an approach that addresses the lack of knowledge about *Q. ajoensis*. A more thorough genetic analysis of known populations would confirm identification, especially given multiple collection vouchers from the northern edge of the species' range, which seem likely to be Q*. turbinella* x *ajoensis* hybrids or possibly misidentified *Q. turbinella*. No vouchers seem to exist from Sonora, Mexico, despite expectations that the species likely inhabits canyons there, and populations putatively identified within Baja California, Mexico should also be confirmed. A thorough investigation of these areas is needed to estimate species range size and determine its vulnerability status.

Reinforcement and/or translocation should be a consideration if populations are found to be rapidly declining, lacking recruitment, or facing severe human impact that cannot be mitigated; propagation would likely need to be carried out to support these initiatives. Further management of non-native grasses may also be required to replicate the natural disturbance regime in some areas. Given the multiple high impact threats, the species should also be conserved in more *ex situ* collections. Finally, further monitoring and research regarding climate change impacts should be carried out to determine appropriate action plans for possible reinforcement and/or translocation initiatives.

Conservation recommendations for *Quercus ajoensis*

Highest Priority

- Population monitoring and/or occurrence surveys
- Wild collecting and/or *ex situ* curation
- Reintroduction, reinforcement, and/or translocation
- Research (climate change modeling; demographic studies/ecological niche modeling; population genetics; restoration protocols/guidelines; taxonomy/phylogenetics)

Recommended

- Sustainable management of land
- Propagation and/or breeding programs

Beth Fallon

REFERENCES

1. **Müller, C. H. (1954).** A new species of *Quercus* in Arizona. Madroño, 12(5), 140-145. Retrieved from https://www.jstor.org/stable/41422802
2. **Tucker, J. M., & Müller, C. H. (1956).** The geographic history of *Quercus ajoensis. Evolution*, 10(2), 157-175. doi:10.2307/2405891
3. **Wiens, J. F., & Thibault, T. (2019).** Exploring for *Quercus ajoensis* and *Quercus toumeyi*. Petersburg, IL: International Oak Society.
4. **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
5. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
6. **Arizona Climate Office. (2016).** Arizona drought. Retrieved from https://azclimate.asu.edu/drought/
7. **Peterson, J. (2014, September 17).** After 11 years, Organ Pipe Cactus National Monument reopens. *High Country News*. Retrieved from https://www.hcn.org/articles/after-12-years-organ-pipe-national-monument-reopens
8. **Arizona-Sonora Desert Museum. (n.d.).** Current projects - research and conservation. Retrieved from https://www.desertmuseum.org/center/current_projects.php
9. **National Park Service. (2013).** *State of the park report: Organ Pipe Cactus National Monument*. Washington, D.C.: National Park Service. Retrieved from https://www.biologicaldiversity.org/campaigns/borderlands_and_boundary_waters/pdfs/ORPI_2013_State_of_the_Park_report.pdf
10. **U.S. EPA Office of Research & Development. (2013, April).** 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
11. **Wilderness Act of 1964.** Pub. L. No. 88-577.
12. **American Public Gardens Association. (n.d.).** Tree Gene Conservation Partnership Showcase.

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus arkansana***

Emily Beckman, Patrick Thompson, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, *Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis*

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus arkansana Sarg.

Synonyms: *Quercus caput-rivuli* Ashe **Common Names:** Arkansas oak

Species profile co-author: Patrick Thompson, Donald E. Davis Arboretum, Auburn University
Contributors: Michael MacRoberts, Biology Department, Louisiana State University in Shreveport; Jason Singhurst, Nongame and Rare Species Program, Texas Parks and Wildlife Department; Wayne T. Barger, Alabama Department of Conservation and Natural Resources; Jared Chauncey, Missouri Botanical Garden; Gerould Wilhelm, Conservation Research Institute

Suggested citation: Beckman, E., Thompson, P., Meyer, A., & Westwood, M. (2019). *Quercus arkansana* Sarg. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 62-67). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-arkansana.pdf

DISTRIBUTION AND ECOLOGY

Quercus arkansana, or Arkansas oak, is endemic to the southeastern U.S., with a distribution stretching from Georgia to eastern Texas. The species' range generally follows the Gulf Coastal Plain and avoids the Mississippi River Delta. Despite its historic commonality across this large range, the species is now thought to be restricted to isolated populations where it usually occurs sporadically, sometimes making up only 5-10% of woody vegetation at sites in its eastern range. However, a few sites do remain with hundreds of individuals[1]. Limited recent surveys in the species' western range have located it in multiple degraded sites, and it is expected to exist in other similar unknown locations where it is inconspicuous and unsurveyed. These types of degraded areas are widespread in east Texas, west Louisiana, and southwest Arkansas, and provide potential for the discovery of new localities (M. MacRoberts pers. comm., 2018). Healthy sites are typically composed of fine loamy sand or other well-draining sandy soils, mesic pine or southern hardwood forests, and topography such as sandhills, steepheads, or stream heads. Arkansas oak is a small tree found in the shady understory, reaching from one to eight meters in height, but has been seen to reach 15 meters.[1]

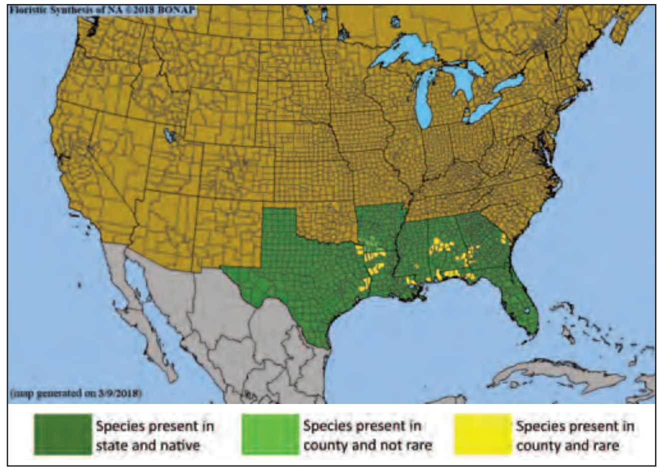


Figure 1. County-level distribution map for *Quercus arkansana*. Source: Biota of North America Program (BONAP).[2]

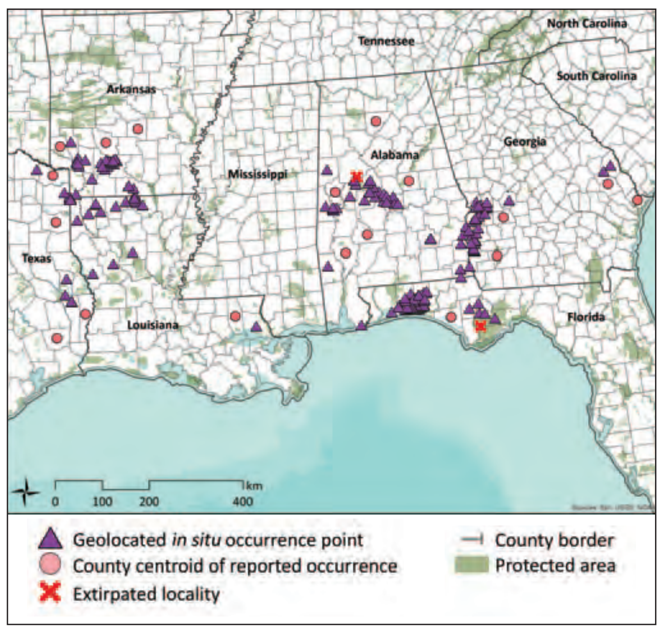


Figure 2. Documented *in situ* occurrence points for *Quercus arkansana.* Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[3]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus arkansana*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	5
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	5
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
						Average vulnerability score	9.2
						Rank relative to all U.S. oak species of concern (out of 19)	10

THREATS TO WILD POPULATIONS

High Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: Detrimental impacts of commercial forestry practices such as timber harvest and prescribed burns have destroyed several known stands of *Q. arkansana*, and continue to threaten small, scattered occurrences. Some threat remains from conversion of habitat to pine plantations.[4]

Human use of landscape — residential/commercial development, mining, and/or roads: Habitat deterioration and destruction by residential and commercial development has been this species' largest threat in the past, and may continue to be. Arkansas oak is mostly distributed on privately owned areas, though many habitat remnants seem unlikely to be developed due to unsuitable landscape type (J. Chauncey pers. comm., 2017).

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Management of *Q. arkansana's* habitat is often directed at restoring populations of other rare plants and animals, which can be incompatible with the oak's needs. Some populations in central Alabama have been removed while restoring longleaf pine habitat and a large population in southwestern Alabama experienced losses due to management aimed at promoting Gopher tortoise.[1]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Recent reports of occurrences in Alabama have noted dieback of trees, with unusual drought suggested as a cause.[1] In an analysis of tree species vulnerability to climate change, *Q. arkansana* was ranked in the highest risk class based on climate change exposure, sensitivity, and low adaptive capacity.[5]

Moderate Impact Threats

Human modification of natural systems — invasive species competition: Two patches of the invasive Chinese wisteria (*Wisteria sinense*) were found during visits to Fort Benning, Georgia. These invasives were able to colonize the area due to erosion.[6]

Genetic material loss — inbreeding and/or introgression: Introgression with more widespread red oaks (Sect. Lobatae) is possible, and this species is particularly susceptible due to its fragmented distribution (J. Chauncey pers. comm., 2017). Increased introgression between *Q. arkansana* and *Q. nigra* was documented at the western edge of *Q. arkansana's* range.[7]

Low Impact Threats

Pests and/or pathogens: Because *Q. arkansana* is a member of the red oak clade it can be affected by oak wilt, Sudden oak death (SOD), and Goldspotted oak borer.[8,9,10] No serious damage has been reported to-date, though monitoring is necessary. Based on environmental conditions in SOD's current California distribution, models "indicated highest potential for establishment [of SOD] in the southeastern USA."[9]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	28
Number of plants in *ex situ* collections:	129
Average number of plants per institution:	5
Percent of *ex situ* plants of wild origin:	79%
Percent of wild origin plants with known locality:	98%

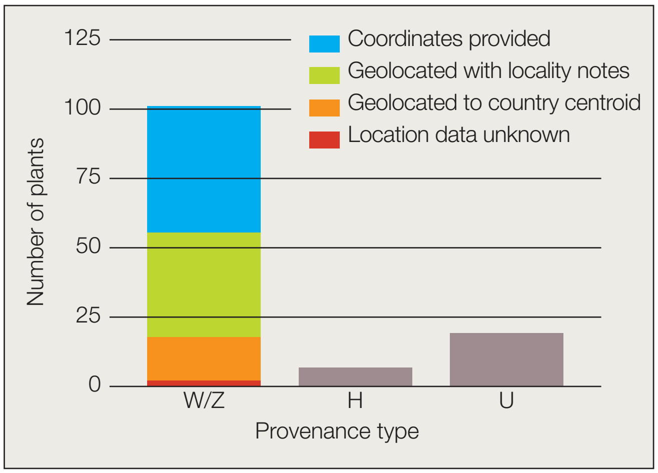


Figure 3. Number and origin of *Quercus arkansana* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

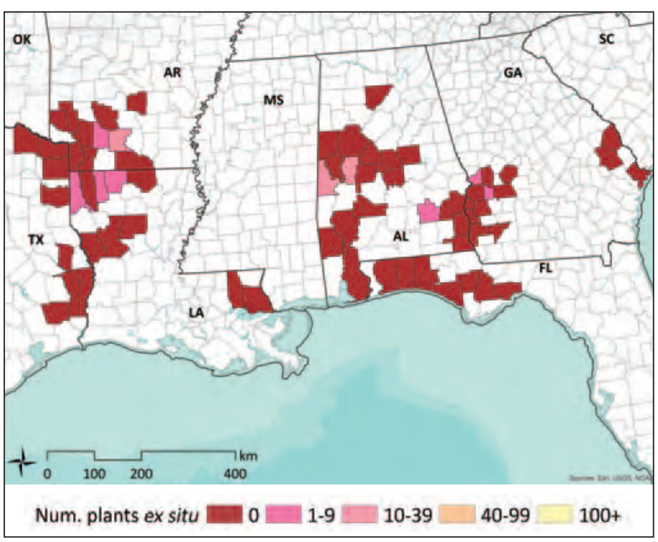


Figure 4. *Quercus arkansana* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	24%
Ecological coverage:	34%

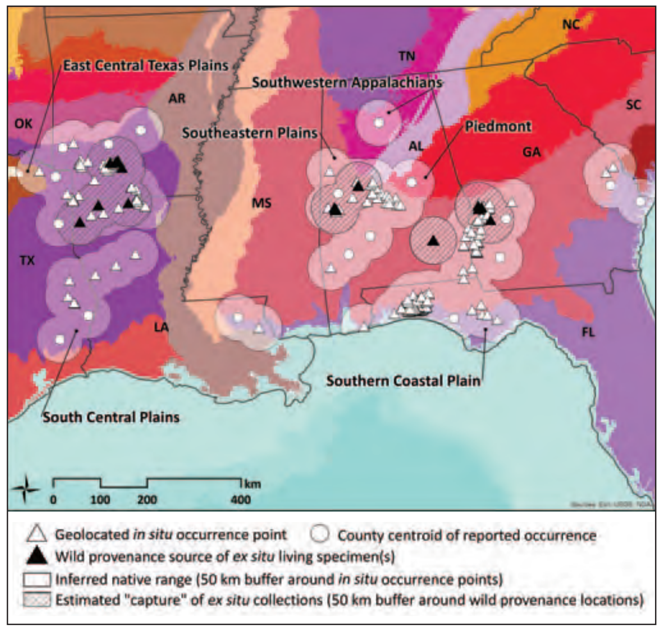


Figure 5. *Quercus arkansana in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[11] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

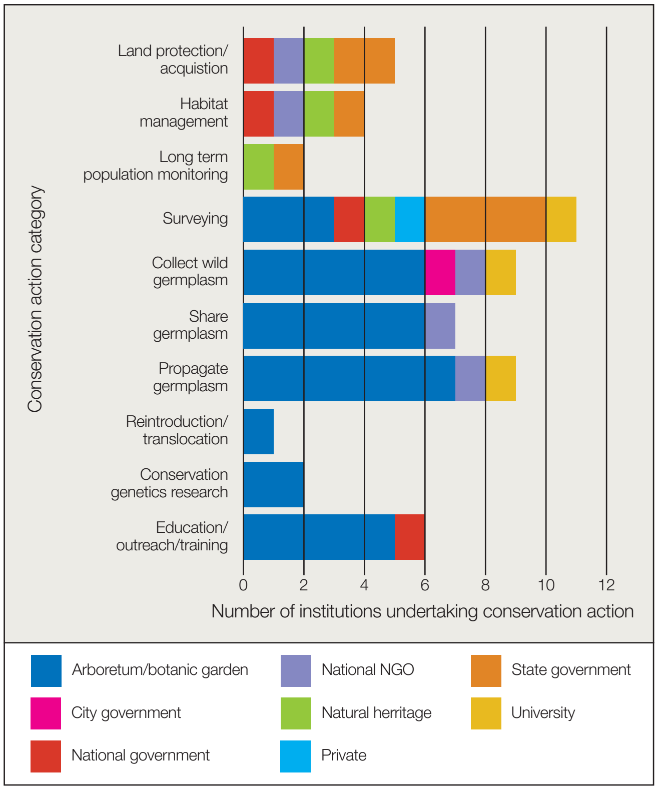


Figure 6. Number of institutions reporting conservation activities for *Quercus arkansana* grouped by organization type. Twenty-four of 252 institutions reported activities focused on *Q. arkansana* (see Appendix D for a list of all responding institutions).

Land protection and/or acquisition: Within the inferred native range of *Q. arkansana*, only 10% of the land is covered by protected areas (Figure 7). While some of these areas contain large, healthy populations, many are not managed optimally for *Q. arkansana* and are unlikely to provide long term protection to the species.

There are two Arkansas Oak Natural Areas, one is a 200 acre plot in Nevada County, Arkansas, owned by the Arkansas Natural Heritage Commission, and the the other is a 673 acre natural area owned by the US Army Corps of Engineers, created specifically to protect *Q. arkansana* in Bossier Parish, Louisiana. The Louisiana area includes two plant community types—mixed hardwood pine forest and stream forest—which provide habitat for Arkansas oak on sandy ridges, knolls, and a bayou bank. The species is thought to be common throughout, though a recent expedition only located heavily shaded *Q. marilandica* (M. MacRoberts pers. comm., 2018).[12] Little River Bottoms in Arkansas also provides protected habitat for *Q. arkansana* through its 18,000 contiguous acres of bottomland hardwood forest. The majority of the tract is privately owned by hunting clubs and land trusts, with smaller portions owned by the Arkansas Natural Heritage Commission or Arkansas Game and Fish Commission.[13] Caddo Black Bayou Preserve in Caddo Parish, Louisiana, is owned by The Nature Conservancy and houses a sandy woodland area dominated by *Q. incana*, *Q. stellate* var. *margaretta*, and *Q. arkansana*. The protected area covers 656 acres, which have a variety of rare plant species, and is surrounded by pine plantations, oil and gas sites, and rural residential areas.[14] The area is currently degraded ecologically (M. MacRoberts pers. comm., 2018).

The Talladega National Forest Oakmulgee District in Alabama completed a Biological Evaluation (BE) for the Longleaf Ecosystem Restoration Project in 2005, in compliance with the Forest Service Manual. The evaluation reported *Q. arkansana* within their project area and determined there to be possible effects on the species, though likely only beneficial.[15] *Quercus arkansana* also occurs at Pike County Pocosin, a site owned and managed by Forever Wild, a land trust operated by the Alabama Department of Conservation and Natural Resources. The population is known by the land managers and discussions of augmenting the population by outplanting propagules grown by AU Davis Arboretum are underway (W. T. Barger pers. comm., 2017). Fred Gannon Rocky Bayou State Park in Georgia has a robust population in a maritime hammock habitat.[16]

Longleaf Ridge Phase II is a conservation easement in Jasper County, Texas, which was acquired by Texas A&M Forest Service in 2017. The area will permanently protect nearly 5,500 acres of sustainably managed timberland in East Texas. A natural Arkansas oak community was documented in a ten acre area within the easement, with immature oaks observed most abundantly, including thousands of trees dominating the understory (J. Singhurst pers. comm., 2018).[17]

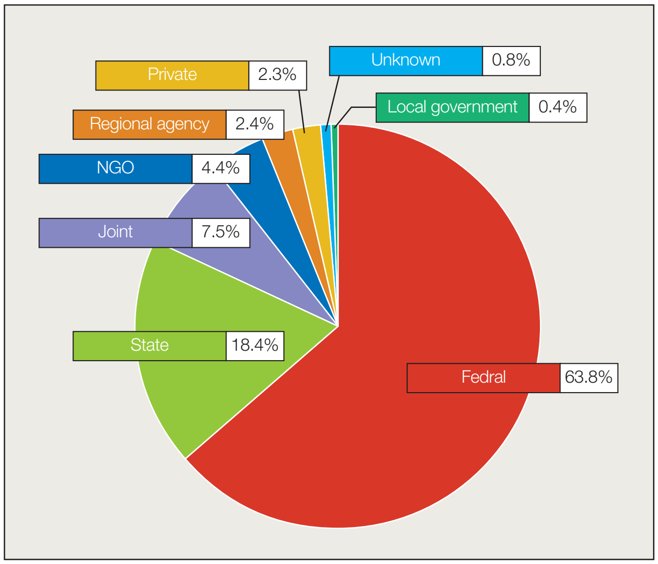


Figure 7. Management type of protected areas within the inferred native range of *Quercus arkansana*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[2]

Sustainable management of land: National Forests in Alabama are managed for pine, which could conflict with *Q. arkansana's* needs, but the species is protected where possible.[1] Upper Ouachita National Wildlife Refuge works to conserve and restore Arkansas oak habitat, and the Central Sandhills and Miller County Sandhills sites prescribe ecological fire regimes and stem thinning to encourage *Q. arkansana* health and regeneration.[18,19] Eglin Air Force Base, Florida, and Fort Benning, Georgia, hold thousands of trees in healthy subpopulations and protect the plants through an effective land management program.[1] Within the Caddo Black Bayou Preserve, The Nature Conservancy is “focusing its efforts on restoring and enhancing remnant western xeric sandhill plant communities by reintroducing fire as an ecological process.”[14]

Population monitoring and/or occurrence surveys: The Integrated Natural Resources Management Plan for Fort Benning, Georgia, prescribes regular monitoring of both erosion and invasive plants within the Unique Ecological Area (UEA). Missouri Botanical Garden and Auburn University received a 2017 APGA-USFS Tree Gene Conservation Partnership grant that provided resources to scout populations of *Q. arkansana* across Alabama, Florida, and Georgia in both the summer and fall. Populations in Alabama and west Georgia were visited multiple times between summer and fall to gauge population health, acorn maturity, acorn drop, and leaf drop (J. Chauncey pers. comm., 2017).

Wild collecting and/or *ex situ* curation: With funding from the 2017 APGA-USFS Tree Gene Conservation Partnership grant, the Missouri Botanical Garden led the collection of propagules across Alabama, Florida, and Georgia. Twenty-eight individuals were sampled, resulting in the collection of 281 viable acorns.[16]

Propagation and/or breeding programs: Funding from the 2017 APGA-USFS Tree Gene Conservation Partnership grant also provided resources to propagate *Q. arkansana* for *ex situ* conservation. Acorns are being propagated at the Missouri Botanical Garden and grown out to the appropriate size for distribution. Seven project partner institutions, representing a large geographic and climatic range, will receive seedlings for addition to their collections.[16]

Reintroduction, reinforcement, and/or translocation: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Research: The Native Plant Network Propagation Protocol Database provides information about established propagation techniques specific to *Q. arkansana*.[18] Because *Q. caput-rivuli*, currently a synonym of *Q. arkansana*, may deserve species status, further biosystematics examination should be carried out regarding the issue (J. Wilhelm pers. comm., 2018). Leaf samples collected during the 2017 expedition are stored in the Missouri Botanical Garden DNA bank, awaiting sequencing by additional collaborators.[16]

Education, outreach, and/or training: A joint restoration project between The Conservation Fund, USDA Forest Service, and U.S. Fish and Wildlife Service, entitled Restoring a Forest Legacy at Upper Ouachita National Wildlife Refuge, supports environmental education and interpretation in areas inhabited by *Q. arkansana*.[19] These efforts could have an especially meaningful impact if efforts can focus on Arkansas oak.

Species protection policies: *Quercus arkansana* is protected as a Threatened species by the Florida Department of Agriculture and Consumer Services, as decided by the Florida Endangered Plant Advisory Council. Texas maintains a list of more than 1,300 Species of Greatest Conservation Need (SGCN) that are “declining or rare and in need of attention to recover or to prevent the need to list under state or federal regulation”. *Quercus arkansana* is listed as a SGCN.[21]

PRIORITY CONSERVATION ACTIONS

Arkansas oak is a widespread, cryptic species susceptible to numerous threats outlined in this review. One challenge presented by its evasive nature is that it is largely unknown within its range and can be easily overlooked or mistaken for common oak species. In addition to further occurrence surveys, the species should be highlighted in outreach efforts to increase awareness within the general public. This is especially important in the species' southeastern range, because the vast majority of land is privately owned and forestry is a major part of the regional economy.

Preserving and appropriately managing areas where these rare trees grow is also key to avoiding extinction. For *Q. arkansana*, fire frequency and intensity are important management factors. Increased census and survey work, coupled with long term monitoring, should also be carried out; these data will allow for quantification of the effects of climate change on this species, which will be paramount in aiding and informing future conservation work.

Finally, an evaluation of the genetic diversity within the remaining known populations will be necessary for creating an informed conservation plan for *Q. arkansana*. If there are hotspots for genetic diversity within the range, efforts to conserve those plants *in situ* and *ex situ* can receive priority. Regardless of genetic diversity, small and isolated populations are under increased pressure of genetic swamping from other red oaks. Efforts such as those executed by the 2017 APGA-USFS Tree Gene Conservation Partnership grant should be repeated until acorn production captures a significant amount of viable seed. Of the 26 trees collected in 2017, only 3 yielded more than 10 acorns.[16] Replicating this work would establish a greater understanding of mast year frequency for the species and further document issues affecting seed viability, such as infestations of acorn weevil. If infrequent acorn production is a limiting factor, research regarding vegetative propagation through stem cuttings and/or tissue culture could be of great conservation value. Propagated plants can be secured in *ex situ* collections, and used to augment *in situ* populations in order to reduce introgression and genetic swamping pressures.

Conservation recommendations for *Quercus arkansana*

Highest Priority

- Education, outreach, and/or training
- Population monitoring and/or occurrence surveys
- Sustainable management of land
- Wild collecting and/or *ex situ* curation

Recommended

- Land protection
- Population monitoring and/or occurrence surveys
- Reintroduction, reinforcement, and/or translocation
- Research (climate change modeling; demographic studies/ecological niche modeling; land management/disturbance regime needs; pests/pathogens; population genetics; restoration protocols/guidelines)

REFERENCES

1. **Jerome, D., Wenzell, K., & Kenny, L. (2017).** *Quercus arkansana*. The IUCN Red List of Threatened Species 2017: e.T30953A88108282. Retrieved from http://dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T30953A88108282.en
2. **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
3. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
4. **Hunt, D. (1986).** Distribution of Quercus arkansana in Georgia. Castanea, 51(3), 183-187. Retrieved from https://www.jstor.org/stable/4033385
5. **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
6. **Directorate of Public Works Environmental Management Division. (2014).** *Integrated natural resources management plan*. Fort Benning, GA. Retrieved from http://www.benning.army.mil/Garrison/DPW/EMD/Content/PDF/4%20-%20Fort%20Benning%202014%20INRMP%20Revision_Final%20Draft.pdf
7. **Hunt, D. M., MacRoberts, M. H., & MacRoberts, B. R. (1995).** The status of *Quercus arkansana* Sarg. (Fagaceae) in Texas. Phytologia, 79(1), 22-24. Retrieved from http://biostor.org/reference/167651
8. **Canadian Food Inspection Agency (2019).** *Bretziella fagacearum* (previously known as *Ceratocystis fagacearum* (Oak Wilt) - Fact Sheet. Retrieved from http://www.inspection.gc.ca/plants/plant-pests-invasive-species/diseases/oak-wilt/fact-sheet/eng/1325629194844/1325632464641
9. **Kluza, D. A., Vieglais, D. A., Andreasen, J. K., & Peterson, A. T. (2007).** Sudden oak death: geographic risk estimates and predictions of origins. *Plant Pathology*, 56(4), 580-587. doi:10.1111/j.1365-3059.2007.01602.x
10. **Colman, T. W., Jones, M. I., Smith, S. L., Venette, R. C., Flint, M. L., & Seybold, S. J. (2017).** Goldspotted Oak Borer. Forest Insect & Disease Leaflet 183. U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf
11. **U.S. EPA Office of Research & Development. (2013, April).** 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
12. **Jones, J. (2007, June).** Natural Areas Registry Update. *Louisiana Natural Areas Registry*, 4(4). Baton Rouge, LA: Louisiana Department of Wildlife and Fisheries. Retrieved from http://www.wlf.louisiana.gov/sites/default/files/natural_area_newsletter-june_2007.pdf
13. **Audubon. (n.d.).** Important bird areas: Little River Bottoms, Arkansas. Retrieved from https://www.audubon.org/important-bird-areas/little-river-bottoms
14. **The Nature Conservancy. (n.d.).** Louisiana Caddo Black Bayou Preserve: Discover one of the rarest ecological communities in the Upper West Gulf Coastal Plain ecoregion.
15. **Ragland, C. O., & Shores, J. (Eds.). (2005).** *Longleaf ecosystem restoration project, Talladega National Forest - Oakmulgee District: Final environmental impact statement.* National Forests in Alabama, Forest Service, U.S. Department of Agriculture.
16. **Chauncey, J., & Gunn, D. (2017).** *APGA-USFS Tree Gene Conservation Partnership grant report: 2017 scouting/collecting trip,* Quercus arkansana *and* Aesculus parviflora.
17. **Texas A&M Forest Service. (n.d.).** Newsroom: Longleaf Ridge phase II. Beaumont, TX. Retrieved from https://tfsweb.tamu.edu/content/article.aspx?id=28422
18. **Pearson, S. (2008).** *2007 state wildlife grant: Implementing state wildlife action plan startegies in the West Gulf Coastal Plain Sandhill oak--Shortleaf pine forest and woodlands to benefit CWCS Species of Concern.* AR: The Nature Conservancy. Retrieved from https://www.wildlifearkansas.com/materials/ProjectReports/T26-12%20Sandhill%20pine%20forest%20and%20woodland%20FINAL.pdf
19. **The Conservation Fund. (2016).** *Restoring a forest legacy at Upper Ouachita National Wildlife Refuge: A forestland restoration partnership between the US Fish and Wildlife Service and The Conservation Fund's Go Zero® program, project implementation report.* Contributions from United States Fish and Wildlife Service & TerraCarbon LLC.
20. **Baskin, J. M., & Baskin, C. J. (2001).** Propagation protocol for production of container (plug) *Quercus arkansana* Sarg. plants. Forest Service, US Department of Agriculture. Retrieved from https://rngr.net/renderNPNProtocolDetails?selectedProtocolIds=fagaceae-quercus-2014
21. **Texas Parks and Wildlife Department. (n.d.).** Species of Greatest Conservation Need. Retrieved from https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/tcap/sgcn.phtml

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus austrina***

Emily Beckman, Ron Lance, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, ***Quercus austrina***, *Quercus georgiana, Quercus oglethorpensis, Quercus similis*

The Morton Arboretum®
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U S DEPARTMENT AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus austrina Sarg.

Synonyms: *Quercus durandii* var. *austrina* (Small) E.J.Palmer **Common Names:** Bluff oak, Bastard white oak

Species profile co-author: Ron Lance, North American Land Trust
Contributors: David Pivorunas, National Forest System, USDA Forest Service

Suggested citation: Beckman, E., Lance, R., Meyer, A., & Westwood, M. (2019). *Quercus austrina* Sarg. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 68-73). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-austrina.pdf

DISTRIBUTION AND ECOLOGY

Quercus austrina, or Bluff oak, is endemic to the Southeastern Coastal Plain of the U.S., distributed from North Carolina to Georgia, and possibly west to Arkansas; it stretches from maritime forests near the coastline, inland to sandy coastal plains. The species was described in 1918 as "although not generally distributed is not rare."[1] Since then, habitat clearing and disturbance by human activities may have led to a decline in the species' prevalence. It is also possible that further taxonomic research and skill in identification have created the illusion of decline. In 1997 Bluff oak was described as "apparently abundant only in local areas," and "nowhere common" in 2015.[2,3] In 2005 NatureServe recorded only 38 occurrences that were not historic or extirpated.[4] This limited abundance is largely a response to *Q. austrina*'s habitat specificity and rarity. Flat tops of wooded bluffs and nearby stream ravines currently harbor most remaining *Q. austrina*, in addition to hardwood hammocks; further occurrences sprinkle the woods of the sandy coastal plains where regeneration can be difficult. There is potential to find *Q. austrina* in any deep, mesic or sub-mesic sandy soil with high organic content (R. Lance pers. comm., 2015).[3,5] Bluff oak is a relatively small or medium-sized tree, typically reaching 20 to 26 meters in height, and thrives at 0 to 200 meters above sea level.[2]

Significant work remains in understanding the distribution of Bluff oak. Species records within Arkansas, Mississippi, and Alabama are highly suspicious and need further investigation. It is likely that many of the herbarium specimens have been confused with *Q. sinuata*. Recent expert surveys in Alabama have not positively identified any *Q. austrina*, and if the species is present within the western half of its currently-recorded range, it is certainly not common. Herbarium and field work could substantially change the range and conservation status of this species, and is a vital element of analysis moving forward (R. Lance & D. Pivorunas pers. comm., 2018).

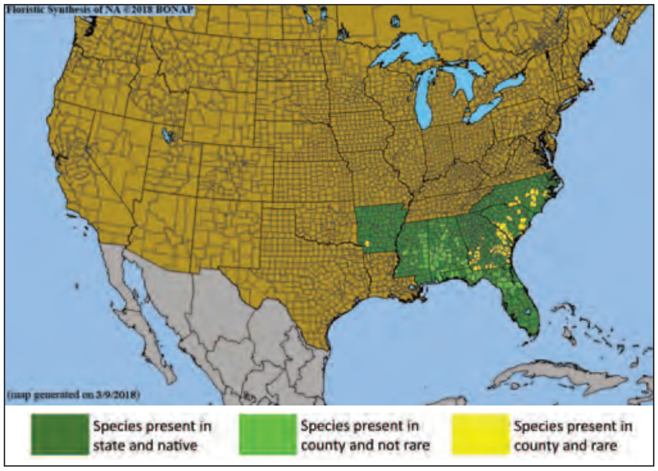


Figure 1. County-level distribution map for *Quercus austrina*. Source: Biota of North America Program (BONAP).[6]

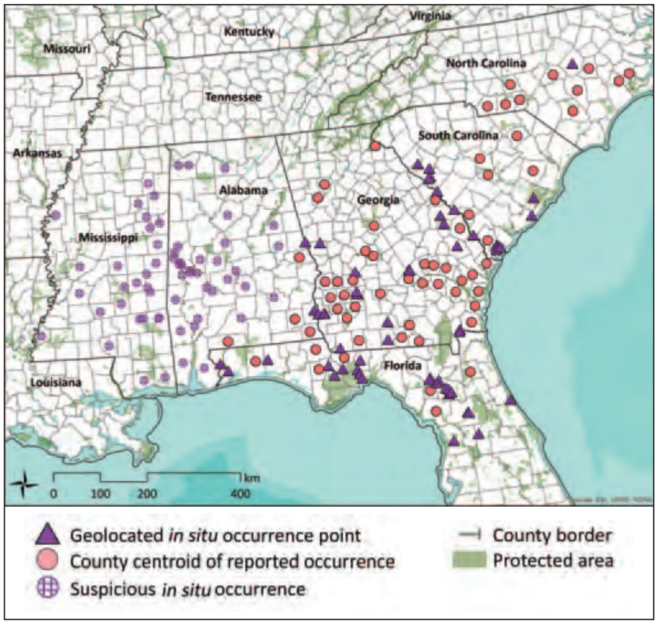


Figure 2. Documented *in situ* occurrence points for *Quercus austrina*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[7]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus austrina*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	Score
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	-
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	5
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
Average vulnerability score							10.0
Rank relative to all U.S. oak species of concern (out of 19)							9

THREATS TO WILD POPULATIONS

High Impact Threats

Genetic material loss — inbreeding and/or introgression: Hybridization is a likely threat, as hybrid swarms are reported surrounding almost all Bluff oak populations. The extent of isolated occurrences also causes concerns of introgression or the complete loss of genotypes as unique pockets disappear (R. Lance pers. comm., 2016).

Moderate Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: On private lands across the floodplains and forests of the Southeast, the vast majority of natural landscape has been severely altered either for agriculture or timber harvesting.[8]

Human use of landscape — residential/commercial development, mining, and/or roads: Oil exploration and other land disturbances have been documented as causing stress to *Q. austrina* on private land.[8]

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: A majority of the previously-farmed land in Bluff oak's range has been abandoned due to poorly drained soils, and has subsequently succumb to shrubs and woody vines that crowd out *Q. austrina*.[8]

Low Impact Threats

Human use of landscape — tourism and/or recreation: Within state parks, *Q. austrina* undergoes stress from maintenance and recreational disturbances, which decrease the tree's ability to successfully reproduce. Because some individuals decline visually in response to these disturbances, the chance of removal within frequently-visited parks increases due to aesthetic concerns (R. Lance pers. comm., 2016).

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Dry-season fires are a rising concern as they increase in the southeastern U.S. In 2016 the National Significant Wildland Fire Potential Outlook predicted "to see a large area of above normal significant fire potential for November and December." Severe droughts as well as stronger winds have been persisting in fall and winter across the region in response to climate change.[9]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey	
Number of *ex situ* collections reporting this species:	16
Number of plants in *ex situ* collections:	47
Average number of plants per institution:	3
Percent of *ex situ* plants of wild origin:	64%
Percent of wild origin plants with known locality:	97%

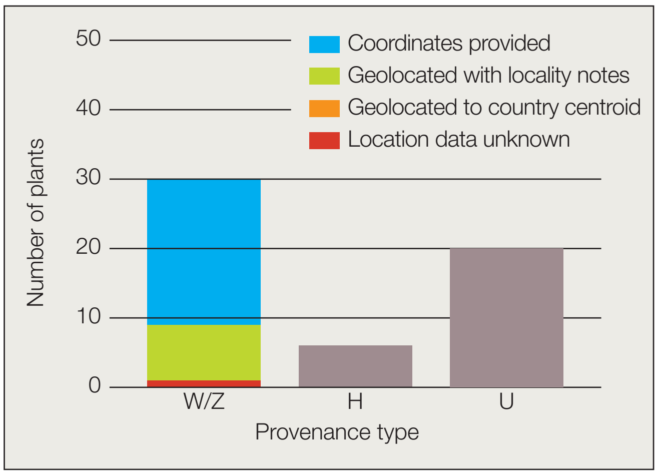


Figure 3. Number and origin of *Quercus austrina* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

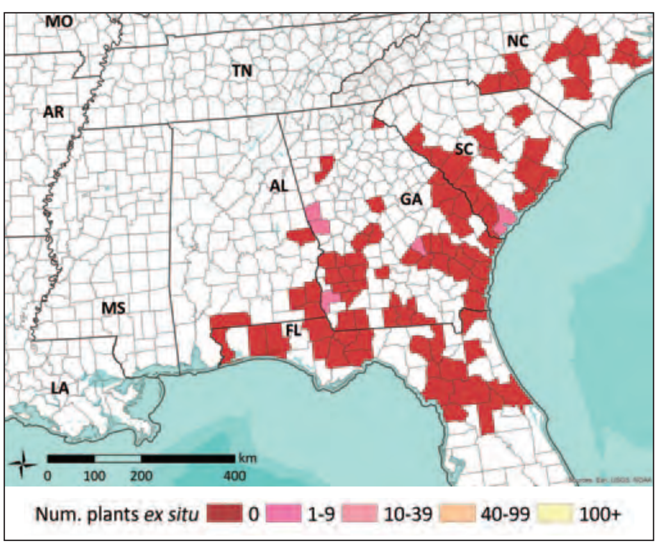


Figure 4. *Quercus austrina* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation	
Geographic coverage:	10%
Ecological coverage:	36%

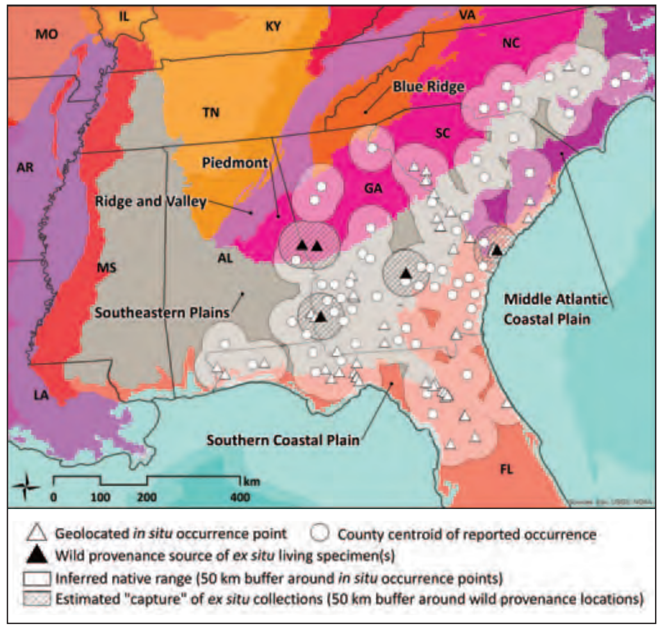


Figure 5. *Quercus austrina in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[10] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

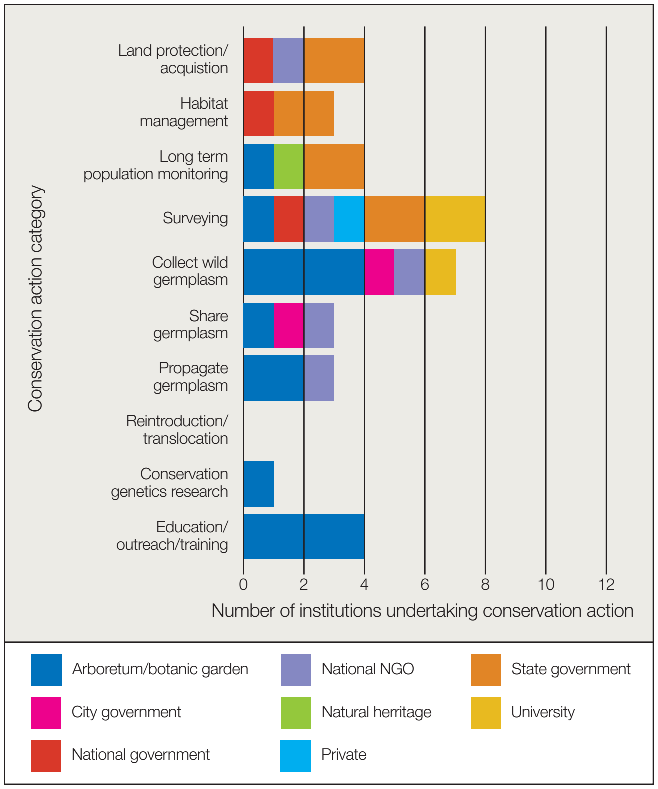


Figure 6. Number of institutions reporting conservation activities for *Quercus austrina* grouped by organization type. Seventeen of 252 institutions reported activities focused on *Q. austrina* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. austrina*, 13% of the land is covered by protected areas (Figure 7). Although the vast majority of *Q. austrina* occurrences are on private land where management and future use are uncertain, there are a few well-protected populations within high quality habitat. However, these areas do not capture the wide variety of ecological adaptations present within the species large but fragmented range.

Altamaha Grit outcrops of Georgia, also called sandstone outcrops, house *Q. austrina* and boast a few conservation lands with high-quality examples; these include Flat Tub Wildlife Management Area and Broxton Rocks, which is a private preserve.[11] Other protected areas in Georgia containing *Q. austrina* include George L. Smith State Park (87 hectares), Charles Harrold Nature Preserve (28 hectares), and Fort Stewart Military Base (162 hectares).[12]

Sustainable management of land: The neighborhood of SouthWood, Florida, keeps all native, mature trees and works to maintain them, including *Q. austrina*.[13] George L. Smith State Park is managed by the Georgia Department of Natural Resources, and consists of sandhill habitat that undergoes prescribed fires. Charles Harrold Nature Preserve is a sandhill and wetland depression ecosystem, managed by The Nature Conservancy, and was not fire managed until recently. Fort Stewart Military Base undergoes prescribed burns directed by the U.S. Army.[12]

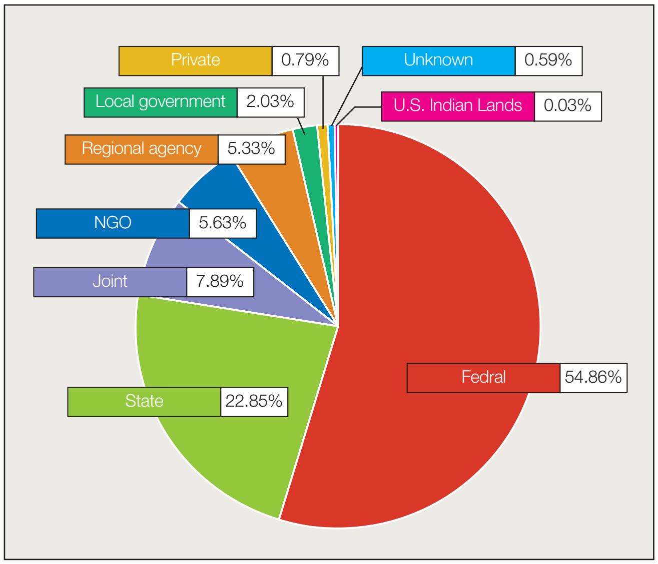


Figure 7. Management type of protected areas within the inferred native range of *Quercus austrina*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[7]

Population monitoring and/or occurrence surveys: A few Bluff oak experts have sought the species while carrying out other botanical exploration and land management responsibilities, but no formal occurrence surveys or monitoring programs are currently known (R. Lance pers. comm., 2018).

Wild collecting and/or *ex situ* curation: Seven institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Propagation and/or breeding programs: The Florida Native Plant Society Citrus County Chapter sold *Q. austrina* at their annual plant sale in 2017.[14] The Florida Association of Native Nurseries' Urban Forestry Services of Alachua County also offers *Q. austrina*.[15] Coastal Wildscapes and Georgia Native Plant Society have published a brochure informing landscaping with native plants in coastal Georgia, which includes a ranking of plants based on their availability in nurseries; Bluff oak is ranked as least available compared to other natives.[16]

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: One institution reported conservation genetics research in the conservation action questionnaire, but no other details are currently known.

Education, outreach, and/or training: Four institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

The sporadic distribution of Bluff oak suggests a need for increased conservation attention in the protected areas where small numbers of individuals are known. Where mature specimens of this oak occur, land management should be geared toward recruitment of seedlings. The hazard of damage to mature specimens or their habitat is most significant where there are very few plants extant, therefore a need exists for education of managerial staff. Mechanisms for the protection of valuable populations on private land, such as conservation easements, should also be considered. Additionally, there is a void in the understanding of how local genotypes may differ across the fragmented range of the species. Barring extensive analytical work of the genetic variation, an increased *ex situ* representation of known populations is recommended.

The taxonomic integrity of this species has been variously treated in the past. Morphological similarity and possible genetic relationship to *Q. sinuata* is one issue that needs elucidation, particularly in the western half of Bluff oak's range (Alabama, Mississippi, Arkansas). The slight differences in leaf morphology that appear among plants in the eastern portions of its range suggest there may be distinct genotypes and/or genetic mixing with other *Quercus* species in local populations. It is likely that *Q. austrina* is often confused with leaf mimics that occur from hybrid events involving other oak taxa, most notably *Q. alba, Q. margarettae, Q. similis, Q. sinuata*, and *Q. stellata*. Plants that are intermediate between typical *Q. austrina* and other taxa are usually made apparent by differences in early season vestiture. An intensive herbarium study and genetic research could aid in resolving residual taxonomic questions, range confirmations, and perhaps address genetic origin. Subsequent field work and field surveys of the variation would be an aid to both *in situ* and *ex situ* conservation efforts.

Conservation recommendations for *Quercus austrina*

Highest Priority

- Population monitoring and/or occurrence surveys
- Sustainable management of land
- Wild collecting and/or *ex situ* curation
- Research (demographic studies/ecological niche modeling; land management/disturbance regime needs; population genetics; taxonomy/phylogenetics)

Recommended

- Land protection
- Education, outreach, and/or training

REFERENCES

1. **Sargent, C. S. (1918).** Notes on North American trees. I. *Quercus. Botanical Gazette*, 65(5), 423-459. Retrieved from https://www.jstor.org/stable/2468891
2. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
3. **Weakley, A. S. (2015).** *Flora of the Southern and Mid-Atlantic states: Working draft of 21 May 2015.* University of North Carolina Herbarium, North Carolina Botanical Garden, University of North Carolina at Chapel Hill. Retrieved from http://www.herbarium.unc.edu/FloraArchives/WeakleyFlora_2015-05-29.pdf
4. **NatureServe. (2017).** NatureServe Explorer: An online encyclopedia of life [online]. Version 7.1. Arlington, VA. Retrieved from http://explorer.natureserve.org.
5. **Lance, R. (2004).** *Woody plants of the southeastern United States: A winter guide.* Athens, GA: University of Georgia Press.
6. **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
7. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
8. **Rogers, K. E. (1977).** Vascular flora of the Ragland Hills area, Forrest and Perry Counties, Mississippi. *Contributions to Botany*, 7(1), 51-79. Retrieved from https://www.jstor.org/stable/41966516
9. **National Interagency Fire Center. (2016).** National significant wildland fire potential outlook: Outlook period – November, December and January through February 2017. Boise, IA. Retrieved from https://www.predictiveservices.nifc.gov/outlooks/outlooks_archive.htm
10. **U.S. EPA Office of Research & Development. (2013, April).** 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
11. **Chafin, L. G. (2007).** *Field guide to the rare plants of Georgia. Athens*, GA: The State Botanical Garden of Georgia and University of Georgia Press.
12. **Long, J. M., & Schenk, J. (2017).** *Comparative floristic studies of Georgian Sandhill ecosystems reveals a dynamic composition of endemics and generalists*. Georgia Southern University Honors Program Theses. 247. Retrieved from http://digitalcommons.georgiasouthern.edu/honors-theses/247
13. **SouthWood. (n.d.).** Landscape. Tallahassee, FL. Retrieved from https://www.joe.com/community/southwood/area-information/maps-and-details
14. **Florida Native Plant Society. (n.d.).** Citrus County Chapter. Retrieved from http://citrus.fnpschapters.org/
15. **Florida Association of Native Nurseries. (n.d.).** Urban forestry services. Retrieved from https://www.afnn.org/professionals/
16. **Coastal Wildscapes & Georgia Native Plant Society. (n.d.).** Landscaping & gardening with native plants in coastal Georgia. Retrieved from https://www.coastalwildscapes.org/resources/Documents/Education%20TAB/Plant%20Info/Coastal_Native.Plant.brochure_2014_.pdf

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus boyntonii***

Emily Beckman, Emma Spence, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, ***Quercus boyntonii***

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum®
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U S DEPARTMENT AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus boyntonii Beadle

Synonyms: *Quercus stellata* var. *boyntonii* (Beadle) Sarg.   **Common Names:** Boynton oak

Species profile co-authors: Sean Hoban, The Morton Arboretum; Emma Spence, Center for Large Landscape Conservation
Contributors: Adam Black, Peckerwood Garden

Suggested citation: Beckman, E., Hoban, S., Spence, E., Meyer, A., & Westwood, M. (2019). *Quercus boyntonii* Beadle. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 74-79). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-boynotnii.pdf

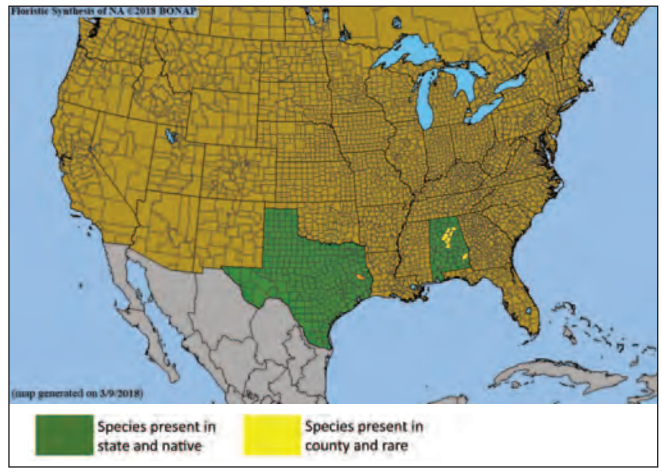


Figure 1. County-level distribution map for *Quercus boyntonii*. Source: Biota of North America Program (BONAP).[3]

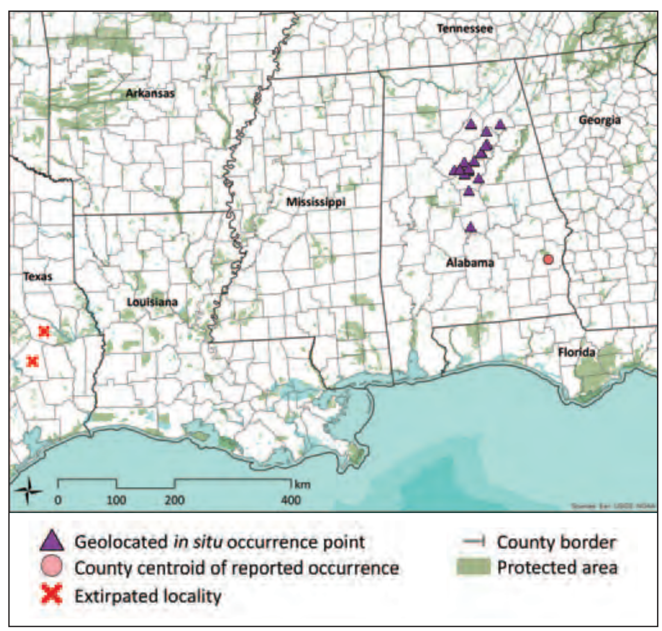


Figure 2. Documented *in situ* occurrence points for *Quercus boyntonii*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

DISTRIBUTION AND ECOLOGY

Quercus boyntonii, or Boynton oak, has a restricted distribution and is believed to be endemic to Alabama, U.S. The species was historically documented in eastern Texas, but recent efforts to locate this population have failed.[1] Boynton oak is best known from a few main populations, including Oak Mountain State Park, Moss Rock Preserve, and Hind's Rock. Localized occurrences of sandstone outcrops within pine-oak-hickory forest frequently correlate with the presence of *Q. boyntonii* (E. Spence pers. comm., 2018).[2] In Texas, it was found in the shrub layer of Loblolly Pine-oak (Pinus taeda) forests on deep sandy soils in creek bottoms, and possibly in shallower soils of upland prairies. Boynton oak is a small tree reaching two to six meters tall.[1]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus boyntonii*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	10
Range/endemism	Extremely small range or 1 location	EOO < 100 km^2 or AOO < 10 km^2 or 2-4 locations	EOO < 5,000 km^2 or AOO < 500 km^2 or 5-9 locations	EOO < 20,000 km^2 or AOO < 2,000 km^2 or 10+ locations	EOO > 20,000 km^2 or AOO > 2,000 km^2	Unknown	20
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	10
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	10
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	20
						Average vulnerability score	13.3
						Rank relative to all U.S. oak species of concern (out of 19)	4

THREATS TO WILD POPULATIONS

High Impact Threats

Genetic material loss — inbreeding and/or introgression: Due to this species' rarity and occurrence with other oak species, hybridization may be a genetic threat. Morphology at several sites indicates possible introgression. Some populations are extremely small and therefore will likely face inbreeding in the near future. Genetic diversity is moderately low for an oak, based on genetic markers (unpublished). The overall population size of *Q. boyntonii* is likely too small to respond well to natural selection, making genetic adaptation unlikely in the future (S. Hoban pers. comm., 2018).

Moderate Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: *Quercus boyntonii* is experiencing woody encroachment due to fire suppression in its habitat.[5]

Human modification of natural systems — invasive species competition: Invasive plants such as Japanese honeysuckle provide significant competition, initially invading due to fire suppression.[6]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Based on the Hadley B1 Scenario of climate change for 2050, there is only a 10% overlap of future suitable range with present suitable range for *Q. boyntonii*. The percent change in area of suitable range is -52%.[7] A recent analysis of U.S. tree vulnerability to climate change used species-specific intrinsic traits to assess trees species' risk of negative effects from climate change; Boynton oak was found to have moderate to high threat exposure and high sensitivity, but moderate adaptive capacity.[8] Severe fire danger exists in some of the Boynton oak's most pristine and suitable habitat, due to a recent drought that killed many pines in the area (S. Hoban pers. comm., 2018).

Extremely small and/or restricted population: *Quercus boyntonii* has a restricted range due to very specific habitat type needs (E. Spence pers. comm., 2018).

Low Impact Threats

Human use of species — wild harvesting: Boynton oak is sometimes cut for use as firewood.[2]

Human use of landscape — residential/commercial development, mining, and/or roads: Trash disposal in natural areas and human development of land have degraded *Q. boyntonii* habitat.[2]

Human use of landscape — tourism and/or recreation: ATV use has been an issue in areas near Boynton oak populations, but direct effects are unknown.[2]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	17
Number of plants in *ex situ* collections:	320
Average number of plants per institution:	19
Percent of *ex situ* plants of wild origin:	98%
Percent of wild origin plants with known locality:	99%

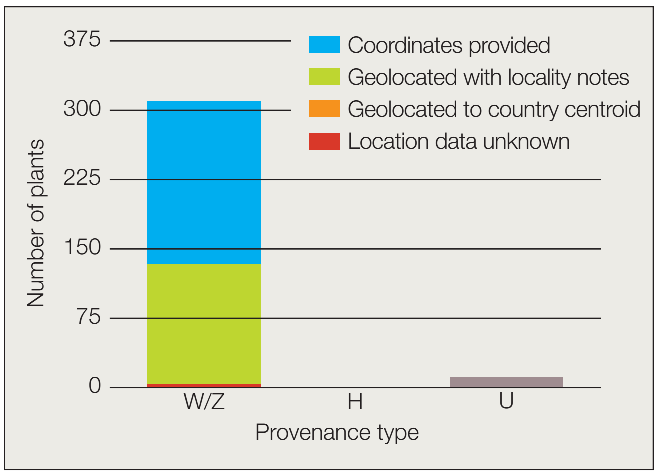


Figure 3. Number and origin of *Quercus boyntonii* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

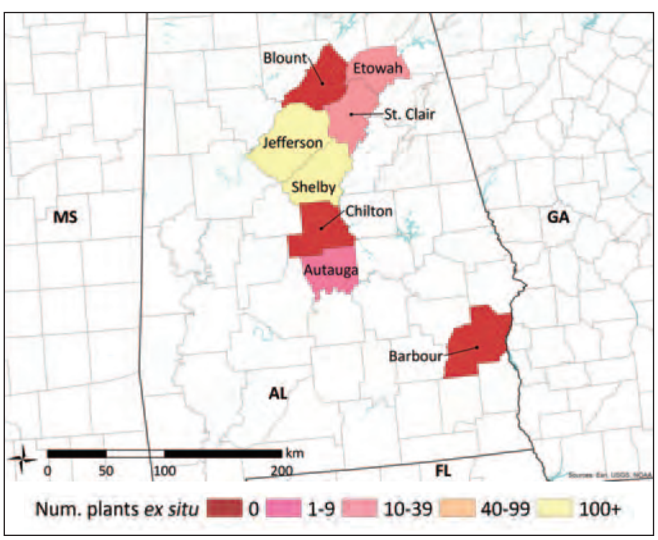


Figure 4. *Quercus boyntonii* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	70%
Ecological coverage:	76%

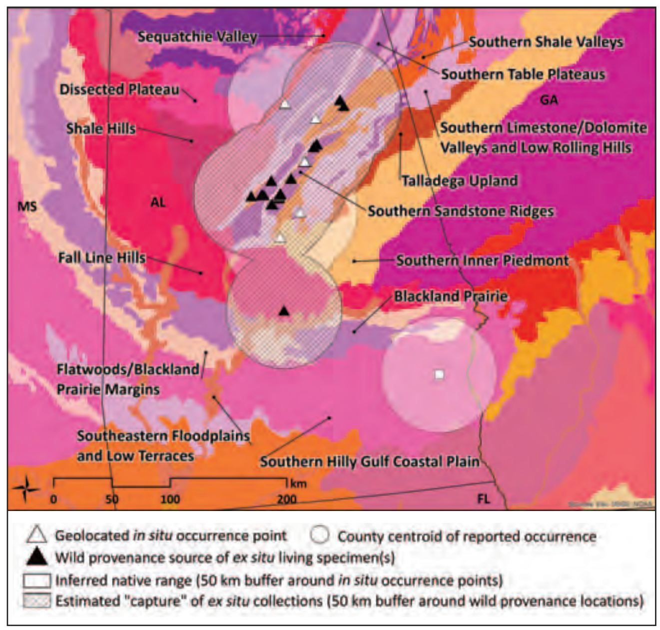


Figure 5. *Quercus boyntonii in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level IV Ecoregions are colored and labelled.[9] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

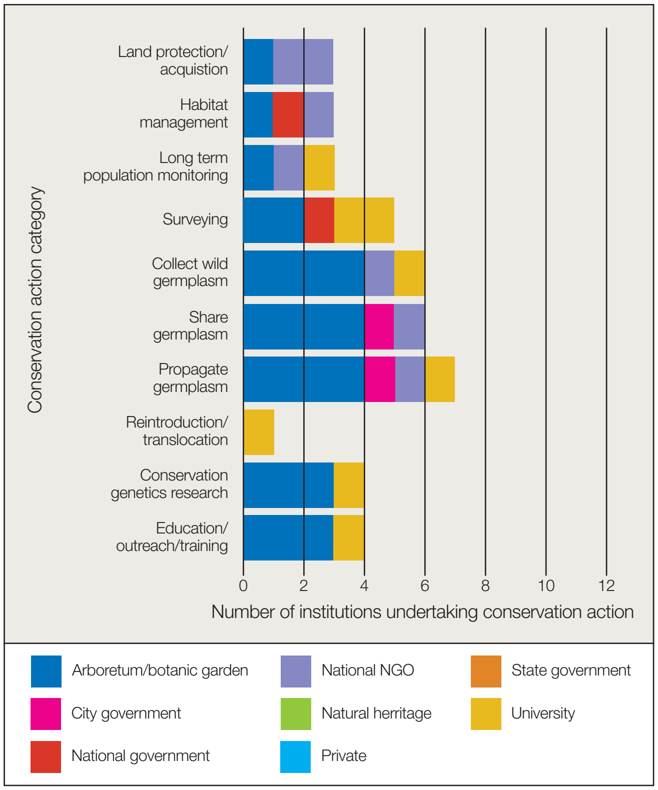


Figure 6. Number of institutions reporting conservation activities for *Quercus boyntonii* grouped by organization type. Twelve of 252 institutions reported activities focused on *Q. boyntonii* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. boyntonii,* 6% of the land is covered by protected areas (Figure 7). Some key populations are protected, but the majority are found on private land; though land management in these protected areas may not be ideal for Boynton oak.

In 2014 an important subpopulation of *Q. boyntonii*, located in the city of Gadsden, Alabama, was purchased by the non-profit Forever Wild.[5] This is the site where the type specimen was collected in 1901. Oak Mountain State Park also provides protection for *Q. boyntonii*, along with Moss Rock Preserve.

Sustainable management of land: While working in Alabama, the North American Land Trust (NALT) Conservation Biologist Lee Echols discovered a population of Boynton oak on privately owned land. NALT is now working with the landowners to develop a management plan to control severe Japanese honeysuckle infestations.[6]

Population monitoring and/or occurrence surveys: The reported population of *Q. boyntonii* in Texas, which has never been relocated and assumed extirpated, will be visited to confirm presence or absence (A. Black pers. comm., 2017).

Wild collecting and/or *ex situ* curation: In 2015, The Morton Arboretum and Donald E. Davis Arboretum of Auburn University, with support from the APGA-USFS Tree Gene Conservation Partnership, collected *Q. oglethorpensis* across its natural range in Mississippi, Alabama, and South Carolina. Because *Q. boyntonii* is located in relative proximity to some *Q. oglethorpensis* populations, they collected Boynton oak as well. Collections were made at three different sites, with one site including six different populations.[10]

Propagation and/or breeding programs: Seeds of *Q. boyntonii* collected in 2015 during the APGA-USFS Tree Gene Conservation Partnership collecting project for *Q. oglethorpensis* were propagated at multiple botanic gardens and arboreta; good germination has been reported from The Morton Arboretum and Davis Arboretum.[11] Birmingham Botanical Gardens has also been propagating *Q. boyntonii* for five years and has distributed these seedlings on a limited basis. They report that, "ease of propagation, relatively small stature, and inherent tolerance of open, dry and rocky sites make this tree species a good candidate for wider landscape use and possible reintroduction."[12]

Reintroduction, reinforcement, and/or translocation: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Research: During an Alabama Plant Conservation Alliance meeting in 2014, Patrick Thompson described Auburn University's current propagation findings and proposed further research: "this species seems to be holding its own, though a narrow range and specific site requirements means it is one worth developing propagation protocols and good baseline data. We have been successful growing it from root cuttings and acorns, though acorn production is often low."[5]

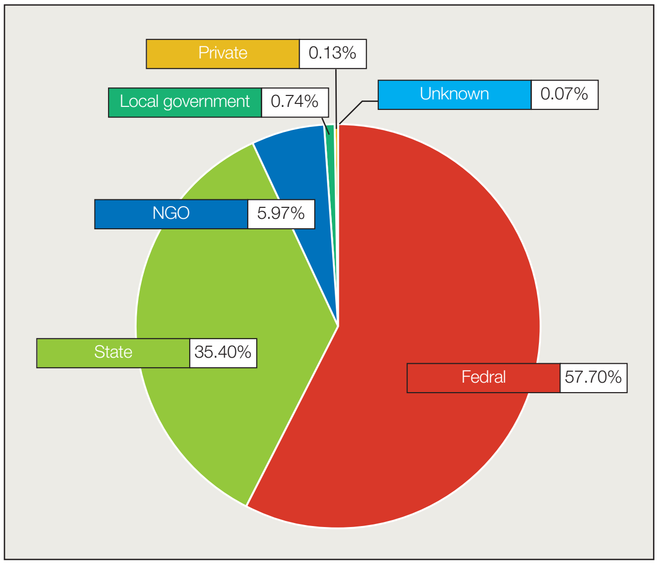


Figure 7. Management type of protected areas within the inferred native range of *Quercus boyntonii*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[3]

Sean Hoban

The Morton Arboretum is performing a conservation genetic analysis of most known populations. Their initial results suggest that the species has moderately low heterozygosity in comparison to most oaks. The species does not appear to be suffering inbreeding yet, but the very small size of most populations (less than 25 individuals) suggests that it will be facing this issue in the near future. Some individuals show morphology that may indicate hybridization and threat of introgression, but this has not yet been confirmed with genetic data. The overall small census size of the species (a few hundred) suggests that even if some populations do avoid inbreeding, the populations are not large enough to respond to natural selection and adapt to a changing environment (S. Hoban & E. Spence pers. comm., 2018).

Education, outreach, and/or training: In his diligent work to conserve *Q. boyntonii*, Thompson is also working to "increase awareness of the species to avoid unnecessary losses."[11] To this end, he and Sean Hoban are continuing to actively seek funding to support *Q. boyntonii* outreach (S. Hoban pers. comm., 2018).

Species protection policies: In June and July 2007, WildEarth Guardians submitted two separate petitions requesting listing of 674 species under the Endangered Species Act (ESA), including *Q. boyntonii*. This species had previously been an ESA candidate in 1990 and 1993, but was removed from the candidate list in 1996.[13] In 2009 another petition for listing *Q. boyntonii* was submitted to the U.S. Fish and Wildlife Service, along with 474 other species in the southwestern U.S. *Quercus boyntonii* was determined to have an inadequate amount of threat information provided in the petition, and was subsequently rejected.[14]

In addition to listing species as endangered or threatened, Texas maintains a list of more than 1,300 Species of Greatest Conservation Need (SGCN). These species are "declining or rare and in need of attention to recover or to prevent the need to list under state or federal regulation…[and are] the focus of Texas Parks and Wildlife Department's Texas Conservation Action Plan," but are not provided the same protections as endangered or threatened species. *Quercus boyntonii* is listed as a SGCN.[15]

PRIORITY CONSERVATION ACTIONS

Severe fire danger exists in some of the Boynton oak's most pristine and suitable habitat, due to a recent drought that killed many pines in the area. This buildup of fuel could cause an unusually severe fire, likely destroying all oaks in the area. Thus, a reduction in fuel load by removal of dead wood is urgent. Eventually a return of regular, low-level fire should help alleviate this threat. Due to the suburban location of some sites, and significant edge effects, numerous invasive plants have also established and seem to be outcompeting Boynton oak for light. Removal of invasive species, and continued routine monitoring and management of invasive species is needed.

There is also a lack of knowledge regarding population size, species distribution, and hybridization and regeneration rates. While all Boynton oak sites have small populations, it is difficult to determine actual population size and regeneration due to a propensity of this species to expand clonally. DNA fingerprinting could be used to determine whether observed stems are clones or unique individuals, allowing for a more accurate count of population size and updating of its threat status. To determine species distribution and perhaps identify additional population locations, surveys of a few large, unexplored private and public tracts of land are needed. In addition, a study of hybridization and introgression is necessary to assess whether hybridization could threaten genetic integrity of this species. Protection of significant populations on private land could also be considered when possible.

Lastly, both *ex situ* conservation to safeguard against loss in the wild and increasing public awareness will aid in averting species decline. One avenue includes establishing plantings and interpretive material at zoos and botanic gardens. Interpretative information can educate the public about Boynton oak, provide advice (e.g., information about accidental damage from firewood collection, off-road vehicle use, etc.), and help encourage public commitment towards volunteer efforts (e.g., invasive plants or fuel load removal). Furthermore, seed from *ex situ* material can be used for planting and restoration *in situ* if needed, such as augmentation or relocation of very small populations or those experiencing severe threat from hybridization.

Conservation recommendations for *Quercus boyntonii*

Highest Priority
- Sustainable management of land
- Population monitoring and/or occurrence surveys
- Research (demographic studies/ecological niche modeling; land management/disturbance regime needs; population genetics)
- Education, outreach, and/or training

Recommended
- Land protection
- Wild collecting and/or *ex situ* curation
- Reintroduction, reinforcement, and/or translocation

REFERENCES

1. **Poole, J. M., Carr, W. R., Price, D. M. & Singhurst, J. R. (2007).** *Rare plants of Texas*. College Station, TX: Texas A&M University Press.
2. **Kenny, L., Wenzell, K., & Beckman, E. (2016).** *Quercus boyntonii*. The IUCN Red List of Threatened Species 2016: e.T33635A2838274. Retrieved from http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T33635A2838274.en
3. **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
4. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
5. **Thompson, P. (2014, May).** APCA meeting minutes 1 May 2014: Held at Auburn University. Auburn, AL. Retrieved from http://www.auburn.edu/cosam/arboretum/links_resources/apca/minutes/may_1_2014.htm
6. **North American Land Trust. (2013, September 11).** While working in Alabama, NALT Conservation Biologist Lee Echols recently discovered a population of the rare Boynton's oak (Quercus boyntonii) [Press release]. Retrieved from https://www.facebook.com/NorthAmericanLandTrust/photos/a.511498562270906.1073741834.407752389312191/511498585604237
7. **Hargrove, W. W., & Potter, K. M. (2016).** The ForeCASTS project: Forecasts of climate-associated shifts in tree species. Version 5 Tree Atlas. Retrieved from https://www.geobabble.org/ForeCASTS/index.html
8. **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
9. **U.S. EPA Office of Research & Development. (2013, April).** 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
10. **Bunting, A. (2016, January 21).** A search for rare oak species yields results. IL: Chicago Botanic Garden. Retrieved from http://my.chicagobotanic.org/horticulture/behind-the-scenes/a-search-for-rare-oak-species-yields-results/
11. **Thompson, P. (2016, May).** APCA Meeting Minutes University of Montevallo 13 May 2016. Auburn, AL. Retrieved from http://www.auburn.edu/cosam/arboretum/links_resources/apca/minutes/may_13_2016.htm
12. **Birmingham Botanical Gardens. (2015).** *Conservation programs.* Retrieved from https://trekbirmingham.com/wp-content/uploads/2015/02/Conservation-Overview-27-jan-15-FINAL.pdf
13. **Rosmarino, N. J. (2008, June 12).** *A petition requesting emergency listing of 32 species under the Endangered Species Act*. WildEarth Guardians. Retrieved from https://pdf.wildearthguardians.org/support_docs/petition_emergency-listing_6-12-08.pdf
14. **U.S. Fish and Wildlife Service. (2009).** Endangered and threatened wildlife and plants; Partial 90 day finding on a petition to list 475 species in the Southwestern United States as threatened or endangered with critical habitat; proposed rule. *Federal Register*, 74(240), 66866-66905.
15. **Texas Parks and Wildlife Department. (2013).** Species of greatest conservation need. Retrieved from https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/tcap/sgcn.phtml

Conservation Gap Analysis of Native

U.S. Oaks

Species profile: *Quercus carmenensis*

Emily Beckman, Shannon M. Still, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis,
Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum®
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U S DEPARTMENT AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus carmenensis C.H.Müll.

Synonyms: N/A **Common Names:** Del Carmen oak, Mexican oak, Sierra del Carmen oak

Species profile co-author: Shannon M. Still, UC Davis Arboretum and Public Garden
Contributors: Adam Black, Peckerwood Garden; Andrew McNeil-Marshall, Lady Bird Johnson Wildflower Center, The University of Texas at Austin

Suggested citation: Beckman, E., Still, S. M., Meyer, A., & Westwood, M. (2019). *Quercus carmenensis* C.H.Müll. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 80-85). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-carmenensis.pdf

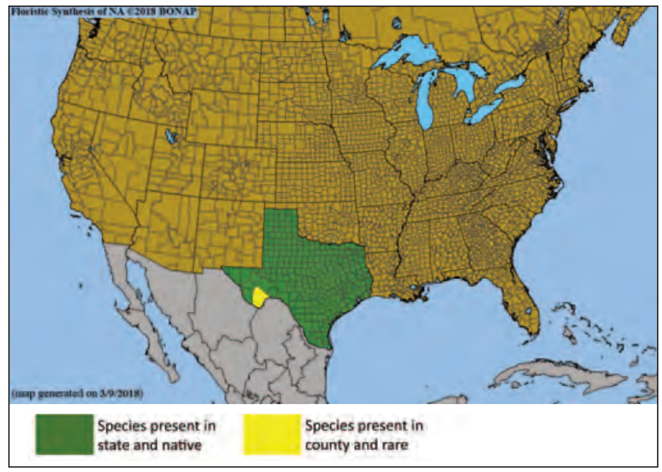


Figure 1. County-level distribution map for the U.S. distribution of *Quercus carmenensis*. Source: Biota of North America Program (BONAP).[2]

DISTRIBUTION AND ECOLOGY

Quercus carmenensis, also known as Del Carmen oak, is only recorded in the U.S. within Brewster County in southwestern Texas, and is originally known from the Sierra del Carmen region in Coahuila, Mexico. Michael Powell made the first U.S. collections of *Q. carmenensis* in 1982, on the slopes of Casa Grande Peak within the Chisos Mountains of Big Bend National Park. In 1991, Powell documented the species at a second location in the park, Laguna Meadows, and specimens were also verified by Billy Turner. However, since their discovery, attempts to find the species at either site have been inconclusive (S. Still pers. comm., 2018).[1] Although, on a recent collecting trip seeking *Q. carmenensis* in its documented Texas location, experts could not confidently identify the species; this calls into question the species' occurrence in the U.S. If Del Carmen oak is not present in the U.S., original documentation could have misidentified the species, or hybridization with *Q. intricata* and/or *Q. grisea* have diluted *Q. carmenensis* individuals past clear identification. Oak hybridization is rampant in the region and correctly identifying species is quite difficult (A. Black pers. comm., 2018). Photos of what could be *Q. carmenensis* have been provided. Ideal environmental factors for *Q. carmenensis* include shallow soils and shrublands or woodlands of high intermountain valleys, 2,000 to 2,500 meters above sea level, especially slopes with north or northwest facing exposures. The species is typically a shrub, one-half to two meters tall, but on better sites can grow to be a small tree, reaching 12 meters high, with a maximum height of about 15 meters, and trunk diameter of 0.75 meters wide (S. Still pers. comm., 2018).

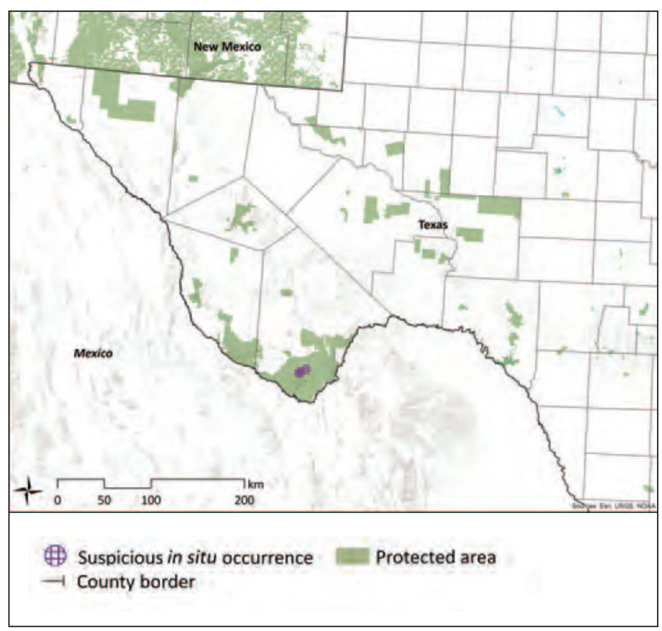


Figure 2. Documented *in situ* occurrence points for the U.S. distribution of *Quercus carmenensis*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[3]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus carmenensis*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						Score
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	5
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	10
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	-
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	20
Average vulnerability score							12.0
Rank relative to all U.S. oak species of concern (out of 19)							6

THREATS TO WILD POPULATIONS

High Impact Threats

Genetic material loss — inbreeding and/or introgression: If the species is present in the U.S., regular hybridization with *Q. intricata* and/or *Q. grisea* is highly likely, threatening the genetic integrity of *Q. carmenensis* (A. Black pers. comm., 2018).

Extremely small and/or restricted population: If present in the U.S., Del Carmen oak has a very restricted range and only a few individuals have been documented over the past 30 years during multiple surveys.[1] Recent visits to the putative sites in the Chisos Mountains have been inconclusive (S. Still pers. comm., 2018).

Moderate Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: *Quercus carmenensis* does occur in the Maderas Del Carmen Flora and Fauna Protection Area in Mexico, however a combination of communal land use for agriculture and grazing, as well as private land holdings, still exist in much of the Sierra del Carmen region. These land uses may pose future threats to the species.[1] Extensive grazing activity has also altered the hydrology of streams and groundwater in the region, which could impact the vitality of *Q. carmenensis*.[4]

Low Impact Threats

Human modification of natural systems — invasive species competition: Invasive plant species pose a significant threat to the unique and rare species within Big Bend National Park, but this threat has not yet been recorded for *Q. carmenensis*.[5]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Drought, flood, and fire all pose threats, especially since the potential population within Big Bend National Park could be wiped out by one extreme event (A. McNeil-Marshall pers. comm., 2016).

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figure 3). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 5).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	1
Number of plants in *ex situ* collections:	2
Average number of plants per institution:	2
Percent of *ex situ* plants of wild origin:	100%
Percent of wild origin plants with known locality:	100%

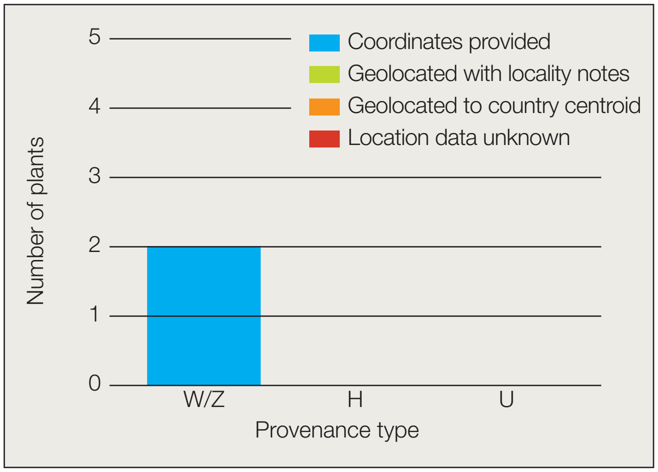


Figure 3. Number and origin of *Quercus carmenensis* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 4). Only the native U.S. distribution of the species was considered in this analysis, due to availability of ecoregion maps. Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	0%
Ecological coverage:	0%

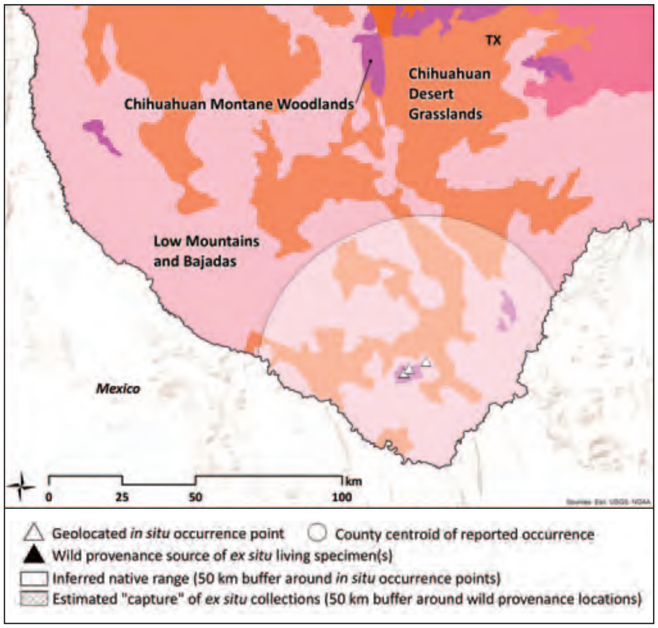


Figure 4. *Quercus carmenensis in situ* occurrence points and *ex situ* collection source localities within the United States. U.S. EPA Level IV Ecoregions are colored and labelled.[6] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

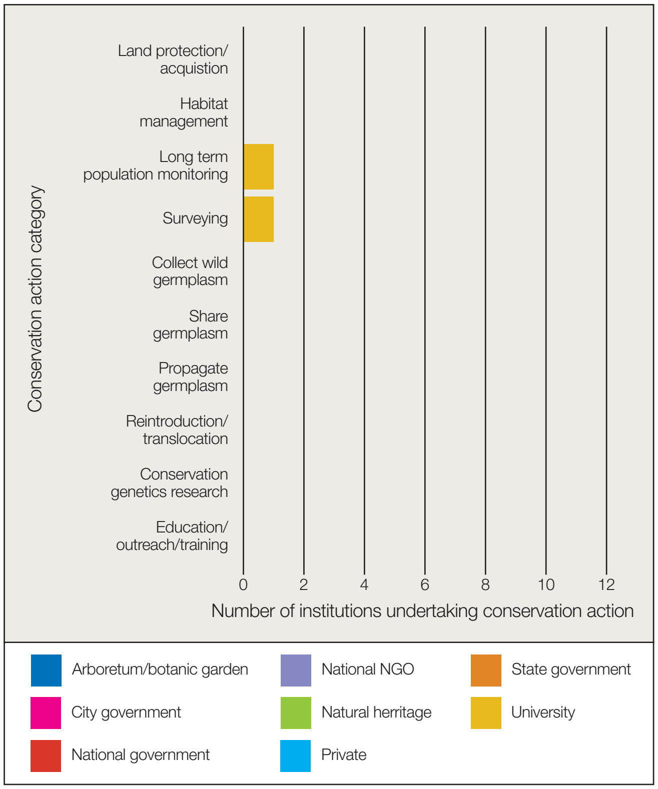


Figure 5. Number of institutions reporting conservation activities for *Quercus carmenensis* grouped by organization type. One of 252 institutions reported activities focused on *Q. carmenensis* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. carmenensis* in the U.S., 62% of the land is covered by protected areas (Figure 6). However, because this species' distribution is small and well-documented, we know that 100% of the species' potential occurrences within the U.S. are within protected areas.

If present in the U.S., populations of *Q. carmenensis* are completely within Big Bend National Park, and well protected from human impact. The Critical Ecosystem Partnership Fund also defines Madrean Pine-Oak Woodlands of Mexico as a biodiversity hotspot, which could incentivise further protection.[7]

Sustainable management of land: The Ecoregional Conservation Assessment of the Chihuahuan Desert ranks Big Bend Triangle with the highest Irreplaceability Index and 9th highest overall conservation priority out of 39 areas of conservation concern in Texas.[4] Big Bend Triangle is currently the only potential location of Del Carmen oak in the U.S. The 2012 Texas Conservation Action Plan: Chihuahuan Desert and Arizona-New Mexico Mountains Ecoregions Handbook outlines general trends and needs in the region as a whole, including Big Bend National Park; there is no specific mention of *Q. carmenensis* outside the "Species of Greatest Conservation Need" list.[8]

Population monitoring and/or occurrence surveys: A vegetation survey was conducted in the Sierra del Carmen in 1997 and within Big Bend National Park in 1998. *Quercus carmenensis* was on the plant checklist used for the surveys.[9] There have been three visits to the Chisos Mountains since 2016 to find and collect *Q. carmenensis* germplasm. Two teams were able to find some plants that could be *Q. carmenensis*, but identification of the individuals is uncertain and there is question as to the validity of the species' presence in the Chisos Mountains at locations visited (S. Still pers. comm., 2018).[10]

Wild collecting and/or *ex situ* curation: Members of the International Oak Society completed a fruitful *Q. carmenensis* collecting trip in 2010 within the Sierra del Carmen of Coahuila, Mexico.[11] In 2017, an expedition worked to collect the species in southwestern Texas, to no avail. The next year, with support from the APGA-USFS Tree Gene Conservation Program, a second collecting trip was executed, and still no individuals were confidently identified. No acorns were present on individuals that bared the most similarity to *Q. carmenensis*, but germplasm was collected for *ex situ* growth and study (S. Still pers. comm., 2018).[10]

Propagation and/or breeding programs: No known initiatives at the time of publication.

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

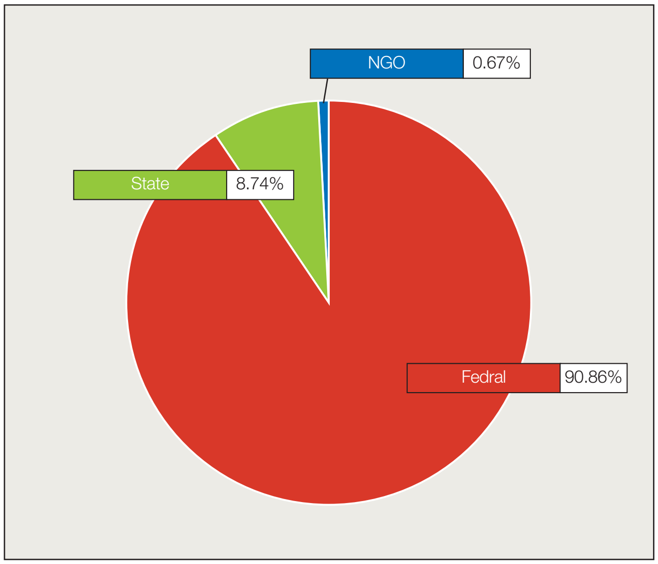


Figure 6. Management type of protected areas within the inferred native range of *Quercus carmenensis*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[3]

Research: The Ecoregional Conservation Assessment of the Chihuahuan Desert also outlines areas needing conservation research within *Q. carmenensis*' range. They emphasize the role of site-specific conservation planning and "implementation of creative strategies to abate such threats as altered hydrology of streams and groundwater, poor grazing practices, and invasive animals and plants," which require working at multiple scales and sustaining partnerships with stakeholders such as multi-generation ranching landowners.[4]

Education, outreach, and/or training: No known initiatives at the time of publication.

Species protection policies: In addition to listing species as endangered or threatened, Texas maintains a list of more than 1,300 Species of Greatest Conservation Need (SGCN). These species are "declining or rare and in need of attention to recover or to prevent the need to list under state or federal regulation…[and are] the focus of Texas Parks and Wildlife Department's Texas Conservation Action Plan," but are not provided the same protections as endangered or threatened species. *Quercus carmenensis* is listed as a SGCN.[12]

PRIORITY CONSERVATION ACTIONS

Del Carmen oak appears to be in a good position for ample conservation due to its protection within Big Bend National Park. However, there are only two putative populations documented, and difficulties in identification of the Chisos Mountain populations create uncertainty as to whether the species is extant in the U.S. Despite a few trips to the region since 2016 to search for *Q. carmenensis*, the species has still not been verified in the Chisos Mountains. The species may still be present in the region, but it is possible there are fewer individuals or that they have hybridized with other taxa in the area, becoming more difficult to identify. Molecular research should be conducted to compare the samples taken in the U.S. in August 2018 with verified samples of *Q. carmenensis* from Mexico. It would be useful to revisit populations in the Sierra del Carmen mountains of Mexico to compare with live individuals found putatively in the U.S. Further wild collecting efforts in Mexico should also be carried out to secure more germplasm in *ex situ* collections. Propagation followed by reinforcement and/or translocation could be considered if populations are not currently sustainable.

Conservation recommendations for *Quercus carmenensis*

Highest Priority

- Population monitoring and/or occurrence surveys
- Research (taxonomy/phylogenetics)
- Wild collecting and/or *ex situ* curation

Recommended

- Propagation and/or breeding programs
- Reintroduction, reinforcement, and/or translocatio


Shannon Still

REFERENCES

1. **Kenny, L., Wenzell, K., & Beckman, E. (2016).** *Quercus carmenensis*. The IUCN Red List of Threatened Species 2016: e.T194072A2296216. Retrieved from http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T194072A2296216.en
2. **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
3. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
4. **Pronatura Noreste, The Nature Conservancy, & World Wildlife Fund. (2004).** Ecoregional conservation assessment of the Chihuahuan Desert (Second edition). Retrieved from https://www.conservationgateway.org/ConservationPlanning/SettingPriorities/EcoregionalReports/Documents/Chihuahuan Desert Report.pdf
5. **National Park Service. (2016).** *Foundation document, Big Bend National Park.* TX: U.S. Department of the Interior. Retrieved from http://www.npshistory.com/publications/foundation-documents/bibe-fd-2016.pdf
6. **U.S. EPA Office of Research & Development. (2013, April).** 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
7. **Critical Ecosystem Partnership Fund. (n.d.).** Madrean Pine-Oak Woodlands. Retrieved from https://www.cepf.net/our-work/biodiversity-hotspots/madrean-pine-oak-woodlands
8. **Texas Parks and Wildlife Department. (2012).** *Texas conservation action plan: Chihuahuan Desert and Arizona-New Mexico mountains ecoregions handbook*. Connally, W. (Ed.). Austin, TX. Retrieved from https://tpwd.texas.gov/landwater/land/tcap/documents/chih_tcap_2012.pdf
9. **Muldavin, E. H., Harper, G., Neville, P., & Wood, S. (2014).** A vegetation classification of the Sierra del Carmen, U.S.A. and Mexico. In Hoyt, C. A., & Karges, J. (Eds.), *Proceedings of the sixth symposium on the natural resources of the Chihuahuan Desert region, October 14–17*. Fort Davis, TX: Chihuahuan Desert Research Institute. Retrieved from http://www.cdri.org/symposium-proceedings.html
10. **Still, S., Griswold, E., & McNeil-Marshall, A. (2016).** *Scouting and collection trips for Trans-Pecos Quercus germplasm: APGA-USFS Tree Gene Conservation Partnerships*. Retrieved from https://www.publicgardens.org/file/2016-trans-pecosoaksreportpdf
11. **Chassé, B. (2011, January 5).** 9490 kilometres across Mexico, Sep.-Oct. 2010. International Oak Society. Retrieved from http://www.internationaloaksociety.org/content/9490-kilometres-across-Mexico-sep-oct-2010
12. **Texas Parks and Wildlife Department. (2013).** Species of greatest conservation need. Retrieved from https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/tcap/sgcn.phtml

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus cedrosensis***

Emily Beckman, Duncan Bell, Cheryl Birker, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, *Quercus dumosa, Quercus engelmannii*

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus cedrosensis C.H.Müll.

Synonyms: *Quercus sedrosensis* C.H.Müll. **Common Names:** Cedros Island oak

Species profile co-authors: Duncan Bell, Rancho Santa Ana Botanic Garden; Cheryl Birker, Rancho Santa Ana Botanic Garden
Contributors: Jon Rebman, San Diego Natural History Museum, Botany

Suggested citation: Beckman, E., Bell, D., Birker, C., Meyer, A., & Westwood, M. (2019). *Quercus cedrosensis* C.H.Müll. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 86-91). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-cedrosensis.pdf

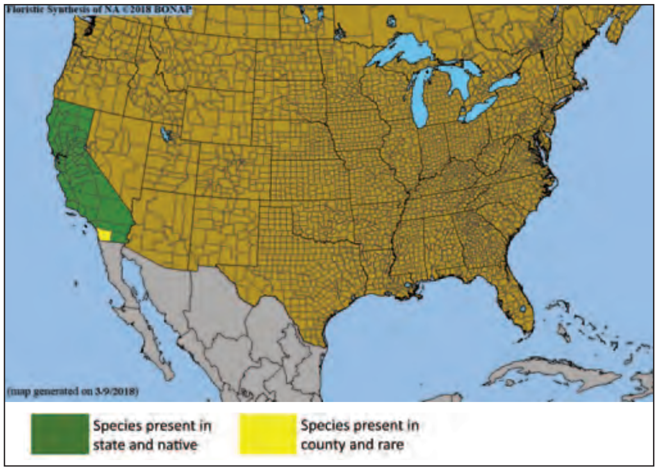


Figure 1. County-level distribution map for the U.S. distribution of *Quercus cedrosensis*. Source: Biota of North America Program (BONAP).[3]

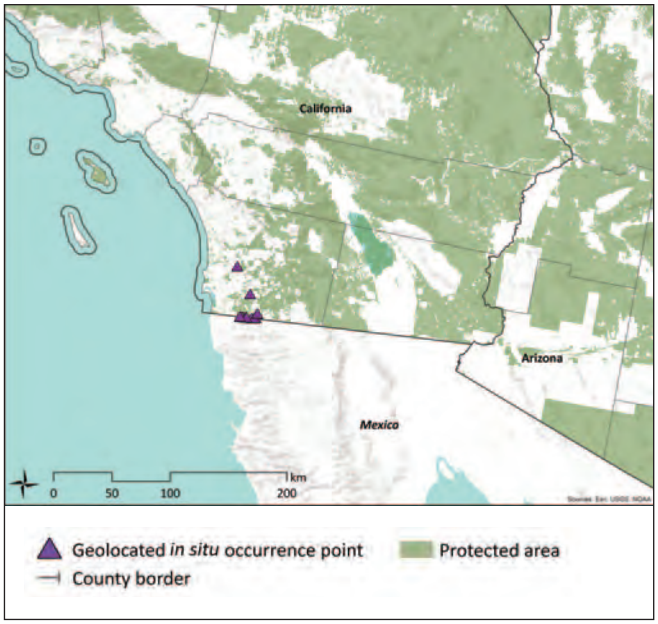


Figure 2. Documented *in situ* occurrence points for the U.S. distribution of *Quercus cedrosensis*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

DISTRIBUTION AND ECOLOGY

Quercus cedrosensis, or Cedros Island oak, is distributed across Baja California, Mexico, and extends slightly into southern California, U.S. One unverified occurrence is located further south, across the border into Baja California Sur, Mexico. Most populations are concentrated in the northern half of the Baja Peninsula and on Cedros Island, located off the western coast of the peninsula. Recent discoveries have also documented a small but significant population near the Otay Mountains in southwestern San Diego County. Soil preferences likely restrict the distribution of *Q. cedrosensis*, though more research is necessary to determine its specific range of tolerance (J. Rebman pers comm., 2018). Other shrubs and trees coexisting in this chaparral habitat are evergreens with leaves that are thick, leathery, and small. Cedros Island oak is shrubby and very occasionally reaches a maximum of five meters in height. The species tolerates a wide range of elevation, from 75 to 1,400 meters above sea level.[1,2]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus cedrosensis*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	5
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	5
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	10
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	10
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	-
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
Average vulnerability score							8.0
Rank relative to all U.S. oak species of concern (out of 19)							12

TTHREATS TO WILD POPULATIONS

High Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: Grazing is a significant issue on the mainland, especially within Southern California Dry Mesic Chaparral, which is dominated by *Q. cedrosensis*, Malosma laurina, and Lotus scoparius.[5] Goats were introduced on Cedros Island in the nineteenth century, but introduced wild dogs kept their numbers low, reducing their impact.[6]

Human use of landscape — residential/commercial development, mining, and/or roads: *Quercus cedrosensis* is affected by land use changes including road construction, border patrol activities, and both urban and rural development. In 2007, the Customs and Border Patrol Agency proposed to "construct, operate, and maintain tactical infrastructure consisting of primary pedestrian fence and associated patrol roads, and access roads along two discrete areas of the U.S./Mexico international border" in San Diego County.[7] Similar border safety projects continue today. In Baja California, more than 120,000 acres have been lost to urbanization, agriculture, and rural residential development in the past ten years.[8]

Moderate Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: There is evidence of a burn around 2003 within the U.S. population of *Q. cedrosensis*, and the native vegetation seems to be struggling to recover.[5]

Human modification of natural systems — invasive species competition: Cedros Island oak habitat in the U.S. is "of moderate to poor quality," with some invasive plant species. Footpaths and grazing activities have facilitated the spread of invasive plants, which further hinder fire recovery.[5]

Genetic material loss — inbreeding and/or introgression: There is concern that mainland populations are facing threats of introgression, as leaf morphology begins to shift.[2]

Low Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Drought has lead to a slow recovery from the 2003 fire.[5]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figure 3). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 5).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	1
Number of plants in *ex situ* collections:	1
Average number of plants per institution:	1
Percent of *ex situ* plants of wild origin:	100%
Percent of wild origin plants with known locality:	100%

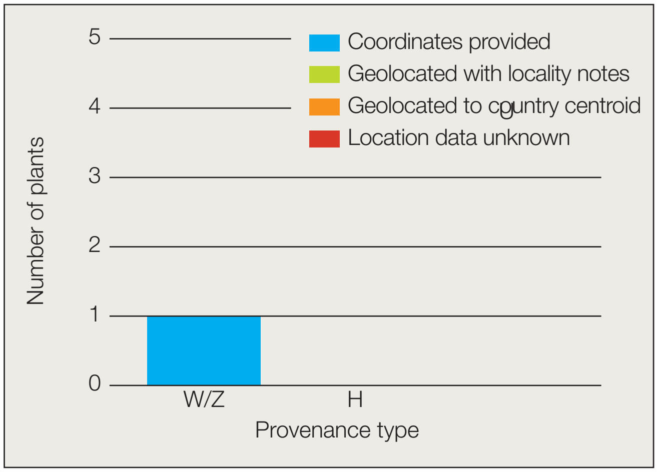


Figure 3. Number and origin of *Quercus cedrosensis* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 4). Only the native U.S. distribution of the species was considered in this analysis, due to availability of ecoregion maps. Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	0%
Ecological coverage:	0%

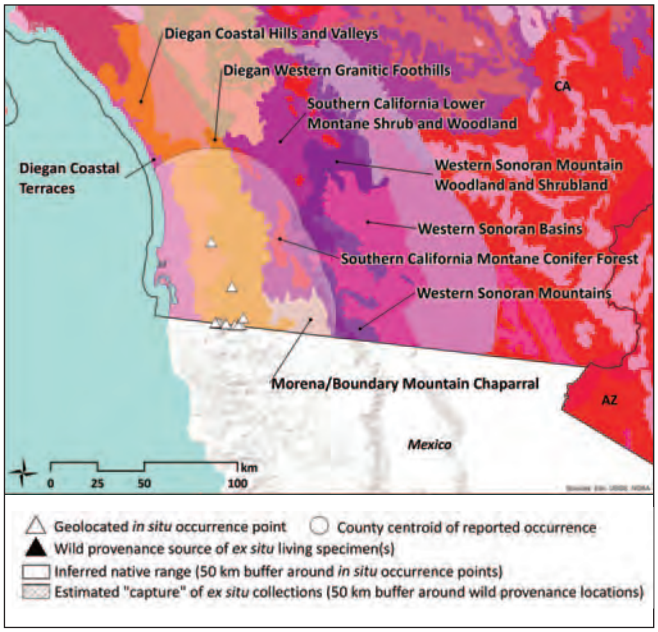


Figure 4. *Quercus cedrosensis in situ* occurrence points and *ex situ* collection source localities within the United States. U.S. EPA Level IV Ecoregions are colored and labelled.[9] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

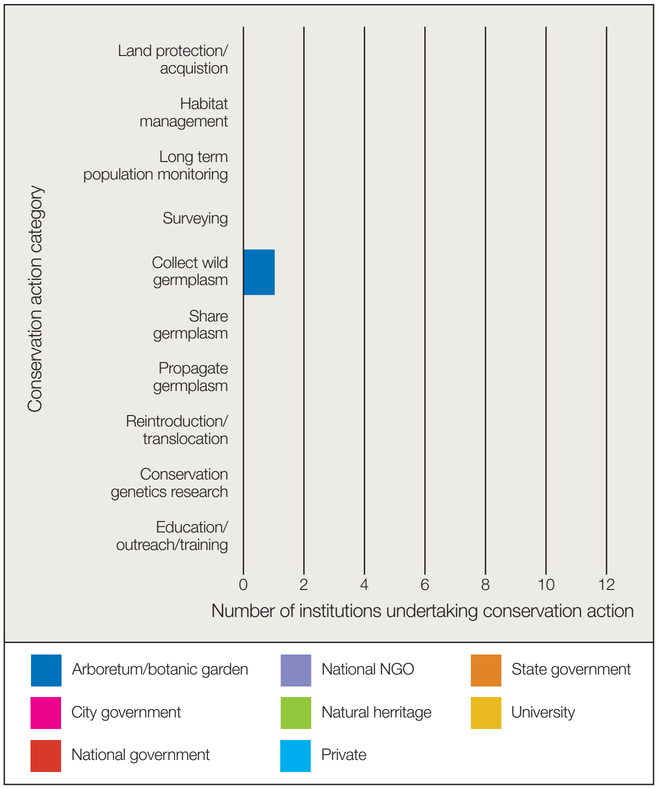


Figure 5. Number of institutions reporting conservation activities for *Quercus cedrosensis* grouped by organization type. One of 252 institutions reported activities focused on *Q. cedrosensis* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. cedrosensis* in the U.S., 48% of the land is covered by protected areas (Figure 7). However, while portions of a few occurrences of *Q. cedrosensis* lie within protected areas, this provides little protection.

President Nieto of Mexico and Governor Brown of California met in 2014 and committed to "more effective cross-border coordination in development, transportation, and the environment." As part of California's Natural Community Conservation Planning program, more than 13,000 acres of private land were acquired in southern San Diego County between 2004 and 2014. This created a "conservation core" of almost 82,000 acres. The Las Californias Binational Conservation Initiative found the Otay Mountains Wilderness Area to be a critically important protected site for *Q. cedrosensis*.[8]

Sustainable management of land: The Las Californias Binational Conservation Initiative, located in the Baja California Border Region, began as a partnership in 2004 among Terra Peninsular, Pro Natura, and The Nature Conservancy. A review document was published in 2015 to outline the conservation gains and habitat losses over the last ten years, underscoring the urgency of conservation investments in the region. Conservation gains include "additional habitat conservation, launch of new management and monitoring programs."[8]

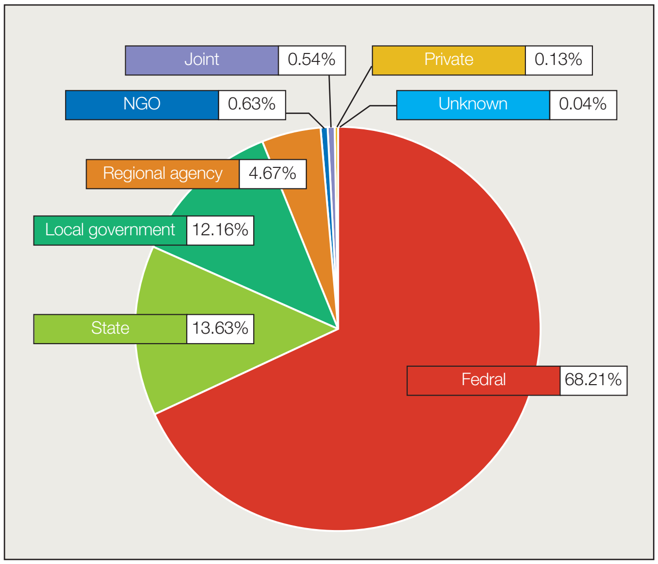


Figure 6. Management type of protected areas within the inferred native range of *Quercus cedrosensis*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

Population monitoring and/or occurrence surveys: *Quercus cedrosensis* populations were surveyed as part of the Vegetation Classification Manual for Western San Diego County, lead by the California Department of Fish and Game's Vegetation Classification and Mapping Program, in partnership with the Conservation Biology Institute. The recently discovered population at Otay Mountain was surveyed, in addition to smaller populations near the mountain. They found that these very localized populations are not well documented currently, and are therefore "special stands." At least four of these stands were newly discovered, expanding the species known range.[10] The Las Californias Binational Conservation Initiative also plans to launch additional management and monitoring programs.[8]

Wild collecting and/or *ex situ* curation: In 2018, Rancho Santa Ana Botanic Garden (RSABG) was awarded funds through the APGA-USFS Tree Gene Conservation Partnership to make maternal line acorn collections of multiple *Q. cedrosensis* occurrences, establish a conservation grove at RSABG, and distribute propagules to other botanic institutions. After 2018 scouting efforts found that no acorns had been produced that year, acorn collecting was postponed until 2019 (C. Birker & D. Bell pers. comm., 2018).

Propagation and/or breeding programs: No known initiatives at the time of publication.

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: The Las Californias Binational Conservation Initiative's 2015 review compiles the conservation gains and habitat losses over the last ten years, using these data to determine areas of success and need.[8]

Education, outreach, and/or training: Growth of private land trusts and community outreach non-profits in both southern California and Baja California, Mexico, have increased the public visibility of the region's conservation importance and the value of open space protection.[8]

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

In California, Cedros Island oak is primarily found immediately along the border between the U.S. and Mexico, which sees a great deal of activity from both border patrol security as well as from groups of people crossing the border. While portions of a few occurrences of *Q. cedrosensis* lie within a wilderness area, this provides little protection. It is the roadside occurrences, however, that are the most vulnerable. For conservation purposes it is recommended that all known *Q. cedrosensis* occurrences be fully mapped and that annual or even bi-annual field surveys be conducted. These monitoring activities will help determine whether or not these populations are being damaged by the heavy vehicle and OHV traffic through this area, in addition to road and fence maintenance and expansion, brush clearing, and other border activities. Being of chaparral habitat, this area is also strongly prone to human-caused fires. Demographic studies could also be carried out during monitoring activities to determine population trends.

In terms of *ex situ* conservation, it is recommended that maternal line conservation "groves" be established at a number of botanical institutions, with source material from as many wild populations as possible. These groves could serve as source material for restoration purposes in case any *Q. cedrosensis* occurrences are destroyed or heavily damaged by border management, fire, etc. Population genetics research could inform these collecting activities by aiding in the prioritization of subpopulations for inclusion in conservation groves. Development of restoration protocols would also be important if populations must be reinforced and/or translocated.

Conservation recommendations for *Quercus cedrosensis*

Highest Priority
- Population monitoring and/or occurrence surveys
- Wild collecting and/or *ex situ* curation

Recommended
- Land protection
- Propagation and/or breeding programs
- Reintroduction, reinforcement, and/or translocation
- Research (climate change modeling; demographic studies/ecological niche modeling; population genetics; restoration protocols/guidelines)
- Sustainable management of land

REFERENCES

1. **le Hardÿ de Beaulieu, A. & Lamant, T. (2010).** *Guide illustré des chênes.*
2. **Müller, C. H. (1965).** Relictual origins of insular endemics in *Quercus*. In Philbrick, R. N. (Ed.), *Proceedings of the symposium on the biology of the California Islands*. Santa Barbara, CA. Retrieved from http://repository.library.csuci.edu/bitstream/handle/10139/887/Müller1965Relictual~.pdf?sequence=3
3. **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
4. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
5. **NatureServe. (2017).** NatureServe Explorer: An online encyclopedia of life [online]. Version 7.1. Arlington, VA. Retrieved from http://explorer.natureserve.org.
6. **Schoenherr, A. A., Feldmeth, C. R., Emerson, M. J., & Mooney, D. (2003).** *Natural history of the islands of California*. Berkeley, CA: University of California Press.
7. **U.S. Department of Homeland Security, U.S. Customs and Border Protection, & U.S. Border Patrol. (2007, December).** *Draft environmental impact statement for the proposed construction, operation, and maintenance of tactical infrastructure.* San Diego, CA: U.S. Department of Homeland Security, U.S. Customs and Border Protection, & U.S. Border Patrol. Retrieved from https://nemo.cbp.gov/sbi/san_diego/sdeis_entire_draft.pdf
8. **Stallcup, J. A., Randall, J. M., Smith, T., Cohen, B. S., Guerrero Avila, C., Vargas, M. A., & Morrison, S. A. (2015).** *Las Californias binational conservation initiative 2015: A decadal review of conservation status of the California—Baja California border region*. Conservation Biology Institute, Terra Peninsular, Pronatura Noroeste, and The Nature Conservancy. 48 pp. Retrieved from https://d2k78bk4kdhbpr.cloudfront.net/media/content/files/LasCals2report_2015-10-3_m1PoSNi.pdf
9. **U.S. EPA Office of Research & Development. (2013, April).** 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
10. **Sproul, F., Keeler-Wolf, T., Gordon-Reedy, P., Dunn, J., Klein, A., & Harper, K. (2011, February).** *Vegetation classification manual for western San Diego County.* AECOM, California Department of Fish and Game Vegetation Classification and Mapping Program, & Conservation Biology Institute. Retrieved from https://portal.sdmmp.com/upload/projects/20160330_2357_94.pdf

Conservation Gap Analysis of Native

U.S. Oaks

Species profile: ***Quercus chapmanii***

Emily Beckman, Patrick Griffith, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, *Quercus inopina, Quercus pumila*

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus chapmanii Sarg.

Synonyms: N/A **Common Names:** Chapman oak

Species profile co-authors: Patrick Griffith, Montgomery Botanical Center
Contributors: Adam Black, Peckerwood Garden; Jared Chauncey, Missouri Botanical Garden; Michael Jenkins, Florida Forest Service, Florida Department of Agriculture and Consumer Services

Suggested citation: Beckman, E., Griffith, P., Meyer, A., & Westwood, M. (2019). *Quercus chapmanii* Sarg. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 92-97). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-chapmanii.pdf

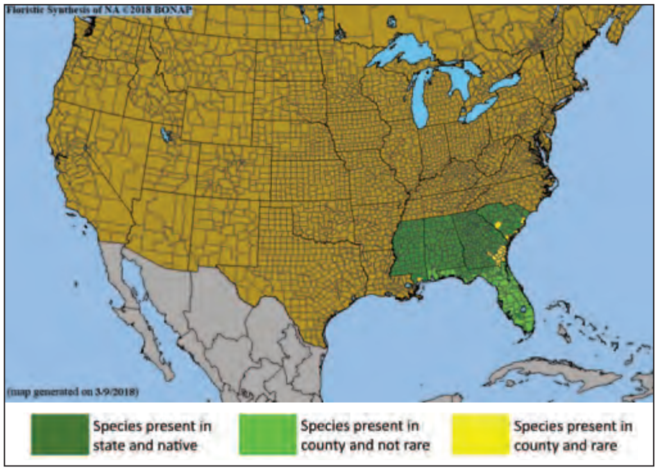


Figure 1. County-level distribution map for *Quercus chapmanii*. Source: Biota of North America Program (BONAP).[4]

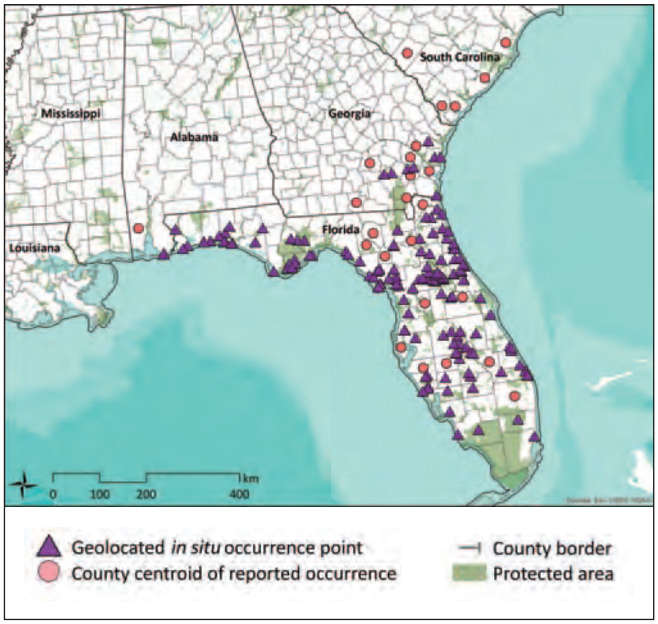


Figure 2. Documented *in situ* occurrence points for *Quercus chapmanii.* Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

DISTRIBUTION AND ECOLOGY

Quercus chapmanii, or Chapman oak, occurs abundantly in Florida, U.S., especially along the western coast, and creeps up the coasts of Georgia, South Carolina, Alabama, and perhaps into Mississippi. Favorable habitat includes dry, xeric sandy ridges and coastal dunes that foster sandhill, scrub, and scrubby flatwood ecosystems. Pine-scrub forests are a favorite ecosystem for Chapman oak, which can thrive both inland and along the coast. Commonly associated species include *Quercus myrtifolia, Q. incana, Q. laevis, Q. geminata, Q. hemisphaerica, Q. laurifolia, Q. nigra, Q. minima, Ilex glabra*, Serenoa repens, Sabal minor, *Pinus clausa, Carya*, and *Vitis rotundifolia*. *Quercus chapmanii* is evergreen with a spreading crown and leaves that are shiny on top and somewhat hairy on the underside; the leaves are also occasionally slightly lobed. Its broad acorns are mostly enclosed in their cup and mature in one season. Chapman oak declines in areas with long-term flooding by salt water, but has a high drought tolerance. This species grows as a large shrub or small tree, reaching between three and 13 meters tall.[1,2,3]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus chapmanii*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km^2 or AOO < 10 km^2 or 2-4 locations	EOO < 5,000 km^2 or AOO < 500 km^2 or 5-9 locations	EOO < 20,000 km^2 or AOO < 2,000 km^2 or 10+ locations	EOO > 20,000 km^2 or AOO > 2,000 km^2	Unknown	0
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	10
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	0
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	-
						Average vulnerability score	3.0
						Rank relative to all U.S. oak species of concern (out of 19)	19

THREATS TO WILD POPULATIONS

High Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: In Florida, natural, lightning-caused fires once occurred at an average rate of more than 1,000 fires per year, and burned through the landscape until fuel decreased or wetlands created a firebreak.[6,7] These fires provided room for *Q. chapmanii* to reproduce, but have been suppressed by human settlement. The disappearance of *Q. chapmanii* subpopulations has been witnessed due to infrequent or a complete lack of prescribed burns, which leads to intense competition with aggressive colonizers (A. Black pers. comm., 2017).

Moderate Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: Though there are few recorded land development threats specific to Chapman oak itself, its habitat is known to face many threats. Scrub communities in the southeastern U.S. have been widely destroyed, fragmented, and degraded due to developed or disturbed lands. The U.S. Fish and Wildlife Service estimates that "virtually all remaining significant scrub tracts that are not currently protected are proposed for development, or are for sale."[7]

Human use of landscape — tourism and/or recreation: Scrub habitat is readily damaged by off-road vehicle traffic or even foot traffic, which destroys the delicate ground cover and causes the loose sand to erode.[8]

Low Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Scrub communities are known to be sensitive to disturbance regime changes, which are altered by a changing climate. Further research is necessary regarding the the effects of climate change on the fluctuation of fire regimes.[9] No climate change projections are known for *Q. chapmanii* specifically.

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	9
Number of plants in *ex situ* collections:	17
Average number of plants per institution:	2
Percent of *ex situ* plants of wild origin:	71%
Percent of wild origin plants with known locality:	83%

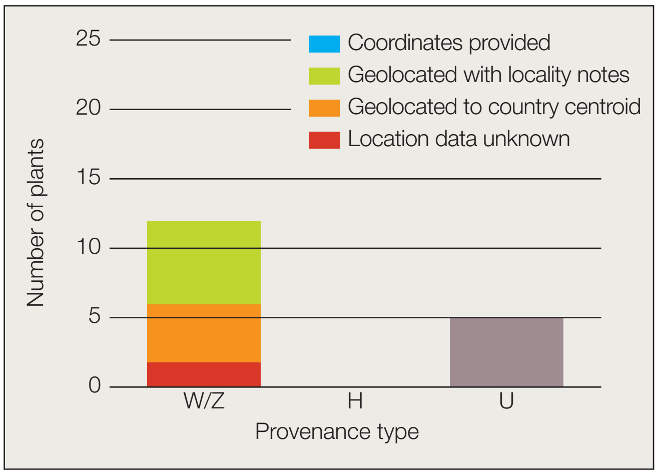


Figure 3. Number and origin of *Quercus chapmanii* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

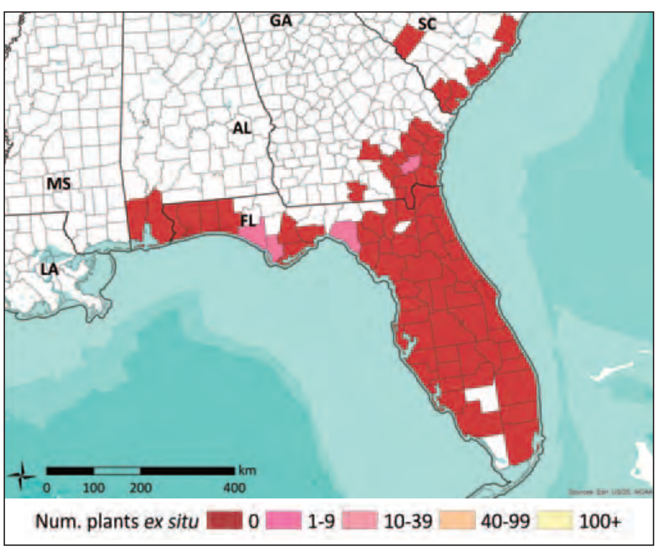


Figure 4. *Quercus chapmanii* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	13%
Ecological coverage:	54%

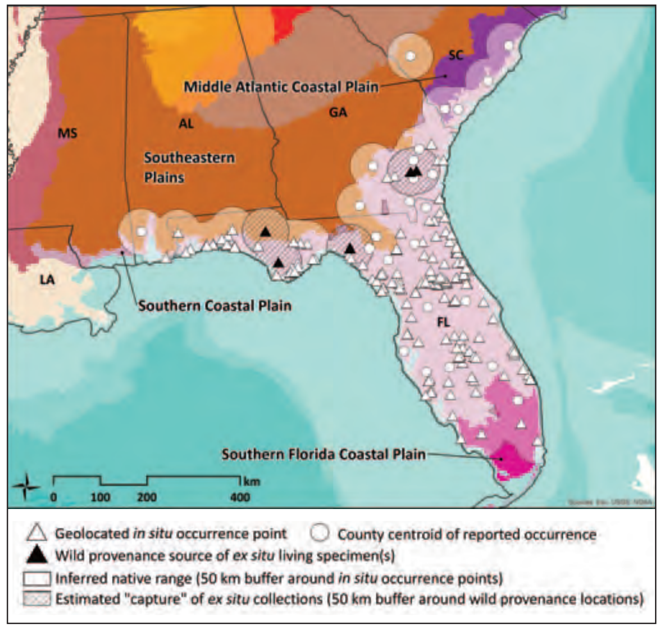


Figure 5. *Quercus chapmanii in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[10] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

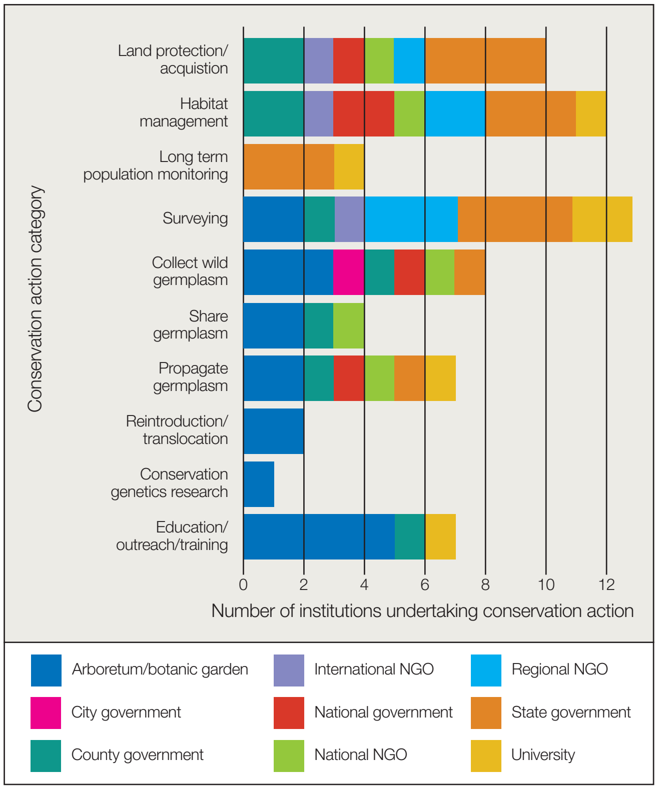


Figure 6. Number of institutions reporting conservation activities for *Quercus chapmanii* grouped by organization type. Twenty-seven of 252 institutions reported activities focused on *Q. chapmanii* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. chapmanii* in the U.S., 24% of the land is covered by protected areas (Figure 7). However, there are significant populations within protected areas; fragmentation of protected areas generally takes precedence as the source of concern, rather than a lack of protected populations.

The Institute for Regional Conservation has created an online profile for *Q. chapmanii*, which lists 41 specific conservation areas that contain the species.[11] Florida has many public lands with local biologists who monitor ecosystem health, an active native plant society, and a significant non-profit presence (M. Jenkins pers. comm., 2017). In addition, *Q. arkansana* often occurs with stands of *Q. chapmanii* in Florida, potentially providing some indirect protection due to Arkansas oak's distinction as a Threatened species by the Florida Department of Agriculture and Consumer Services (J. Chauncey pers. comm., 2017).

Sustainable management of land: Florida scrub is a plant community easily recognized by the dominance of evergreen shrubs and frequent patches of bare, white sand. With more than two dozen threatened and endangered species dependent upon scrub, the community is, itself, considered endangered. Recovery of the community and its associated plants and animals depends upon land protection and effective land management.[7] Many protected areas within Florida do manage for fire (M. Jenkins pers. comm., 2017).

Population monitoring and/or occurrence surveys: The APGA-USFS Tree Germplasm Conservation Partnership funded a scouting and collecting trip for Zamia integrifolia in 2015, lead by the Montgomery Botanical Center. The team reviewed herbarium specimens of *Q. chapmanii* and *Q. myrtifolia* due to their frequent association with *Z. integrifolia* in the northeastern part of its range, including Camden County, Georgia.[12] Perhaps further collecting efforts for *Z. integrifolia* could include scouting and/or collecting for *Q. chapmanii* as well.

The Florida Natural Areas Inventory (FNAI) documents all species within the majority of state forests by collecting spatial point data. For example, Lake Wales Ridge State Forest has recorded hundreds of data points for *Q. chapmanii* and *Q. inopina* within their boundaries. Florida state forests cover over a million acres of natural land within three-fourths of the state (M. Jenkins pers. comm., 2017).

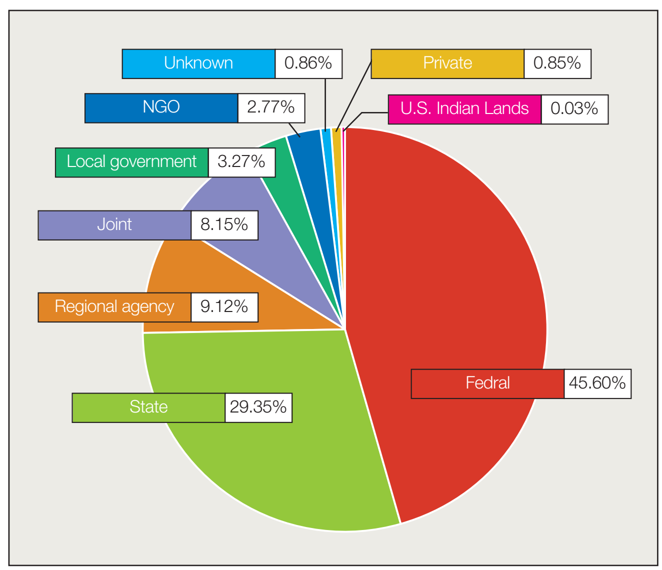


Figure 7. Management type of protected areas within the inferred native range of *Quercus chapmanii*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

Wild collecting and/or *ex situ* curation: It is suggested that researchers give at least three months lead time for collection permits with state and federal managed area staff, and six months is recommended (M. Jenkins pers. comm., 2017).

Propagation and/or breeding programs: Chapman oak is available at one or two native plant nurseries in southern Florida, as listed by the Natives for your Neighborhood program.[11] The Florida Fish and Wildlife Conservation Commission sometimes also propagate the species for restoration of habitat supporting the federally endangered Scrub Jay (M. Jenkins pers. comm., 2017).

Reintroduction, reinforcement, and/or translocation: In 2015, Project Acorn, "a multiyear effort that combines the initiative of the Florida Fish and Wildlife Conservation Commission (FWC), financial backing from the Disney Worldwide Conservation Fund and the work of local volunteers" continued to work towards the restoration of damaged scrub oak habitat within Lake Wales Ridge Wildlife and Environment Area by planting native oaks, including *Q. chapmanii*. The initiative is led by Bill Parken and Nicole Ranalli, who manage volunteers as they collect acorns in the fall, pot the seeds, and plant the seedlings out in the summer. In 2013, the first year of the initiative, 800 scrub oak sprouts were planted; each year following, volunteers planted about 2,500 sprouts, with about 800 participants. Twelve acres had been restored by 2015, and twenty acres is the project goal.[13] The Hilochee Mitigation Bank is also undergoing restoration, and in 2016 the absolute cover of appropriate shrub species had increased from an average baseline of 9.8% to more than 30%. This was accomplished through the planting of oak species including, but is not limited to, *Q. geminata, Q. myrtifolia,* and *Q. chapmanii.*[14] Florida Fish and Wildlife Conservation Commission also grows *Q. geminata*, and sometimes *Q. chapmanii*, for restoration of habitat supporting the federally endangered Scrub Jay (M. Jenkins pers. comm., 2017).

Research: One institution reported conservation genetics research in the conservation action questionnaire, but no other details are currently known.

Education, outreach, and/or training: The Florida Natural Resources Conservation Service (NRCS) has published the Plant List for Conservation Alternatives, which provides a list of species that are appropriate for planting within agricultural filter strips. These strips typically run adjacent to waterways and reduce sediment and chemical runoff, as required or suggested within NRCS Conservation Stewardship or Easement Programs. Chapman oak is included on this list.[15]

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

The conservation status of Chapman oak appears to be currently secure. The species' distribution, range, and documented localities overlap with a variety of local, state, and federal protected areas. However, regardless of these protections, *in situ* conservation concerns remain. These include human-mediated fire suppression that increases the density and abundance of competitors, habitat fragmentation and degradation, and the effects of climate change.

To address the *in situ* concerns, it is recommended that prescribed burns be performed where appropriate and permissible, *in situ* or "inter situ" plantings of *Q. chapmanii* be considered to mitigate habitat fragmentation, and further research investigates the effects of climate change on Florida scrub habitat and its species. Sustainable management of land, including prescribed burns, will likely require education/training of practitioners, and further climate change research will necessitate population monitoring. With regard to *ex situ* collections, it is furthermore recommended to systematically evaluate and expand the geographic breadth of coverage for *Q. chapmanii*, with a specific emphasis on capturing the populations at the margins of the distribution (Georgia, Mississippi, South Carolina, Alabama, as well as South Florida), and to network these collections in local (southeastern U.S.) botanic gardens, as possible. Bringing these potentially differing genotypes into protective cultivation will help mitigate potential losses from fire suppression, habitat degradation, and climate transition, as well as provide a reserve of germplasm for potential restoration efforts.

Conservation recommendations for *Quercus chapmanii*

Highest Priority
- Sustainable management of land
- Wild collecting and/or *ex situ* curation

Recommended
- Education, outreach, and/or training
- Population monitoring and/or occurrence surveys
- Reintroduction, reinforcement, and/or translocation
- Research (climate change modeling; land management/disturbance regime needs)

REFERENCES

1. **Stein, J., Binion, D., & Acciavatti, R. (2003).** *Field guide to native oak species of eastern North America*. Forest Service, U.S. Department of Agriculture.
2. **Coastal Plain Plants. (n.d.).** *Quercus chapmanii*. Retrieved from http://coastalplainplants.org/wiki/index.php/Quercus_chapmanii
3. **McDougall, S. (n.d.).** Chapman oak - *Quercus chapmanii*. Retrieved from http://northamericantrees.com/quercus-chapmanii.html
4. **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
5. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
6. **Komarek, E. V. (1964).** The natural history of lightning. In *Proceedings, third annual Tall Timbers fire ecology conference*. Tallahassee, FL: TallTimbers Research Station.
7. **U.S. Fish and Wildlife Service. (1999).** *Multi-species recovery plan for south Florida*. Vero Beach, FL: South Florida Ecological Services Field Office. Retrieved from https://www.fws.gov/verobeach/ListedSpeciesMSRP.html
8. **Florida Natural Areas Inventory. (2010).** *Guide to the natural communities of Florida: 2010 edition*. Tallahassee, FL. Retrieved from: https://www.fnai.org/naturalcommguide.cfm
9. **Defenders of Wildlife. (n.d.).** Climate change and Florida Scrub jays. Retrieved from http://www.landscope.org/article/FL/climate_scrub_jays/1/
10. **U.S. EPA Office of Research & Development. (2013, April).** 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
11. **The Institute for Regional Conservation. (n.d.).** Natives for your neighborhood. Delray Beach, FL. Retrieved from https://regionalconservation.org/beta/nfyn/default.asp
12. **Griffith, P., Calonje, M., Goldman, D., & Black, A. (2016, April 8).** *APGA–USFS Gene Conservation Partnership: 2015-2016 scouting/collecting trip for* Zamia integrifolia, Phase 1 report. Retrieved from http://www.montgomerybotanical.org/media/expeditions/USAFlorida2016.pdf
13. **Cameron, R. (2015, May 27).** Project Acorn: Putting Florida scrub oaks back where they belong. International Oak Society. Retrieved from http://www.internationaloaksociety.org/content/project-acorn-putting-florida-scrub-oaks-back-where-they-belong
14. **Environmental Consulting and Design Inc. (2016).** Hilochee Mitigation Bank. Gainesville, FL.
15. **Natural Resources Conservation Service. (2006).** Florida NRCS plant list for conservation alternatives. Retrieved from https://efotg.sc.egov.usda.gov/references/Delete/2006-11-25/FloridaNRCSPlantListforConservationAlternativescommon.pdf

Conservation Gap Analysis of Native

U.S. Oaks

Species profile: ***Quercus dumosa***

Emily Beckman, Abby Meyer, Evan Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, ***Quercus dumosa****, Quercus engelmannii*

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

Quercus dumosa Nutt.

Synonyms: N/A **Common Names:** Coastal sage scrub oak, Nuttall's scrub oak

Species profile co-authors: Abby Meyer, Botanic Gardens Conservation International, U.S.; Evan Meyer, Mildred E. Mathias Botanical Garden, University of California, Los Angeles

Suggested citation: Beckman, E., Meyer, A., Meyer, E., & Westwood, M. (2019). *Quercus dumosa* Nutt. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 98-103). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-dumosa.pdf

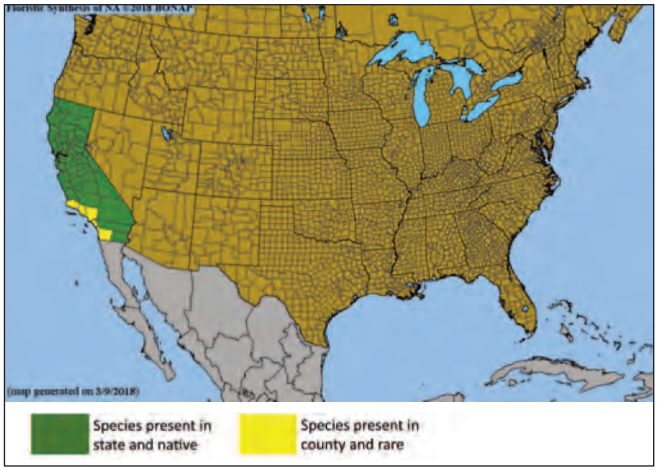


Figure 1. County-level distribution map for the U.S. distribution of *Quercus dumosa*. Source: Biota of North America Program (BONAP).[5]

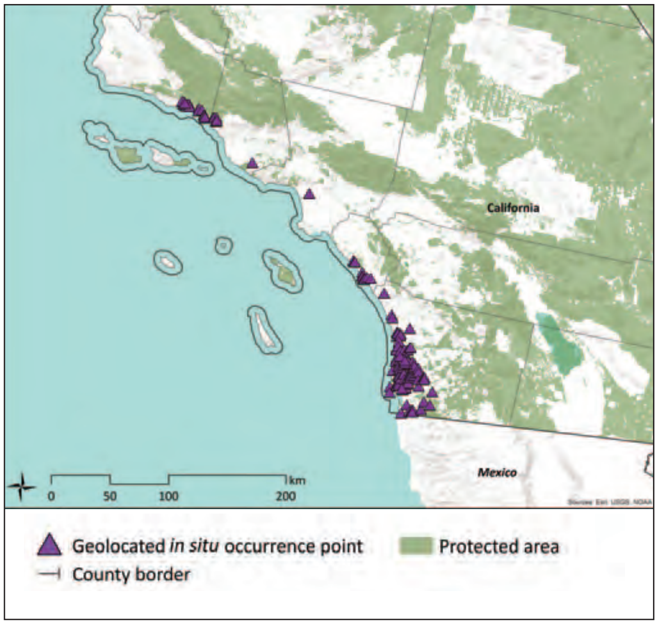


Figure 2. Documented *in situ* occurrence points for the U.S. distribution of *Quercus dumosa*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[6]

DISTRIBUTION AND ECOLOGY

Until recently, the name *Quercus dumosa* referred to many species of shrubby white oaks (Sect. *Quercus*) in California, U.S., including species now known as *Q. berberidifolia, Q. durata, Q. john-tuckeri, Q. cornelius-mulleri, Q. pacifica, Q. macdonaldii*, and *Q. turbinella*. Most of these species are distributed throughout southern California, and though they have close geographical proximity, occurrence in mixed stands is uncommon. *Quercus dumosa* endured many taxonomic shifts until about 2012. *Quercus berberidifolia* was the last species frequently labeled *Q. dumosa*, and therefore represents the majority of misidentified herbarium specimens today.[1] The currently accepted species description limits *Q. dumosa*, or Coastal sage scrub oak, to "scraggly shrubs with short petioles, cordate leaf bases, erect curly trichomes on the abaxial leaf surface, and narrow acute acorns that occur at low elevations almost always within sight of the ocean."[2] *Quercus dumosa* is known to occur within Orange, Santa Barbara, and San Diego counties in southern California, and extends slightly into Baja California, Mexico. It is very habitat-specific and is found in chaparral communities on coastal bluffs, hillsides, canyons, and mesas, where it usually dominates or codominates. This evergreen shrub thrives in very sandy soil, establishing an extensive root network, and typically reaching between one and three meters in height.[3,4] However, heights to five meters have been observed in canyon bottoms of San Diego County (A. Meyer pers. comm., 2018).

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus dumosa*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	10
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	10
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	10
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	5
						Average vulnerability score	10.8
						Rank relative to all U.S. oak species of concern (out of 19)	8

THREATS TO WILD POPULATIONS

High Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: Human development along the coast is likely still the most impactful threat to *Q. dumosa*, and has left very little habitat intact. Southern California's desirable coastal real estate is continuing to undergo conversion from chaparral to housing, though it is unlikely that whole subpopulation(s) will quickly disappear entirely, due to unfavorable areas of distribution and/or protections recently put in place. Past misclassification of other *Quercus* species as *Q. dumosa* also likely hindered possible conservation during times of rapid coastline development since the rarity of this species had not yet been realized.[3]

Moderate Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Altered fire regimes, due to both human influence and climate change impacts, are believed to be of some threat. Rigorous resprouting after fire protects *Q. dumosa* from complete wildfire destruction, but the species seldom recruits seedlings for ten to 20 years following a fire event. This means that long fire-free periods are necessary for substantial reproduction.[7]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Using the PCM climate change scenario, suitable habitat area for *Q. dumosa* is estimated to decline by 59%, in comparison to the modeled species distribution within the current climate.[8]

Low Impact Threats

Genetic material loss — inbreeding and/or introgression: The low elevation and dry habitat occupied by *Q. dumosa* generally protects it from hybridization with other similar white oak species, but some putative hybrids are known with *Q. engelmannii* and *Q. lobata*. Some introgression has also been observed where populations of *Q. berberidifolia* border *Q. dumosa* populations.[2]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	18
Number of plants in *ex situ* collections:	217
Average number of plants per institution:	12
Percent of *ex situ* plants of wild origin:	83%
Percent of wild origin plants with known locality:	99%

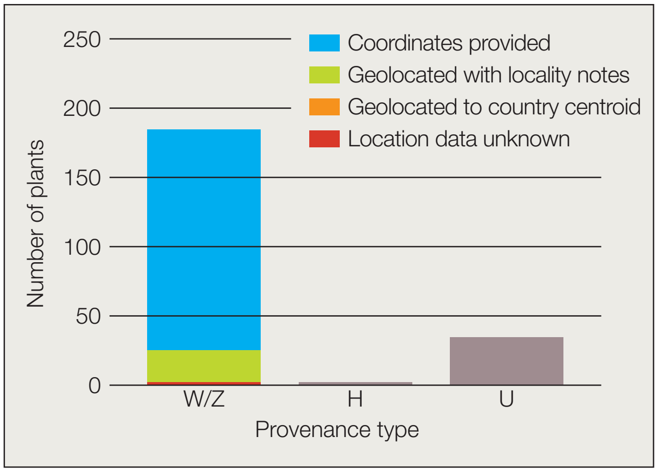


Figure 3. Number and origin of *Quercus dumosa* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

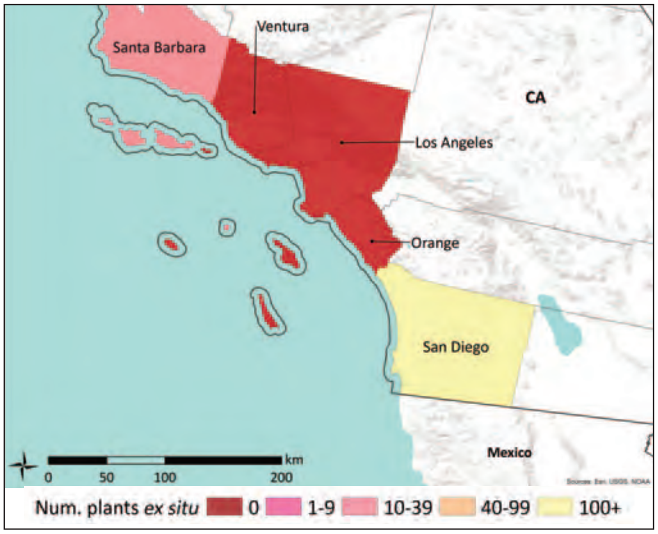


Figure 4. *Quercus dumosa* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Only the native U.S. distribution of the species was considered in this analysis, due to availability of ecoregion maps. Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	44%
Ecological coverage:	75%

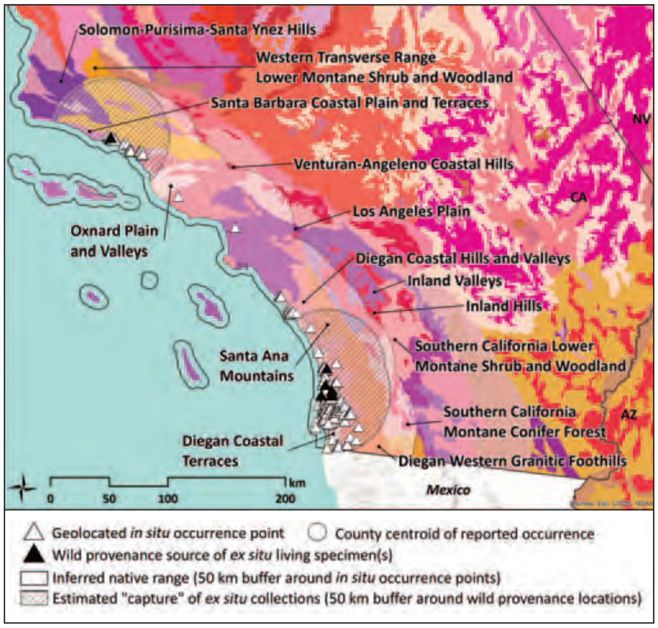


Figure 5. *Quercus dumosa in situ* occurrence points and *ex situ* collection source localities within the United States. U.S. EPA Level IV Ecoregions are colored and labelled.[9] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

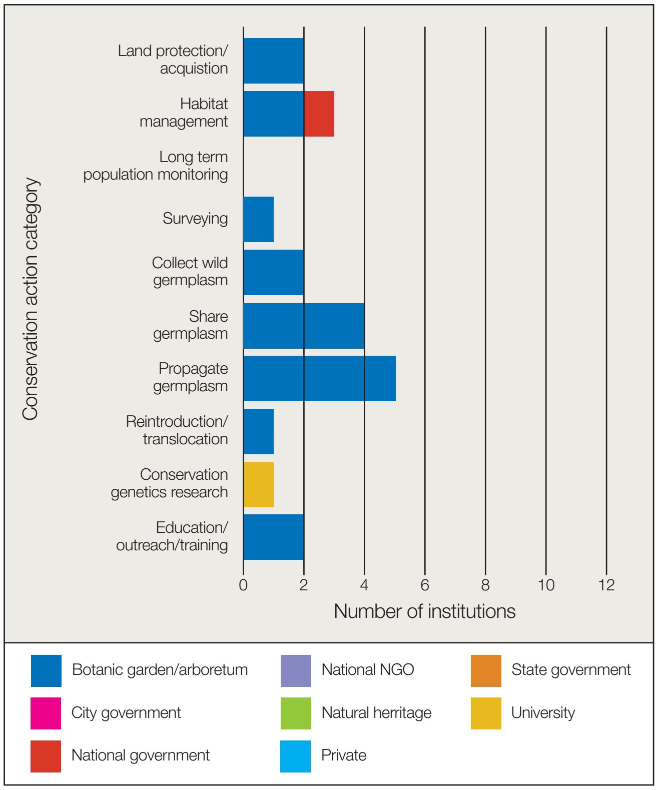


Figure 6. Number of institutions reporting conservation activities for *Quercus dumosa* grouped by organization type. Nine of 252 institutions reported activities focused on *Q. dumosa* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. dumosa*, 44% of the land is covered by protected areas (Figure 7). However, most of the remaining significant populations are protected to some extent.

The Del Mar region contains several large protected populations of *Q. dumosa*.[10] Other protected areas with relatively intact coastal sage scrub habitat include Camp Pendleton Marine Corps base, Santa Monica Mountains parklands, San Joaquin Hills near Laguna Beach, and Irvine Ranch in Orange County.[11] *Quercus dumosa* has also been found near the Los Padres National Forest boundary, but has not been formally documented within the park.[12] Most remaining reserves are small, and almost all are isolated.

Sustainable management of land: Three institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Population monitoring and/or occurrence surveys: The San Diego Chapter of the California Native Plant Society (CNPS) has coordinated with the San Diego Natural History Museum to work on a flora of the Del Mar Mesa. During the CNPS 2013 Rare Plant Treasure Hunt, the San Diego Chapter confirmed a grove previously thought to be *Q. berberidifolia* as *Q. dumosa*.[10]

Wild collecting and/or *ex situ* curation: In 2015, funded by the APGA-USFS Tree Germplasm Conservation Partnership, Rancho Santa Ana Botanic Gardens and Botanic Gardens Conservation International U.S. collaboratively set out to collect *Q. dumosa* acorns for establishment in *ex situ* collections. However, drought and difficulty in receiving collection permits caused additional challenges. Four populations were visited, all within San Diego County, and acorn production was sporadic and unpredictable. Over 500 acorns were collected from four populations and distributed to five gardens in California.[13]

Propagation and/or breeding programs: The California Native Plant Link Exchange provides a platform to search nurseries and seed sources for native California plants; *Quercus dumosa* is listed as propagated by at least nine different seed sources.[14] Two-hundred *Q. dumosa* acorns had germinated at Rancho Santa Ana Botanic Garden by December, 2015, which were collected through funding from the above-mentioned APGA-USFS grant. Germinations are ongoing. Seeds were also distributed to UC Davis Arboretum, Huntington Botanical Gardens, UC Berkeley Botanic Garden, and UC Fullerton Arboretum for propagation, with each garden receiving about 100 acorns.[13] The Tree of Life Nursery has been producing native California plants for more than two decades and is one of the largest suppliers of native plants in the state. The nursery includes 30 acres of growing area as well as laboratories for propagation and testing. They grow a wide variety of native oak species, including *Q. dumosa*.[15]

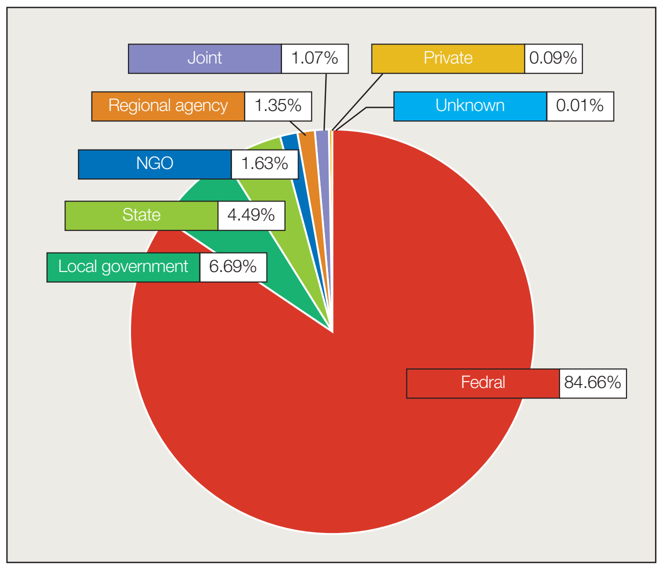


Figure 7. Management type of protected areas within the inferred native range of *Quercus dumosa*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[6]

Reintroduction, reinforcement, and/or translocation: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Research: The potential distribution of *Q. dumosa* has been estimated using species distribution modeling. The process revealed that maximum temperature in January, available water holding capacity, and maximum temperature in July are the top three predictor variables for the presence or absence of *Q. dumosa*. Under the PCM climate change scenario, a 59% decline in suitable habitat area is predicted, compared to *Q. dumosa's* modeled species distribution within the current climate.[8]

Education, outreach, and/or training: The USDA Forest Service has classified *Q. dumosa* as a "Sensitive Species" due to the amount of habitat that has been destroyed by coastal development.[12] The World Wildlife Foundation has created an ecoregion profile for California Coastal Sage and Chaparral, of which *Q. dumosa* is an important component. This ecoregion has extremely high levels of species diversity and endemism, which includes the California gnatcatcher. This rare bird is "currently being used as an umbrella species to protect the endemic flora and fauna of this region from urban development." The region has also been listed as an Endemic Bird Area, as identified by BirdLife International, which brings additional awareness to its rare and valuable natural components.[11]

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

Coastal sage scrub oak is geographically limited to coastal areas, however can be easily confused with similar species that are more widespread. Habitat destruction has been the biggest factor in reducing populations to what they are today. Many remaining populations of *Q. dumosa* are on protected land, though inappropriate fire management may negatively impact seedling recruitment. It is unlikely that more populations can be brought under protection, but opportunities to work with landowners to preserve the species habitat should be pursued when possible. Remaining populations are also being monitored by local organizations, providing an invaluable service, which many threatened species do not have. Those organizations, including the California Native Plant Society, should be commended and supported as they continue this important work.

In light of projected habitat decline, genetic diversity of *in situ* and *ex situ* populations needs to be assessed. The species should be highlighted in outreach efforts in order to build local public awareness of its threat status and ecological value. Additional acorn collections should be made to complement existing *ex situ* collections and augment wild populations. Research regarding appropriate land management for the successful regeneration of *Q. dumosa*, as well as best practices for population reinforcement may be necessary for successful *in situ* conservation. Further climate change modeling could also be helpful in determining priority locations for conservation work. Finally, population genetics could greatly inform both *in situ* and *ex situ* conservation efforts if such data were compiled.

Conservation recommendations for *Quercus dumosa*

Highest Priority
- Education, outreach, and/or training
- Wild collecting and/or *ex situ* curation

Recommended
- Land protection
- Population monitoring and/or occurrence surveys
- Reintroduction, reinforcement, and/or translocation
- Research (climate change modeling; land management/disturbance regime needs; population genetics; restoration protocols/guidelines)
- Sustainable management of land

REFERENCES

1. **Fryer, J. L. (2012).** Quercus berberidifolia, *Q. dumosa*. In Fire Effects Information System [online]. CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from https://www.fs.fed.us/database/feis/plants/shrub/quespp2/all.html
2. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
3. **Backs, J. R. & Ashley, M. V. (2016).** Evolutionary history and gene flow of an endemic island oak: *Quercus pacifica. American Journal of Botany*, 103(12). Retrieved from https://doi.org/10.3732/ajb.1600259
4. **California Native Plant Society. (n.d.).** Nuttall's scrub oak: *Quercus dumosa*. Retrieved from http://calscape.org/Quercus-dumosa-(Nuttall's-Scrub-Oak)?srchcr=sc583da0afed148
5. **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
6. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
7. **Keeley, J. E. (1992).** Recruitment of seedlings and vegetative sprouts in unburned chaparral. *Ecology*, 73(4), 1194–1208. doi:10.2307/1940669
8. **Lawson, D. M. (2011).** *Multi-species conservation in the context of global change* (Unpublished doctoral dissertation). Davis, CA: University of California.
9. **U.S. EPA Office of Research & Development. (2013, April).** 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
10. **California Native Plant Society. (2013).** Rare Plant Treasure Hunt, 2013 RPTH award winners. Retrieved from https://www.cnps.org/rare-plants
11. **Olson, D., Valero, A., Schipper, J., & Allnutt, T. (n.d.).** Western North America: Southwestern United States into Northwestern Mexico. World Wildlife Foundation. Retrieved from https://www.worldwildlife.org/ecoregions/na1201
12. **Los Padres ForestWatch. (n.d.).** Oaks of the Los Padres Forest. Retrieved from https://lpfw.org/our-region/wildlife/oaks/
13. **Meyer, E., & Hird, A. (2016).** *2015 USDA–APGA/NAPCC Partnership – Tree germplasm conservation project report*. Retrieved from https://publicgardens.org/sites/default/files/images/documents/RSABG%20Quercus%20dumosa%20final%20report.pdf
14. **California Native Plant Link Exchange. (n.d.).** Local native plants, local sources. Retrieved from http://www.cnplx.info/
15. **McCreary, D. D. (2001).** *Regenerating rangeland oaks in California*. Oakland, CA: University of California, Agriculture and Natural Resources. Retrieved from https://anrcatalog.ucanr.edu/pdf/21601e.pdf


Evan Meyer

Conservation Gap Analysis of Native

U.S. Oaks

Species profile: *Quercus engelmannii*

Emily Beckman, Tom Gaman, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa,
Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum®
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus engelmannii Greene

Synonyms: N/A **Common Names:** Engelmann oak, Mesa oak, Pasadena oak

Species profile co-author: **Tom Gaman,** East-West Forestry Associates, Inc. / California Wildlife Foundation
Contributors: **Jim Henrich,** Los Angeles County Arboretum & Botanic Garden; **Tim Thibault,** The Huntington

Suggested citation: Beckman, E., Gaman, T., Meyer, A., & Westwood, M. (2019). *Quercus engelmannii* Greene. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 104-109). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-engelmanii.pdf

DISTRIBUTION AND ECOLOGY

Quercus engelmannii, or Engelmann oak, is sporadically distributed south from southern California, U.S., to northwestern Baja California, Mexico. It occurs in four California Floristic Provinces: South Coast, San Gabriel Mountains, Peninsular Ranges, and San Jacinto Mountains. A subpopulation is also present on Santa Catalina Island (T. Gaman pers. comm., 2018). Engelmann oak is commonly found growing in stands with Coast live oak. Suitable habitat for *Q. engelmannii* is restricted by adequate rainfall (at least 15 inches per year), rare instances of frost, and moderate summer temperatures. These landscapes include valley grassland, foothill woodlands above the dry coastal plain, and margins of chaparral. Gentle, southern facing slopes are a favorite habitat, with soil type ranging from deep loamy-clay to shallow, rocky soils.[1] *Quercus engelmannii* is characterized by an open structure, reaching five to 25 meters in height. It has dull blue-green leaves, which are oblong to obovate and evergreen.[2]

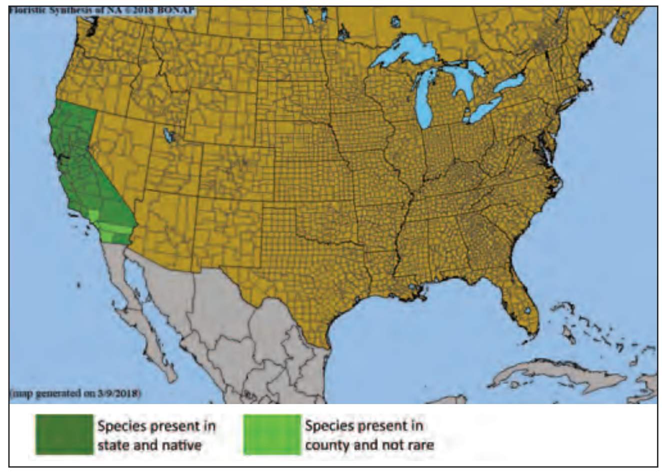


Figure 1. County-level distribution map for the U.S. distribution of *Quercus engelmannii*. Source: Biota of North America Program (BONAP).[3]

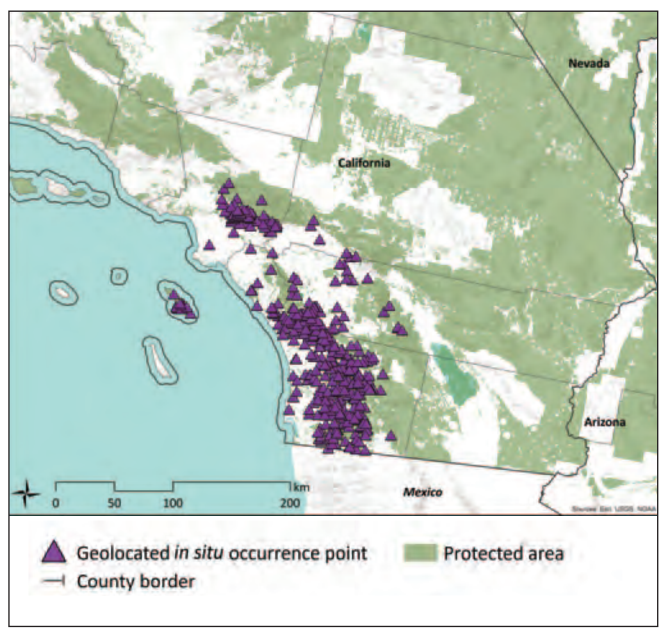


Figure 2. Documented *in situ* occurrence points for the U.S. distribution of *Quercus engelmannii*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus engelmannii*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	Score
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	5
Range/endemism	Extremely small range or 1 location	EOO < 100 km^2 or AOO < 10 km^2 or 2-4 locations	EOO < 5,000 km^2 or AOO < 500 km^2 or 5-9 locations	EOO < 20,000 km^2 or AOO < 2,000 km^2 or 10+ locations	EOO > 20,000 km^2 or AOO > 2,000 km^2	Unknown	5
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	10
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	-
						Average vulnerability score	10.0
						Rank relative to all U.S. oak species of concern (out of 19)	9

THREATS TO WILD POPULATIONS

High Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: Suburban sprawl, especially in the San Gabriel Valley, is causing Engelmann oak populations to become fragmented to the point of falling rates of pollination and acorn production.[1] Because fire damage to the trees is generally low in grasslands, moderate in scrub, and high in chaparral, continued human development of grassland areas could leave remaining Engelmann populations at greater risk to fire in chaparral communities.[5]

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Another effect of development is the increasing risk of human induced wildfire. The entire range Engelmann oak exists within these higher-risk areas. Two of the largest wildfires in California burned extensive portions of the species' range in the 2000's. The 2003 Cedar Fire burned about 53% of monitored trees within Santa Ysabel Open Space Preserve, where the vast majority of Engelmann oak's total population is located.[5]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Climate change models based solely on habitat suitability predict climate change to be the largest threat to *Q. engelmannii*, which is worrying since such models often underestimate the total impact of climate change.[6] A recent analysis of U.S. tree vulnerability to climate change found *Q. engelmannii* to have "potential future vulnerability" based on species-specific traits, due to low threat exposure but high threat sensitivity and low adaptive capacity.[7] Engelmann oak is also predicted to experience net habitat losses under combined impacts (climate change and land use changes), even under best-case unlimited dispersal scenarios.[8] Negative impacts due to increased periods of extreme heat, whiplash precipitation cycles (extremely wet to extremely dry), and consecutive years of drought are predicted; such conditions also increase the threat of severe fire (J. Henrich pers. comm., 2018).

Moderate Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: Reproduction of Engelmann oak on the Santa Rosa Plateau is insufficient to maintain its current distribution, abundance, and demography.[9] This is attributed to past, nearly continuous grazing of the area for the last 75 years, causing soil compaction and damage to existing trees.[1] In some areas, livestock grazing is still a substantial threat.[10]

Pests and/or pathogens: There is recent concern regarding Polyphagous and Kuroshio shot hole borers (PSHB/KSHB) in southern California. These beetles are a host for the pathogenic fungus *Fusarium euwallaceae*, which they carry as they bore into the trunks and branches of trees for reproduction.[11] The fungus is harmful to *Q. engelmannii* and has spread throughout Los Angeles and San Diego Counties. It is very difficult to detect before it is too late (T. Thibault pers. comm., 2016). Goldspotted oak borer injuries have also been observed on dead Engelmann oaks "but tree mortality...was likely a result of a complex of factors (e.g., drought and root disease)."[12]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey	
Number of *ex situ* collections reporting this species:	20
Number of plants in *ex situ* collections:	566
Average number of plants per institution:	28
Percent of *ex situ* plants of wild origin:	77%
Percent of wild origin plants with known locality:	99%

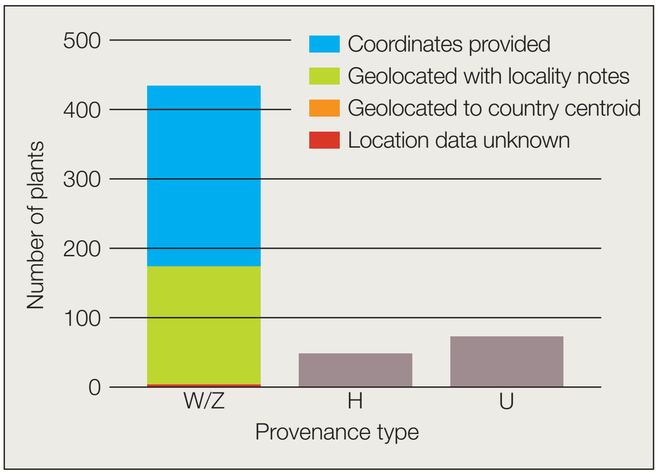


Figure 3. Number and origin of *Quercus engelmannii* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

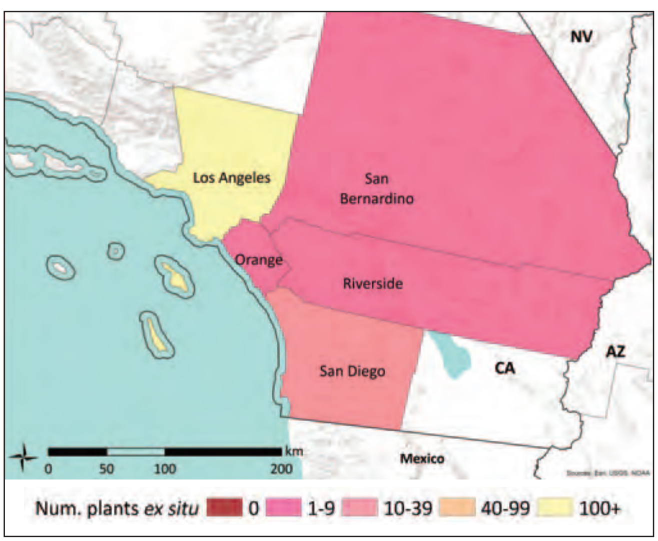


Figure 4. *Quercus engelmannii* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Only the native U.S. distribution of the species was considered in this analysis, due to availability of ecoregion maps. Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation	
Geographic coverage:	74%
Ecological coverage:	79%

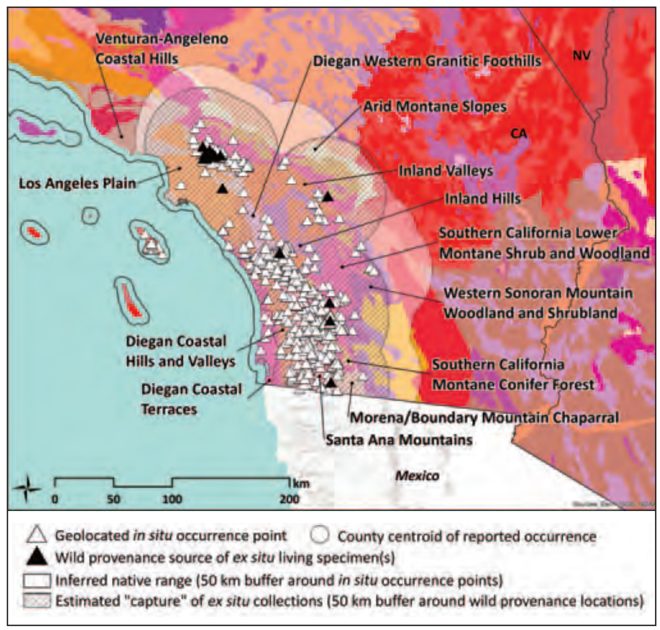


Figure 5. *Quercus engelmannii in situ* occurrence points and *ex situ* collection source localities within the United States. U.S. EPA Level IV Ecoregions are colored and labelled.[13] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

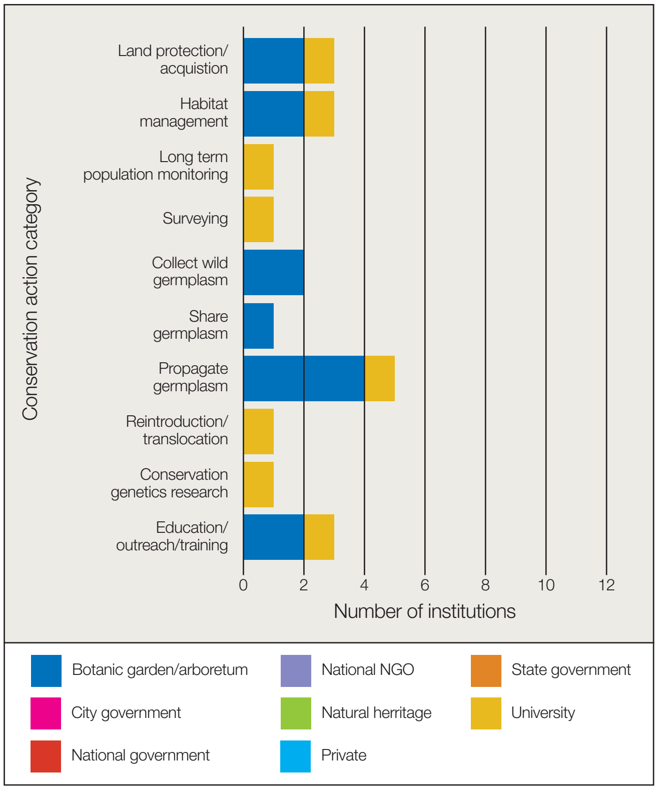


Figure 6. Number of institutions reporting conservation activities for *Quercus engelmannii* grouped by organization type. Six of 252 institutions reported activities focused on *Q. engelmannii* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. engelmannii* in the U.S., 49% of the land is covered by protected areas (Figure 7). However, there are some sizable, healthy populations on protected land.

A USDA Forest Service report explains the status of protected *Q. engelmannii* populations in 1991: "the U.S. Forest Service has the largest tracts of Engelmann oak woodlands under one management, and provides the best opportunity for comprehensive planning for the conservation and management of the species. Land Grants, particularly those which have not been divided into subunits, provide the next largest group of undivided woodland areas...The greatest challenge in Engelmann oak conservation occurs in the small parcels which share 36% of all Engelmann oak woodlands."[14]

A Multiple Habitat Conservation Plan (MHCP) for the cities of Carlsbad, Encinitas, Escondido, Oceanside, San Marcos, Solana Beach, and Vista also provides protection for *Q. engelmannii*. In total there are 230 acres of Engelmann oak vegetative community, which conserves 82% of the species potential habitat and 84% of the main populations within the counties.[10]

Some significant populations are also held within public gardens, including The Los Angeles County Arboretum, which has a population of nearly 250 Engelmann oak trees and is the largest remaining extant population in Los Angeles County.[1] A smaller, neighboring subpopulation can be found at Santa Anita Park, as well as another small stand within Huntington Botanical Gardens in San Marino.[7]

Sustainable management of land: The Santa Rosa Plateau is the only preserve established specifically for Engelmann oaks and is managed by The Nature Conservancy.[1] At their Ecological Reserve located at the southern end of the Santa Ana Mountains, experimental management fires of the grass-layer were initiated in 1988, along with test burns in Riverside County (now the northernmost ecologically-intact population of *Q. engelmannii*) and Santa Ysabel Open Space Preserve.[13] The Los Angeles County Arboretum & Botanic Garden has claimed responsibility for the growth and management of a remnant stand of Engelmann oak within their property and adopted a four-phase management program, which begins with weed abatement and fostering successful establishment of natural recruits.[1] The MHCP for the cities of Carlsbad, Encinitas, Escondido, Oceanside, San Marcos, Solana Beach, and Vista requires subarea plans to implement a fire management plan in all conserved populations.[10]

Population monitoring and/or occurrence surveys: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Wild collecting and/or *ex situ* curation: At the easternmost edge of the species' range is Rancho Santa Ana Botanic Garden in Claremont. Since the late 2000's, they have established a *Q. engelmannii* grove through acorn collection from isolated, wild individuals ranging from Pasadena to Monrovia.[7]

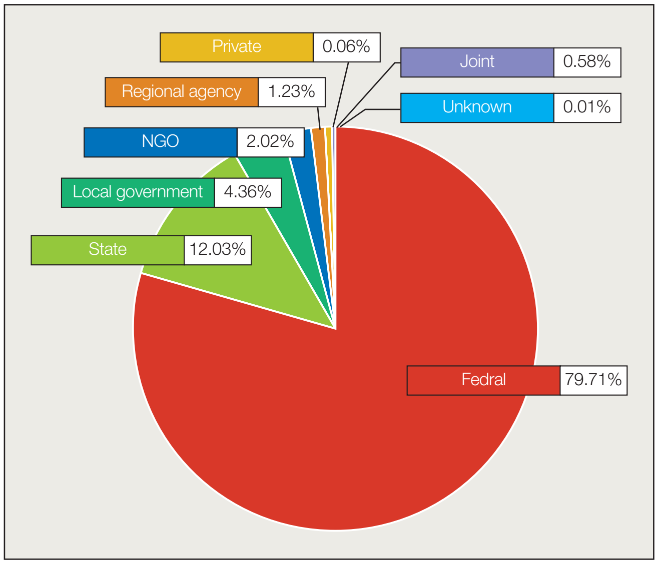


Figure 7. Management type of protected areas within the inferred native range of *Quercus engelmannii*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

Propagation and/or breeding programs: The LA County Arboretum's third phase of management for their native *Q. engelmannii* grove requires supplementing natural recruits with nursery-grown saplings from field-collected acorns, which includes the propagation of hundreds of seedlings.[1] Organizations such as the Arroyo Seco Foundation have sold thousands of trees to parks and natural areas by collecting acorn donations and then propagating them each year. The Tree of Life Nursery has been producing native California plants for more than two decades and is one of the largest suppliers of native plants in the state. Their grounds are located within Engelmann oak's native range, and include 30 acres of growing area in addition to laboratory facilities. They propagate a wide variety of native oak species, and are especially well known for their production of Engelmann oak seedlings in collaboration with conservation groups working to restore the species.[15]

Reintroduction, reinforcement, and/or translocation: The LA County Arboretum is supplementing their native stand of *Q. engelmannii* with seedlings grown from wild collected acorns they have propagated in their nursery.[1] The MHCP for the cities of Carlsbad, Encinitas, Escondido, Oceanside, San Marcos, Solana Beach, and Vista requires subarea plans to enhance declining populations, including reinforcement of existing populations. They require that "unless analyses determine that there is no significant genetic variation between populations, introduced plant materials must be from the parental population or a population in proximity."[10]

Research: As a result of their restoration program, LA County Arboretum reports a variety of findings: "supplemental irrigation is necessary to reduce leaf drop, and maintain health and vigor in the greater Los Angeles area; protecting natural recruits from mechanical damage increases survival rates; *ex situ* sapling production is very successful; and, vegetating with *ex situ* saplings is successful when planted during winter/spring precipitation periods, supplemental irrigation is applied, and protection is provided to prevent mechanical damage."[1]

Utilizing dynamic species distribution models, a study examined the interaction of *Q. engelmannii* life history traits and short-term and long-term climate change projections, to predict the species abundance in the future. These models incorporated data regarding land use change, altered fire frequency, and dispersal and seed predation. Results predicted "dramatic reduction in *Q. engelmannii* abundance, especially under drier climates and increased fire frequency."[16] Another study examined connections between the climate gradient of Engelmann oak's distribution and its spatial genetic structure by combining information from nuclear microsatellite markers and ecological niche modelling. Three main genetic clusters emerged, suggesting that local environmental conditions can influence spatial genetic structure, "even in species with high potential for gene flow and relatively small distribution ranges."[17]

Education, outreach, and/or training: The California Native Plant Society provides information to homeowners regarding the tree's use in landscape, including ecological requirements and locations for purchase. The East Palo Alto Tree Initiative, a "multi-year collaboration to enhance the urban forest in East Palo Alto and plant more than 1,200 trees," included *Q. engelmannii* in their urban plantings, in which hundreds of volunteers participated.[18]

Species protection policies: The city of Los Angeles has adopted a Protected Tree Ordinance that inhibits the removal or relocation of all California native oak species unless a permit is obtained through the Board of Public Works. The Board may require the planting of multiple protected trees within the same property's boundaries in addition to a fee for the removal or relocation of a native oak.[19]

PRIORITY CONSERVATION ACTIONS

Wildfire damage to established native stands, habitat fragmentation and loss due to urbanization, and lack of regeneration are principal reasons for the dramatic decline of Engelmann oak. Climate change and ongoing drought issues also complicate sustenance of natural populations. Protected outplanting in preserve areas within the native range and in other suitable locations may aid in maintaining this rare species. Establishment of suitable conditions for natural regeneration, such as in areas protected by gaps in established stands of native shrub species, could also be key to the perpetuation of this species in natural landscapes. Further research may be needed to inform effective restoration protocols. About 36% of Engelmann oak woodlands exist in small land parcels.[13] Therefore, outreach to individual landowners regarding techniques for sustainable management of oak woodlands will be an important component of the species' conservation. Continued monitoring of wild populations is also necessary, which will aid in the prediction of climate impacts. Further wild collecting for *ex situ* preservation should be carried out, targeting edge populations not yet held in *ex situ* collections. Engelmann oak is also predicted to experience net habitat losses under combined impacts (climate change and land use changes), even under best-case unlimited dispersal scenarios. Therefore dispersal will be vital to assuaging future habitat loss.[8]

Conservation recommendations for *Quercus engelmannii*

Highest Priority
- Education, outreach, and/or training
- Reintroduction, reinforcement, and/or translocation

Recommended
- Population monitoring and/or occurrence surveys
- Research (land management/disturbance regime needs; pests/pathogens; restoration protocols/guidelines)
- Sustainable management of land
- Wild collecting and/or *ex situ* curation

REFERENCES

1. **Henrich, J. (2012, January).** The most majestic southern California oak. *Pacific Horticulture*, 78. Retrieved from https://www.pacifichorticulture.org/articles/the-most-majestic-southern-california-oak/
2. **Rosatti, T. J. & Tucker, J. M. (2014).** *Quercus engelmannii*. In Jepson Flora Project (Eds.), Jepson eFlora, Revision 2. Retrieved from http://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=40590
3. **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
4. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
5. **Principe, Z. (2015).** Influence of fire on Engelmann oak survival – patterns following prescribed fires and wildfires. In *Proceedings of the seventh California oak symposium: managing oak woodlands in a dynamic world* (Gen. Tech. Rep. PSW-GTR-251). Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/treesearch/pubs/49983
6. **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*
7. **Eubank, S. C. (2008).** Discovery trails: Engelmann oaks (*Quercus engelmannii*) in Los Angeles County and their future. Los Angeles County Arboretum and Botanic Garden. Retrieved from https://www.biodiversitylibrary.org/part/144701#/summary
8. **Riordan, E. C., Gillespie, T. W., Pitcher, L., Pincetl, S. S., Jenerette, G. D., & Pataki, D. E. (2014).** Threats of future climate change and land use to vulnerable tree species native to southern California. *Environmental Conservation*, 42(2), 127-138. doi:10.1017/S0376892914000265
9. **Lathrop, E. W., Osborne, C., Rochester, A., Yeung, K., Soret, S., & Hopper, R. (1991).** Size class distribution of *Quercus engelmannii* (Engelmann oak) on the Santa Rosa Plateau, Riverside County, California. In Standiford, R. B. (Tech. coord.), *Proceedings of the symposium on oak woodlands and hardwood rangeland management; October 31 - November 2, 1990; Davis, California* (Gen. Tech. Rep. PSW-GTR-126). Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/treesearch/pubs/28460
10. **California Dept. of Fish and Game, U.S. Fish and Wildlife Service, & Conservation Biology Institute. (2003, March).** *MHCP biological monitoring and management plan*. CA: Multiple Habitat Conservation Program. Retrieved from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=35105
11. **Stouthamer, R., Rugman-Jones, P., Eskalen, A., Kabashima, J., Dimson, M., Gonzalez, A., Arakelian, G., Hodel, D., Drill, S. (2017).** Polyphagous shot hole borer. CA: Department of Entomology & Department of Plant Pathology and Microbiology, University of California.


Jim Henrich

12. **Colman, T. W., Jones, M. I., Smith, S. L., Venette, R. C., Flint, M. L., & Seybold, S. J. (2017).** Goldspotted Oak Borer. Forest Insect & Disease Leaflet 183. U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf
13. **U.S. EPA Office of Research & Development. (2013, April).** 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
14. **Scott, T. A. (1991).** The distribution of Engelmann oak (*Quercus engelmannii*) in California. In *Proceedings of the symposium on oak woodlands and hardwood rangeland management; October 31 - November 2, 1990* (Gen. Tech. Rep. PSW-GTR-126). Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/treesearch/pubs/28457
15. **McCreary, D. D. (2001).** *Regenerating rangeland oaks in California*. Oakland, CA: University of California, Agriculture and Natural Resources. Retrieved from https://anrcatalog.ucanr.edu/pdf/21601e.pdf
16. **Conlisk, E., Lawson, D., Syphard, A. D., Franklin, J., Flint, L., Flint, A., & Regan, H. M. (2014).** Correction: The roles of dispersal, fecundity, and predation in the population persistence of an oak (Quercus engelmannii) under global change. *PLOS ONE*, 9(1). Retrieved from https://doi.org/10.1371/annotation/819da56b-1c8f-445f-80fc-e8d741dc2262
17. **Ortego, J., Riordan, E. C., Gugger, P. F., & Sork, V. L. (2012).** Influence of environmental heterogeneity on genetic diversity and structure in an endemic southern Californian oak. *Molecular Ecology*, 21(13), 3210-3223. doi:10.1111/j.1365-294x.2012.05591.x
18. **Canopy. (n.d.).** East Palo Alto tree initiative. Retrieved from http://canopy.org/our-work/tree-planting/east-palo-alto-tree-initiative/
19. **City of Los Angeles. (2006).** Los Angeles Municipal Code. Ordinance No 177404. Chap 1 $ 5.

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus georgiana***

Emily Beckman, Patrick Thompson, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, ***Quercus georgiana****, Quercus oglethorpensis, Quercus similis*

The Morton Arboretum®
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus georgiana M.A.Curtis

Synonyms: N/A **Common Names:** Georgia oak

Species profile co-author: Patrick Thompson, Donald E. Davis Arboretum, Auburn University of Sciences and Mathematics
Contributors: Sean Hoban, The Morton Arboretum; Ron Lance, North American Land Trust; Murphy Westwood, The Morton Arboretum

Suggested citation: Beckman, E., Thompson, P., Meyer, A., & Westwood, M. (2019). *Quercus georgiana* M.A.Curtis. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 110-115). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-georgiana.pdf

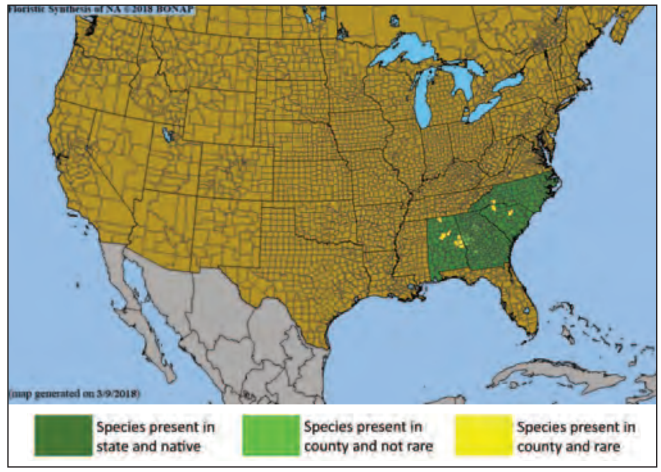


Figure 1. County-level distribution map for *Quercus georgiana*. Source: Biota of North America Program (BONAP).[5]

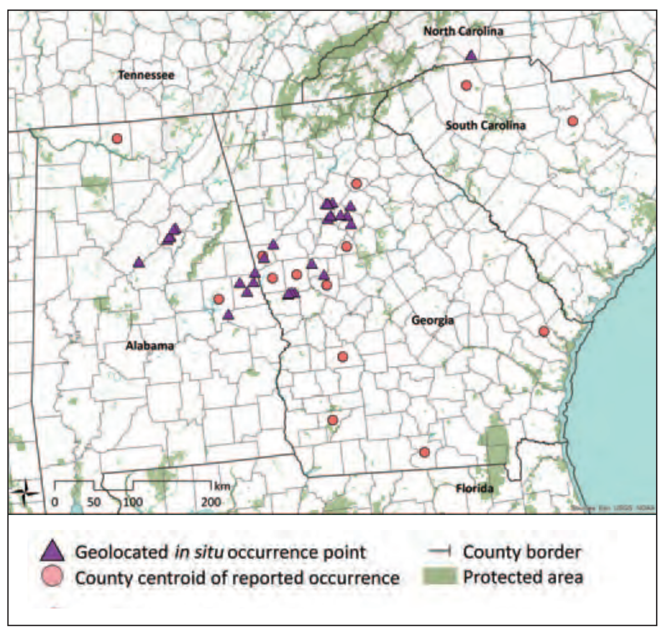


Figure 2. Documented *in situ* occurrence points for *Quercus georgiana.* Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[6]

DISTRIBUTION AND ECOLOGY

Quercus georgiana, or Georgia oak, occurs on isolated granite outcrops and flat-rocks in the Piedmont Plateau of the southeastern U.S., including locations in Georgia and Alabama.[1] In Alabama, *Q. georgiana* can also be found on sandstone outcrops of the Ridge and Valley Province, and more frequently in the margins and surrounding woodlands associated with these outcrops (P. Thompson pers. comm., 2018).[2] Historically, the species was also found along the North Carolina-South Carolina border and further east in South Carolina, but these populations are believed to be extirpated or contain too few individuals to be considered viable. Even within its narrow habitat, Georgia oak is uncommon, and considered abundant in few localities. It is currently known to occupy about 72 kilometers squared, with a maximum of 272 kilometers squared.[3] *Quercus georgiana* thrives in dry oak-pine forests that are found atop granite slabs in the Piedmont. Soil depths at one site, Arabia Mountain, are reported to be only 50 to 100 centimeters. Georgia oak is a small tree, usually multi-stemmed and typically growing eight to 15 meters in height.[4]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus georgiana*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	Score
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	10
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	10
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	10
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
						Average vulnerability score	11.7
						Rank relative to all U.S. oak species of concern (out of 19)	7

THREATS TO WILD POPULATIONS

High Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Climate change may prove a serious threat to *Q. georgiana*, since the species is confined to intermittent "soil islands" on granite outcrops in the Piedmont, which have little connectivity to allow migration. Drought is also a threat, given the species' occurrence on very thin soils (50-100cm deep at some sites) that provide little access to groundwater. *Quercus georgiana* also displays many of the life history traits associated with vulnerability to climate change: limited dispersal ability, slow reproductive rates, specialized habitat requirements, and restricted distribution and rarity.[7,8]

Moderate Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: In the past, land use changes have posed a large threat to *Q. georgiana* habitat, but most areas suitable for agriculture or silviculture have already been cleared; this leaves wetter areas or roadside occurrences remaining (R. Lance pers. comm., 2017).[9]

Human use of landscape — residential/commercial development, mining, and/or roads: *Quercus georgiana* faces significant threat from human development of land and fragmentation (R. Lance pers. comm., 2017).

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Fire has been suppressed due to human habitation in the Pine Mountain Range of west-central Georgia, where it is a key component of the ecosystem.[10]

Genetic material loss — inbreeding and/or introgression: For occurrences with especially few individuals, genetic swamping and introgression from surrounding red oak (Sect. Lobatae) threaten the genetic integrity of *Q. georgiana* (R. Lance & R. Russell pers. comm., 2015). In addition, such small populations are likely to experience inbreeding; preliminary genetic data show moderate to moderately high inbreeding in some locations (S. Hoban pers. comm., 2018).

Pests and/or pathogens: Oak decline has been noted for *Q. georgiana*. This usually occurs when non-lethal stresses, such as drought and pests or pathogens, are combined to overwhelm the oaks' defenses.[11] Because *Q. georgiana* is a member of the red oak clade, it also has potential to be affected by oak wilt, Sudden oak death (SOD), and Goldspotted oak borer.[12,13,14] No serious damage has been reported to-date, though monitoring is necessary.

Low Impact Threats

Human use of landscape — tourism and/or recreation: Erosion, poor regeneration, and compacted soils resulting from foot and vehicle traffic are of concern, especially for the many occurrences within state parks and nature preserves; this is a particular threat at Stone Mountain, where plants grow alongside popular hiking trails (R. Lance pers. comm., 2017).

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	24
Number of plants in *ex situ* collections:	208
Average number of plants per institution:	9
Percent of *ex situ* plants of wild origin:	81%
Percent of wild origin plants with known locality:	93%

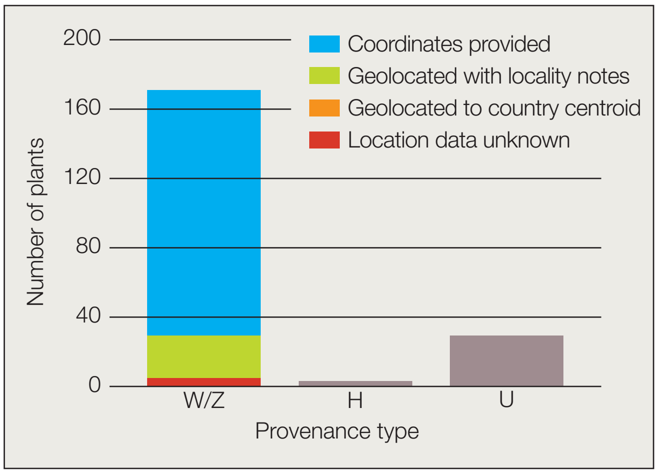


Figure 3. Number and origin of *Quercus georgiana* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

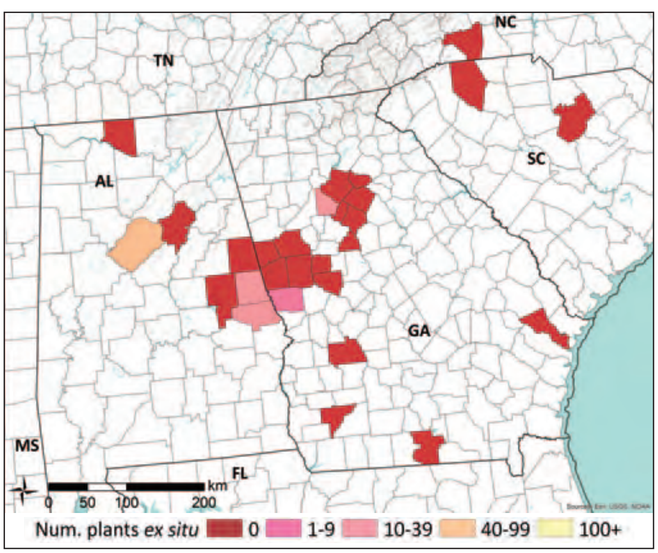


Figure 4. *Quercus georgiana* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	29%
Ecological coverage:	41%

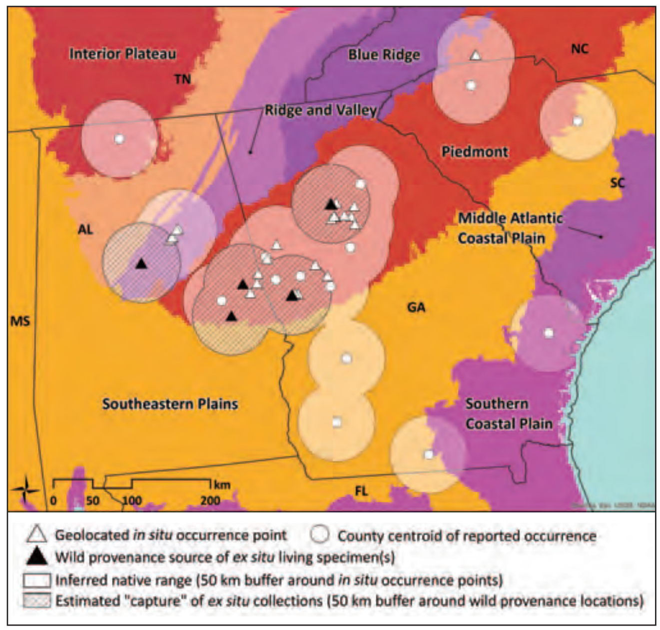


Figure 5. *Quercus georgiana in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level IV Ecoregions are colored and labelled.[15] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

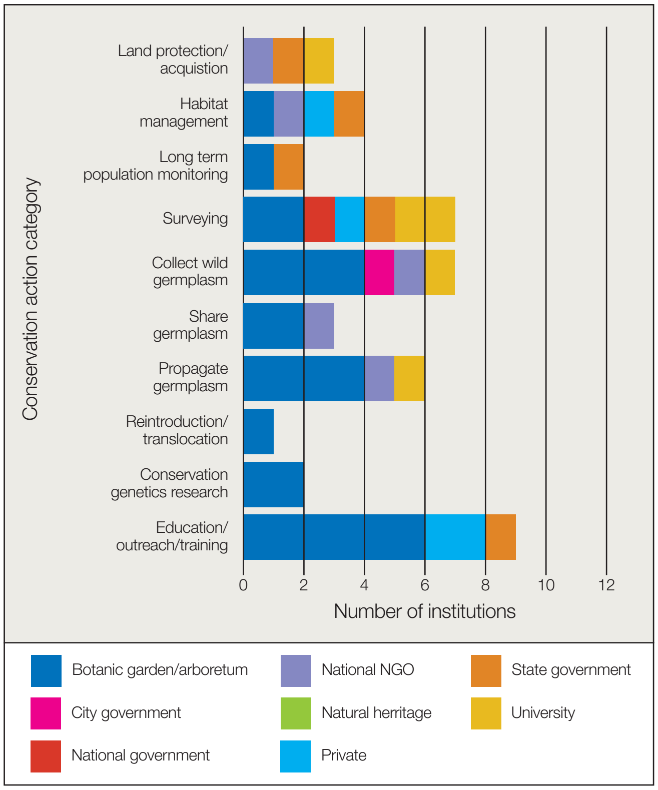


Figure 6. Number of institutions reporting conservation activities for *Quercus georgiana* grouped by organization type. Seventeen of 252 institutions reported activities focused on *Q. georgiana* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. georgiana,* 7% of the land is covered by protected areas (Figure 7). Many of the well-known populations of Georgia oak are located within protected areas, however populations outside these areas are largely undocumented and likely hold a majority of the species' distribution.

The Pine Mountain Region possesses a unique diversity of Appalachian and Coastal Plain plant species, and has therefore been proposed as a vital area for conservation. A wilderness area would be the first choice, but is infeasible because the majority of land in the region is privately owned. Exceptions include FDR State Park, Sprewell Bluff State Park, and Little White House Historic Site. Conservation easements with private landowners could be the best option for protecting this unique habitat.[10]

Sustainable management of land: Volunteers at Moss Rock Preserve worked to restore the understory by removing small invasive stems and raking a quarter-acre area; they plan to continue this work in the future.[16]

Population monitoring and/or occurrence surveys: The Morton Arboretum received funding for collection of *Q. georgiana* germplasm in 2018. Through this funding the Georgia Plant Conservation Alliance (GPCA) will conduct opportunistic population surveys at their study sites throughout the state. These potential population discoveries and information about the health of existing populations will guide further collecting efforts.[17]

Wild collecting and/or *ex situ* curation: The Morton Arboretum is leading a long-term initiative to establish a coordinated national network of *ex situ* conservation groves of *Q. georgiana* and other priority threatened oak species, to act as living germplasm banks. Partner institutions from across the country will collect, distribute, and grow large, genetically diverse collections of wild origin plants from across the range of the species. Through the support of a 2018 APGA-USFS Tree Gene Conservation Partnership grant, extensive field collection of *Q. georgiana* across Georgia and Alabama was completed in 2018 though collaboration with Chicago Botanic Garden, Huntington Library and Botanical Gardens, Atlanta Botanical Garden, and Donald E. Davis Arboretum at Auburn University. Additional germplasm was distributed to five other institutions (M. Westwood pers. comm., 2018).[17]

Propagation and/or breeding programs: As part of the above mentioned *ex situ* collections network, a primary goal of the conservation groves will be to provide source material for propagation and breeding (M. Westwood pers. comm., 2018).

Reintroduction, reinforcement, and/or translocation: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

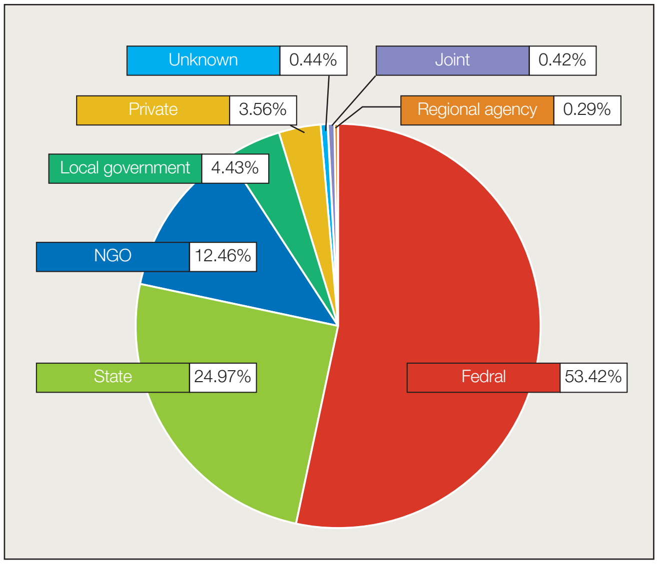


Figure 7. Management type of protected areas within the inferred native range of *Quercus georgiana*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[6]

Research: A research project is currently underway by scientists at The Morton Arboretum and Chicago Botanic Garden to examine the genetic diversity of *Q. georgiana*, both in natural stands and within cultivated collections, by comparing the genetics of *Q. georgiana* to several other oak species (S. Hoban pers. comm., 2018). This study builds upon a 2012 genetic analysis that sampled approximately 25 individual trees from each of nine locations in Georgia and Alabama. Occurrences of *Q. georgiana* were noted as small and geographically isolated, though evidence of gene flow and low genetic isolation between subpopulations was detected.[18] This suggests that subpopulations are not genetically isolated enough to be considered severely fragmented, or the apparent gene flow could be a relict of past interconnectedness while negative consequences of fragmentation may still remain to be seen.[17] Two subpopulations in Georgia were not sampled because trees were infrequent or not positively identifiable, indicating that these occurrences may be declining and/or suffering from introgression.[18]

Education, outreach, and/or training: The Georgia Forestry Commission's Sustainable Community Forestry Program has created the guidebook Recommended Community Tree Ordinance Tree Conservation Standards, which includes *Q. georgiana* as a good candidate for parking lot island trees.[19]

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

Natural populations in the wild remain under threat from numerous circumstances. Preserving Georgia oak's habitat is the best way to avoid extinction. The opportunity for further land protection should be considered where possible, including arrangements such as conservation easements. Maintaining awareness of management needs within these ecosystems will also be required. Because little land within *Q. georgiana's* distribution is protected, sustainable management of land will necessitate engagement of private landowners to provide education and training.

Increased census and survey work coupled with long-term monitoring will allow quantification of the effects of climate change on this species, and will be the key to informing future conservation work. *Quercus georgiana* has recently been shown to display more varied habitat preferences than previously described. While the implications of this are unclear, it is possible that further research into the species preferences could provide new parameters, which could be applied to habitat modeling. This could reveal an increased number of occurrences for the species. These data, as well as the genetic analyses completed by The Morton Arboretum and Chicago Botanic Garden, should also inform further *ex situ* collecting initiatives.

Small and isolated populations may benefit from augmentation via outplanting of propagated material. Research into success of outplantings will be useful to establish sustainable management practices for the species. Though populations are traditionally kept separate to maintain the purity of genetic distribution across the range, another research avenue could evaluate the fecundity of wild collected seed compared to seeds generated by assisted gene flow between populations. Integrating the species into the built landscape does offer another interesting option per The Georgia Forestry Commission's Sustainable Community Forestry Program's guidebook, though rotocols for propagation must be established first. The increasing need for practitioners of conservation horticulture is evidenced by the challenge of growing species like *Q. georgiana*, which are more finicky than other oaks in the nursery trade.

Conservation recommendations for *Quercus georgiana*

Highest Priority
- Education, outreach, and/or training
- Population monitoring and/or occurrence surveys
- Research (climate change modeling; demographic studies/ecological niche modeling; land management/disturbance regime needs; pests/pathogens; restoration protocols/guidelines)
- Sustainable management of land

Recommended
- Population monitoring and/or occurrence surveys
- Land protection
- Propagation and/or breeding programs
- Reintroduction, reinforcement, and/or translocation
- Wild collecting and/or *ex situ* curation

REFERENCES

1. **Schornherst, R. (1945).** Mosses of Stone Mountain, Georgia. *The Bryologist*, *48*(1), 29-33. doi:10.2307/3239320
2. **Duncan, R. S. (2013).** *Southern wonder: Alabama's surprising biodiversity*. Tuscaloosa, AL: University of Alabama Press.
3. **Wenzell, K., & Kenny, L. (2015).** *Quercus georgiana*. The IUCN Red List of Threatened Species 2015: e.T34011A2840268. Retrieved from http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T34011A2840268.en
4. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
5. **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
6. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
7. **Pacifici, M., Foden, W. B., Visconti, P., Watson, J. E. M., Butchart, S. H. M., Kovacs, K. M., Scheffers, B. R., Hole, D. G., Martin, T. G., Akçakaya, H. R., Corlett, R. T., Huntley, B., Bickford, D., Carr, J. A., Hoffmann, A. A., Midgley, G. F., Pearce-Kelly, P., Pearson, R. G., Williams, S. E., Willis, S. G., Young, B., & Rondinini, R. (2015, March).** Assessing species vulnerability to climate change. *Nature Climate Change*, 5, 215-225. doi:10.1038/nclimate2448
8. **Bendixsen, D. P., Hallgren, S. W., & Frazier, A. E. (2015).** Stress factors associated with forest decline in xeric oak forests of south-central United States. *Forest Ecology and Management*, *347*, 40-48. Retrieved from https://doi.org/10.1016/j.foreco.2015.03.015
9. **Haehnle, G. G., & Jones, S. M. (1985).** Geographical distribution of *Quercus oglethorpensis*. Castanea, 50(1), 26-31. Retrieved from https://www.jstor.org/stable/4033102
10. **Carter, R., & Floyd, R. (2013).** Landscape scale ecosystems of the Pine Mountain Range, Georgia. *Castanea, 78*(4), 231-255. doi:10.2179/13-012
11. **Thomas, F. M., Blank, R., & Hartmann, G. (2002).** Abiotic and biotic factors and their interactions as causes of oak decline in Central Europe. *Forest Pathology,* 32, 277-307. Retrieved from https://doi.org/10.1046/j.1439-0329.2002.00291.x
12. **Canadian Food Inspection Agency (2019).** *Bretziella fagacearum* (previously known as *Ceratocystis fagacearum* (Oak Wilt) - Fact Sheet. Retrieved from http://www.inspection.gc.ca/plants/plant-pests-invasive-species/diseases/oak-wilt/fact-sheet/eng/1325629194844/1325632464641
13. **Kluza, D. A., Vieglais, D. A., Andreasen, J. K., & Peterson, A. T. (2007).** Sudden oak death: geographic risk estimates and predictions of origins. *Plant Pathology*, 56(4), 580-587. doi:10.1111/j.1365-3059.2007.01602.x
14. **Colman, T. W., Jones, M. I., Smith, S. L., Venette, R. C., Flint, M. L., & Seybold, S. J. (2017).** Goldspotted Oak Borer. Forest Insect & Disease Leaflet 183. U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf
15. **U.S. EPA Office of Research & Development. (2013, April).** 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
16. **Duncan, R. S. (n.d.).** Biodiversity of Moss Rock. Retrieved from https://trekbirmingham.com/articles/moss-rock%E2%80%99s-biodiversity/
17. **Westwood, M., Lobdell, M., Thompson, P., Thibault, T., Douglas, P., & Coffey, E. (2017).** *APGA/USFS Tree Gene Conservation Partnership 2018 collecting trip proposal for* Quercus georgiana (Unpublished).
18. **Toppila, R. (2012).** *Ex situ conservation of oak* (Quercus L.) *in botanic gardens: A North American perspective* (Master's thesis). University of Delaware. Retrieved from http://dspace.udel.edu/bitstream/handle/19716/12054/Raakel_Toppila_thesis.pdf?sequence=1
19. **Georgia Forestry Commission. (n.d.).** *Recommended community tree ordinance tree conservation standards*. Sustainable Community Forestry Program. Retrieved from http://www.gatrees.org/resources/publications/RecommendedCommunityTreeOrdinanceTreeConservationStandards.pdf

Conservation Gap Analysis of Native

U.S. Oaks

Species profile: ***Quercus graciliformis***

Emily Beckman, Andrew McNeil-Marshall, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, ***Quercus graciliformis****, Quercus hinckleyi, Quercus robusta, Quercus tardifolia*

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus graciliformis C.H.Müll.

Synonyms: *Quercus canbyi* Cory & Parks, *Q. graciliformis* var. *parvilobata* C.H.Müller

Common Names: Graceful oak, Slender oak, Chisos oak

Species profile co-author: Andrew McNeil-Marshall, Lady Bird Johnson Wildflower Center, The University of Texas at Austin;
Shannon M. Still, UC Davis Arboretum and Public Garden

Suggested citation: Beckman, E., McNeil-Marshall, A., Still, S. M., Meyer, A., & Westwood, M. (2019). *Quercus graciliformis* C.H.Müll. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 116-121). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-graciliformis.pdf

DISTRIBUTION AND ECOLOGY

Occurrences of *Quercus graciliformis*, or Graceful oak, have only been verified in an extremely limited range within the Chisos Mountains of western Texas, U.S. Some reports of the species have been documented in the Mexican states of Coahuila, Nuevo Leon, and Tamaulipas, but consensus as to their identify as *Q. graciliformis* has not yet been reached by the botanic community.[1] It is possible Graceful oak also occurs in Chihuahua, Mexico, since there may be suitable habitat, but no extensive searches have yet been completed. Using only verified localities (points from the Chisos Mountains in Brewster County, Texas), *Q. graciliformis* occupies approximately 24 kilometers squared.[2] Past taxonomic confusion with *Q. canbyi* and *Q. gravesii* have also called into question the species' status, though most botanists now accept Graceful oak as a true species. However, some Mexican taxonomists still categorize *Q. graciliformis* as a synonym to *Q. canbyi*.[3] It is difficult to distinguish *Q. graciliformis* from *Q. canbyi*, but the former produces fruit that matures in two years, while the latter only requires one year for fruit maturation. For this report *Q. graciliformis* will be treated as a unique species due to important morphological differences and general agreement on taxonomic status, though more research is necessary. Graceful oak is a small, semi-evergreen tree, reaching eight meters tall, and is named for its skinny, arching branches. It grows in dry oak woodlands, which line the canyon floors of the Chisos Mountains (A. McNeil-Marshall pers. comm., 2016).

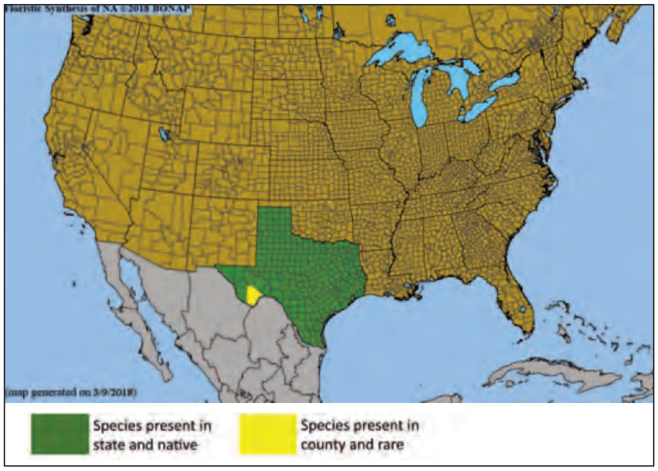


Figure 1. County-level distribution map for the U.S. distribution of *Quercus graciliformis*. Source: Biota of North America Program (BONAP).[4]

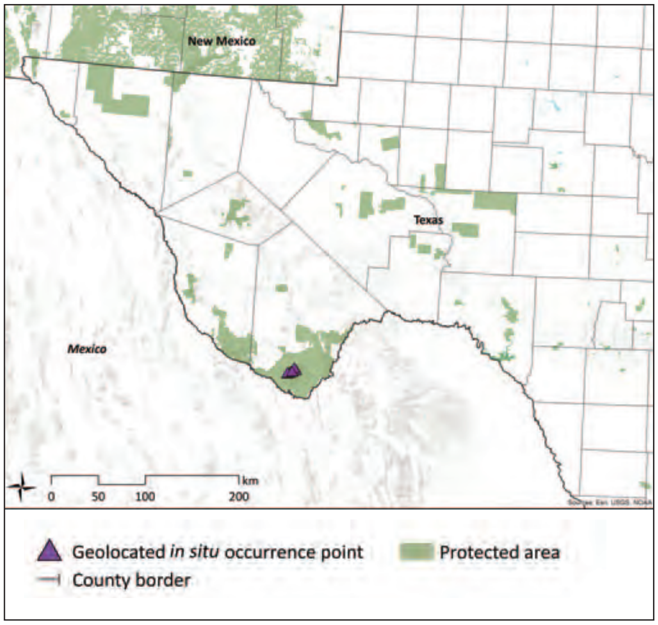


Figure 2. Documented *in situ* occurrence points for the U.S. distribution of *Quercus graciliformis*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus graciliformis*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	Score
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	20
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	40
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	0
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
Average vulnerability score							14.2
Rank relative to all U.S. oak species of concern (out of 19)							3

THREATS TO WILD POPULATIONS

High Impact Threats

Extremely small and/or restricted population: With *Q. graciliformis*' key subpopulation inhabiting one relatively narrow canyon, a single intense fire event could do extensive damage. It is thought that this species will resprout after fire like most oaks, but an intense burn would certainly be a severe threat to at least one generation (A. McNeil-Marshall pers. comm., 2016).

Moderate Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Changing climate could create conditions for extreme drought and fire (A. McNeil-Marshall pers. comm., 2016).

Genetic material loss — inbreeding and/or introgression: There are reports of *Q. graciliformis* hybridizing with *Q. emoyri,* but this does not seem to be an extensive threat currently.[6] The species is also unlikely to adapt under environmental change due to its very small population size.

Low Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: There is possible threat of residential water withdrawals lowering the high water table supporting this species, although this has not yet been recorded on the ground (A. McNeil-Marshall pers. comm., 2016).

Human use of landscape — tourism and/or recreation: Since the known population is entirely held within Big Bend National Park, the only direct anthropomorphic threat is recreational activities. This is not likely to severely damage the population, but Blue Creek Canyon Trail does cut through the most vibrant and well-known subpopulation.[7]

Human modification of natural systems — invasive species competition: Invasive plant species pose a significant threat to the unique and rare species within Big Bend National Park, but severe threat has not yet been witnessed for *Q. graciliformis*.[8]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 5).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	13
Number of plants in *ex situ* collections:	108
Average number of plants per institution:	8
Percent of *ex situ* plants of wild origin:	84%
Percent of wild origin plants with known locality:	100%

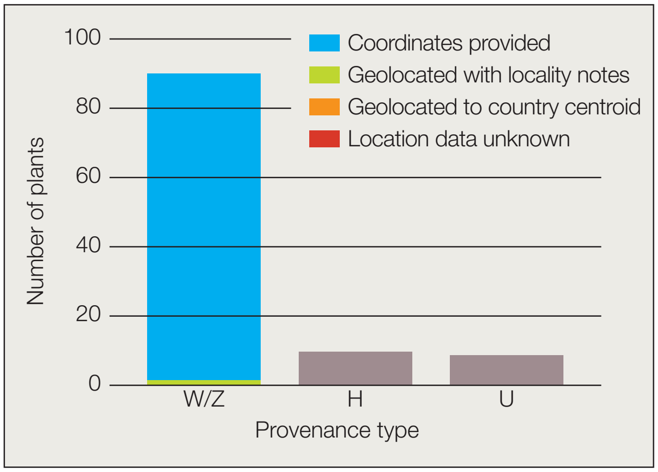


Figure 3. Number and origin of *Quercus graciliformis* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 4). Only the native U.S. distribution of the species was considered in this analysis, due to availability of ecoregion maps. Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	92%
Ecological coverage:	100%

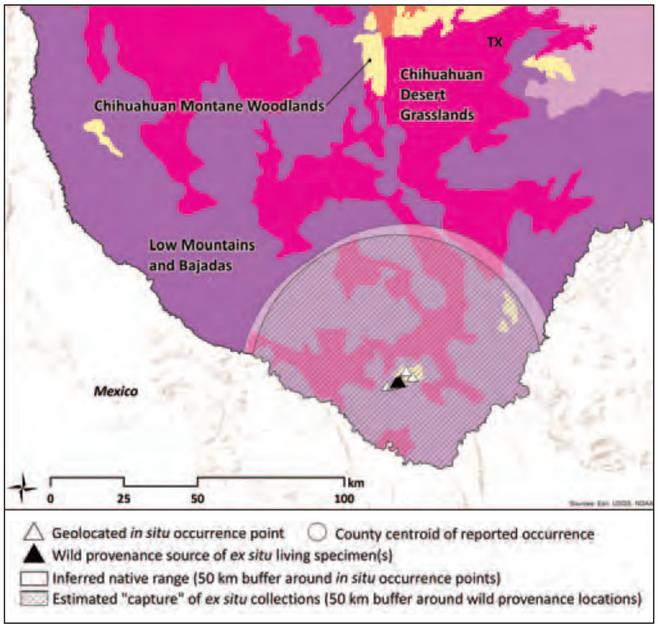


Figure 4. *Quercus graciliformis in situ* occurrence points and *ex situ* collection source localities within the United States. U.S. EPA Level III Ecoregions are colored and labelled.[9] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for more information regarding specific coordinates.

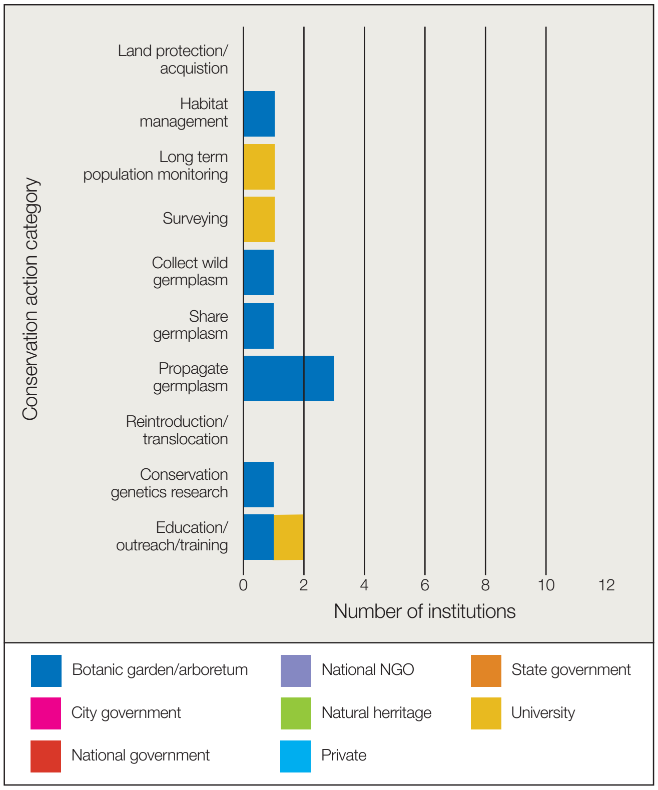


Figure 5. Number of institutions reporting conservation activities for *Quercus graciliformis* grouped by organization type. Seven of 252 institutions reported activities focused on *Q. graciliformis* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. graciliformis*, 65% of the land is covered by protected areas (Figure 6). However, because this species' distribution is small and well-documented, we know that 100% of the species' potential occurrences within the U.S. are protected within Big Bend National Park.

Sustainable management of land: Big Bend National Park's general management plan lays out park-wide goals, including restoration of native plant and animal populations damaged by past human disturbance, continuation of natural processes that support native plants and animals, and protection of genetic diversity of native plant and animal populations.[10] The Park's fire management plan gives a brief history of management as well as current actions. Surveys in the 1940s and 1960s found that fire should be reintroduced to the system, but "limited resources and cautious administrators led to continued suppression of most natural ignitions." A prescribed fire program was implemented in 1980 with the goal of protecting developments. This program has burned 2,080 acres in 25 years, and also lead to the realization that natural fires should be allowed to burn when possible "to reduce fuels and to burn where they occurred historically." Maps in the report show no occurrence of fire within the area containing *Q. graciliformis*.[11] This could be a good thing for the species, but the role of fire is not well understood for Graceful oak. The Texas Parks and Wildlife Department ecoregions handbook for the Chihuahuan Desert and Arizona-New Mexico Mountains outlines general trends and needs in the region as a whole, including Big Bend National Park, but there is no specific mention of *Q. graciliformis* outside the "Species of Greatest Conservation Need" list.[12]

Population monitoring and/or occurrence surveys: Within the general management plan for Big Bend National Park, *Q. graciliformis* has been found within a Project Area, but determined unlikely to be affected by proposed actions.[10] With support from APGA-USFS Tree Gene Conservation Partnership grants, UC Davis Arboretum & Public Garden visited the type locality of Graceful oak in 2016 and 2018. A lesser-known location was also visited in 2018, and the expedition believes to have located *Q. graciliformis* in an area that had not been verified in many years (S. Still pers. comm., 2018).[13]

Wild collecting and/or *ex situ* curation: Funded by the APGA-USFS Tree Gene Conservation Partnership and lead by UC Davis Arboretum & Public Garden, a 2016 expedition collected more than 400 *Q. graciliformis* acorns total, with 30 to 60 acorns from each individual located.[13] UC Davis Arboretum & Public Garden also collected ten acorns in 2017, which they shared with two other gardens for *ex situ* preservation. The APGA-USFS Tree Gene Conservation Program supported another collecting expedition in 2018, which gathered what participants believe to be *Q. graciliformis* acorns from a location that is not yet represented in *ex situ* collections (S. Still pers comm., 2018).

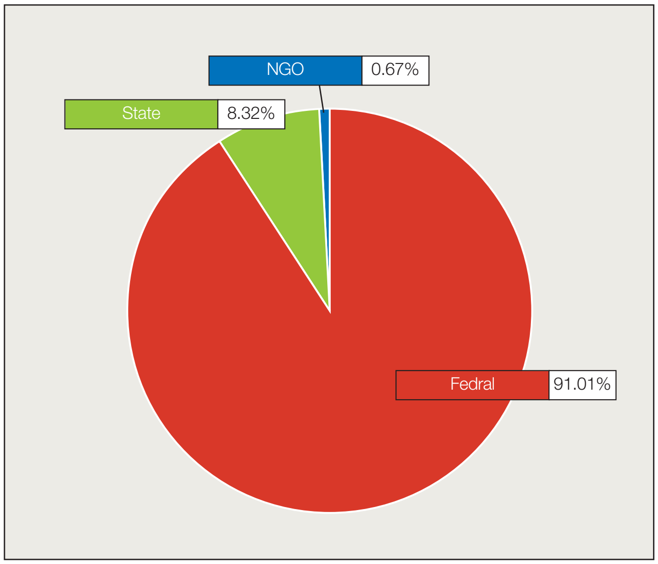


Figure 6. Management type of protected areas within the inferred native range of *Quercus graciliformis*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]


Shannon Still

Propagation and/or breeding programs: Acorns from the 2016 collecting trip were distributed for propagation at four partner institutions: Lady Bird Johnson Wildflower Center, Chihuahuan Desert Botanical Garden and Nature Center, Boyce Thompson Arboretum, and Bartlett Tree Research Laboratories and Arboretum.[13] Acorns collected in 2017 are in propagation at UC Davis Arboretum, The Morton Arboretum, and Boyce Thompson Arboretum, for planting within *ex situ* collections. The 2018 trip also collected acorns, which are in propagation (S. Still pers. comm., 2018).

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: One institution reported conservation genetics research in the conservation action questionnaire, but no other details are currently known.

Education, outreach, and/or training: Two institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Species protection policies: In addition to listing species as endangered or threatened, Texas maintains a list of more than 1,300 Species of Greatest Conservation Need (SGCN). These species are "declining or rare and in need of attention to recover or to prevent the need to list under state or federal regulation…[and are] the focus of Texas Parks and Wildlife Department's Texas Conservation Action Plan," but are not provided the same protections as endangered or threatened species. *Quercus graciliformis* is listed as a SGCN.[14]

PRIORITY CONSERVATION ACTIONS

It would seem that Graceful oak is in a position to be well conserved in its current location within Big Bend National Park. More survey work should be done in the Chisos Mountains to locate and study other populations. A lesser-known location was visited in 2018 and the expedition believes to have located *Q. graciliformis* in a population that had not been verified in many years. If this is indeed a population of *Q. graciliformis*, it is not nearly as morphologically uniform as the Blue Creek Canyon population, displaying a wider range of leaf size and overall plant size and habit. The population at Blue Creek Canyon should also be surveyed to better understand the extent of its area and number of individuals. These data will help determine if this population is static or dynamic in growth. It will be important to have a baseline of information for this species to see how changes in climate affect its range and habitat. Reinforcement and/or translocation should be considered to prevent a single extreme event from wiping out all populations, and could be urgent if populations are determined to be shrinking.

Due to recent *ex situ* collecting efforts, all known populations are now represented in living collections. Further scouting and possible genetic analysis to identify other populations should be accompanied by representation of those locations in *ex situ* collections. Continued study is warranted to illuminate the nature of genetic crossing and the role this plays in species survival in what is essentially an isolated ecosystem. *Quercus graciliformis* should also be further promoted as a unique Texas-endemic native plant. Overall more interest should be cultivated in the oaks of the floristically unique Chisos Mountains and Big Bend region, which houses many flora facing various levels of imperilment.

Conservation recommendations for *Quercus graciliformis*

Highest Priority
- Population monitoring and/or occurrence surveys
- Reintroduction, reinforcement, and/or translocation

Recommended
- Population monitoring and/or occurrence surveys
- Education, outreach, and/or training
- Propagation and/or breeding programs
- Research (climate change modeling; demographic studies/ecological niche modeling; population genetics; restoration protocols/guidelines; taxonomy/phylogenetics)
- Wild collecting and/or *ex situ* curation

REFERENCES

1. **Hélardot, J. L. (2018).** Oaks of the world. Retrieved from http://oaks.of.the.world.free.fr/index.htm
2. **Beckman, E. (2017).** *Quercus graciliformis*. The IUCN Red List of Threatened Species 2017: e.T30954A63729730. Retrieved from http://dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T30954A63729730.en
3. **Romero-Rangel, S. (2006).** Revisión taxonómica del complejo Acutifoliae de *Quercus* (*Fagaceae*) con énfasis en su representación en México. *Acta Botanica Mexicana*, 76, 1-45. doi:10.21829/abm76.2006.1016
4. **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
5. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
6. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
7. **NatureServe. (2017).** NatureServe Explorer: An online encyclopedia of life [online]. Version 7.1. Arlington, VA. Retrieved from http://explorer.natureserve.org.
8. **National Park Service. (2016).** *Foundation document, Big Bend National Park*. TX: U.S. Department of the Interior. Retrieved from http://www.npshistory.com/publications/foundation-documents/bibe-fd-2016.pdf
9. **U.S. EPA Office of Research & Development. (2013, April).** 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
10. **National Park Service. (2004).** *Final general management plan / environmental impact statement Big Bend National Park*. Brewster County, TX: United States Department of the Interior.
11. **Big Bend National Park. (2005).** *Big Bend National Park Texas: Wildland fire management plan*. TX: United States Department of the Interior, National Park Service.
12. **Texas Parks and Wildlife Department. (2012).** *Texas conservation action plan: Chihuahuan Desert and Arizona-New Mexico mountains ecoregions handbook*. Connally, W. (Ed.). Austin, TX. Retrieved from https://tpwd.texas.gov/landwater/land/tcap/documents/chih_tcap_2012.pdf
13. **Still, S., Griswold, E., & McNeil-Marshall, A. (2016).** *Scouting and collection trips for Trans-Pecos Quercus germplasm: APGA-USFS Tree Gene Conservation Partnerships.* Retrieved from https://www.publicgardens.org/file/2016-trans-pecosoaksreportpdf
14. **Texas Parks and Wildlife Department. (2013).** Species of greatest conservation need. Retrieved from https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/tcap/sgcn.phtml

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus havardii***

Emily Beckman, Sean Hoban, Ross McCauley, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, *Quercus laceyi*

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus havardii Rydb.

Synonyms: N/A **Common Names:** Harvard oak, Shinnery oak

Species profile co-author: Sean Hoban, The Morton Arboretum; Ross McCauley, Department of Biology, Fort Lewis College

Suggested citation: Beckman, E., Hoban, S., McCauley, R., Meyer, A., & Westwood, M. (2019). *Quercus havardii* Rydb. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 122-127). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-havardii.pdf

DISTRIBUTION AND ECOLOGY

Quercus havardii, or Harvard oak, occurs in the southwestern U.S., including sites in southeastern New Mexico, northern and western Texas, western Oklahoma, as well as a disjunct series of populations in northern Arizona, southern Utah and minimally in Colorado and northern New Mexico. Harvard oak historically occupied five to seven million acres of the Southern Great Plains: one million acres in Oklahoma, 1.5 million acres in New Mexico, and 3.5 million acres in Texas.[1] This small oak defines Sand Shinnery communities and is the major shrub species compromising plains-mesa sand scrub vegetation in southeastern New Mexico; it thrives in deep sandy soils, including sand dunes.[2] Harvard oak occurs primarily underground, with only one-tenth of the plant (0.6 to 0.8 meters) above ground and roots extending five to six meters below ground. This extensive underground network is vital to the health of the ecological community, due to its stabilizing effects on sand.[3]

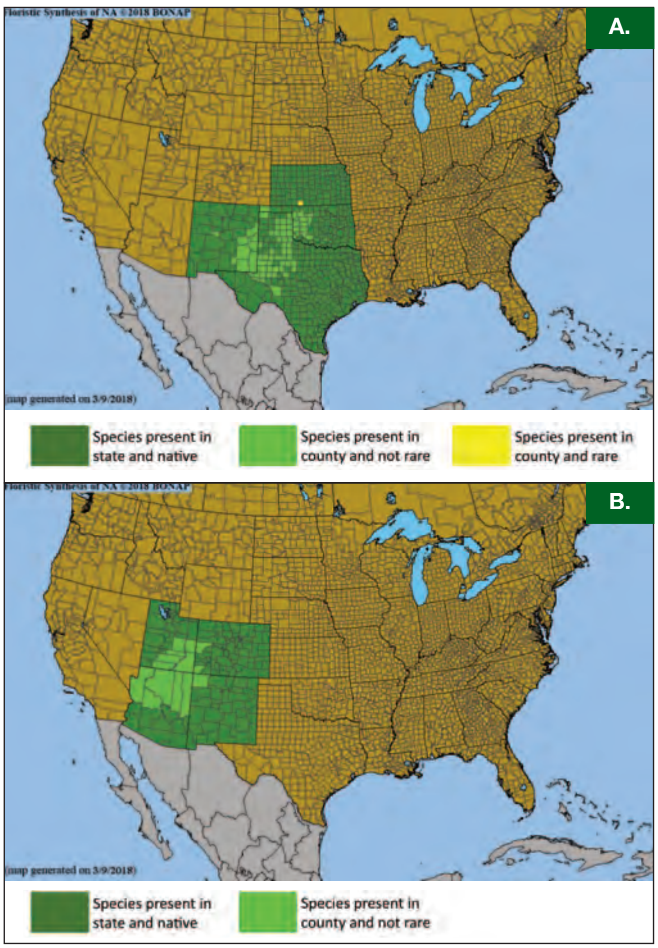


Figure 1. County-level distribution map for **A)** *Quercus havardii* and **B)** *Quercus welshii*. Source: Biota of North America Program (BONAP).[8]

Across its distribution, *Q. havardii* is generally classified as a single species. However, segregation of its disjunct western distribution (*Q. havardii* var. *tuckeri*) as a separate species has been proposed by several authors who label it *Q. welshii*.[4,5,6] Preliminary work focused on oaks of the Four Corners region suggests that *Q. havardii* is distinct in that area, and additional work is underway to address this question at the full range level (S. Hoban & R. McCauley pers. comm., 2017).[7] Without further evidence of species segregation and the similarity in ecological functioning, for the purpose of this report *Q. havardii* is recognized in its broad interpretation as one species with a disjunct distribution.

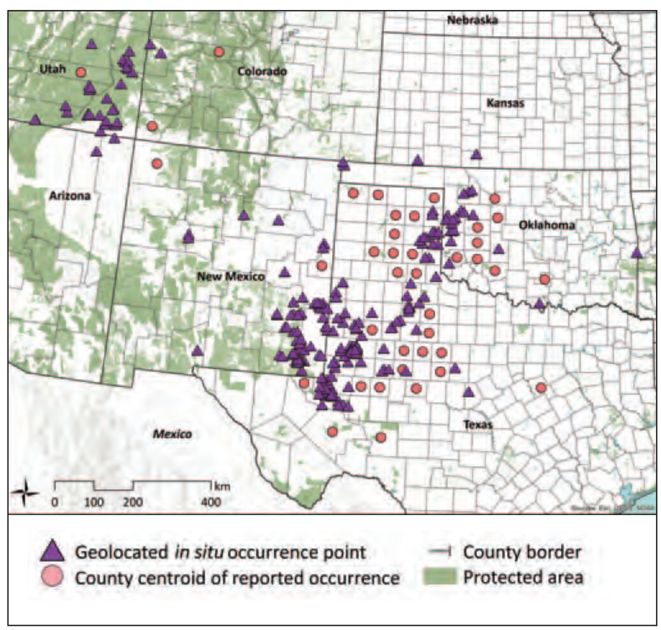


Figure 2. Documented *in situ* occurrence points for *Quercus havardii*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[9]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus havardii*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	0
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	10
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	10
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	5
						Average vulnerability score	5.8
						Rank relative to all U.S. oak species of concern (out of 19)	14

THREATS TO WILD POPULATIONS

High Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: Agriculture has resulted in extensive habitat alteration within *Q. havardii* communities, including soil compaction, decreased stability of microclimates, introduction of invasive plants, loss of habitat, extractive use of groundwater, and fragmentation of the ecosystem.[10]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: *Quercus havardii* inhabits areas that are highly arid, and it is unknown whether the species can adapt to projected increases of aridity. The western portion of the range is projected to dry which may lead to major changes in distribution and abundance of *Q. havardii* (R. McCauley pers. comm., 2018). It already seems as though conditions are too dry to allow for successful regeneration (S. Hoban pers. comm., 2018).

Moderate Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: Habitat loss and fragmentation of Sand Shinnery communities is a concern due to dramatically expanding roads and pipelines for oil and gas development. This is exacerbated by the fragility of *Q. havardii* habitat. Since fragmentation destabilizes sand dunes.[10] Once Havard oak is removed from a location, its recolonization is slow, though it can show vigorous resprouting if some plants do remain (S. Hoban pers. comm., 2018).

Human use of landscape — tourism and/or recreation: Damage from off-road vehicles has been observed in multiple locations, though the extent of damage throughout the species range is not currently known (S. Hoban pers. comm., 2018).

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: *Quercus havardii* is poisonous to livestock during the spring and competes with grass and forbs for water and nutrients; this is often detrimental to ranching operations. Herbicides such as Tebuthiuron are used to eradicate Harvard oak. In 1998 it was reported that 100,000 acres of Harvard oak habitat were targeted for treatment in New Mexico, and 320,000 in Texas. These are likely underestimates, since most of Harvard oak exists on private land.[1]

Low Impact Threats

Genetic material loss — inbreeding and/or introgression: Introgression of *Q. havardii* with other oaks has been observed in multiple locations. Suspected hybrid populations occur with *Q. gambelii* and *Q. turbinella* in Harvard oak's western range, and with *Q. stellata* in the East, (R. McCauley pers. comm., 2018). Genetic analyses show that the species has moderate to moderate-low levels of heterozygosity overall. Some populations may also be moderately or highly inbred, potentially impeding future reproduction. The species does occur across a very wide environmental gradient, which suggests that there may be enough genetic variation for adaptation. Some populations remain quite large, with hundreds of individuals (S. Hoban pers. comm., 2018).

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	12
Number of plants in *ex situ* collections:	417
Average number of plants per institution:	35
Percent of *ex situ* plants of wild origin:	98%
Percent of wild origin plants with known locality:	93%

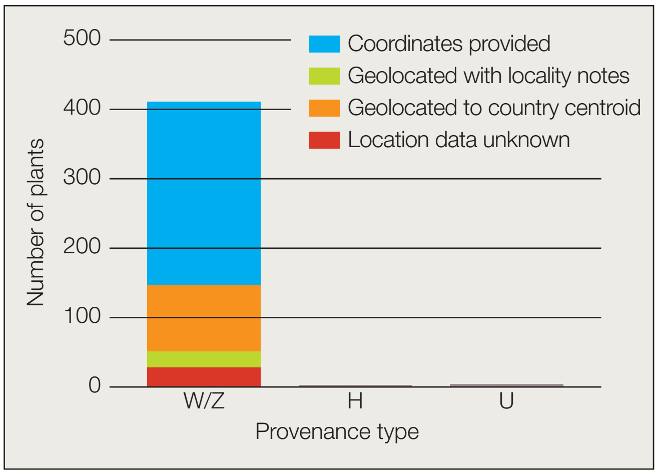


Figure 3. Number and origin of *Quercus havardii* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

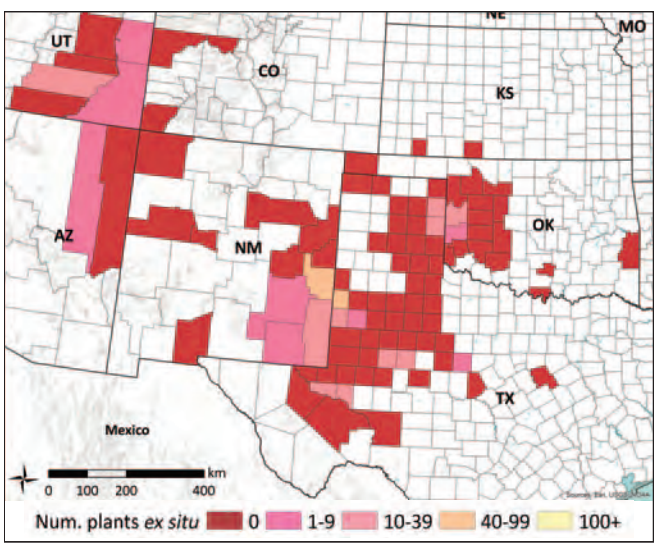


Figure 4. *Quercus havardii* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	26%
Ecological coverage:	39%

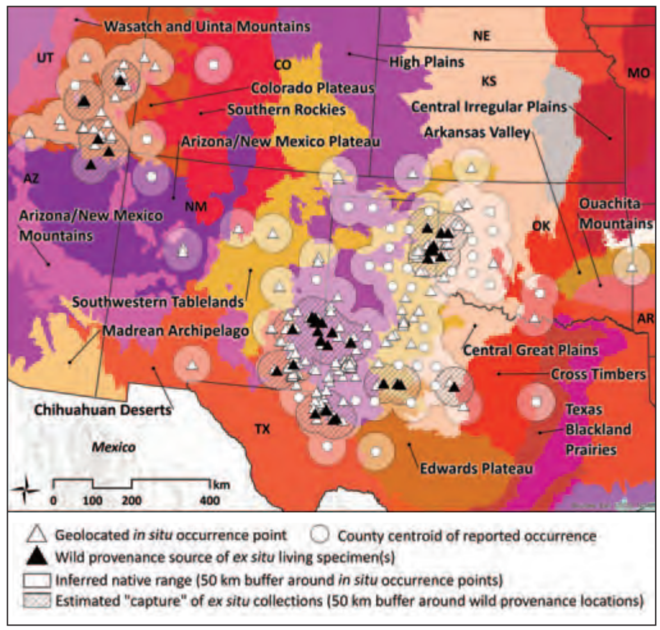


Figure 5. *Quercus havardii in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[11] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

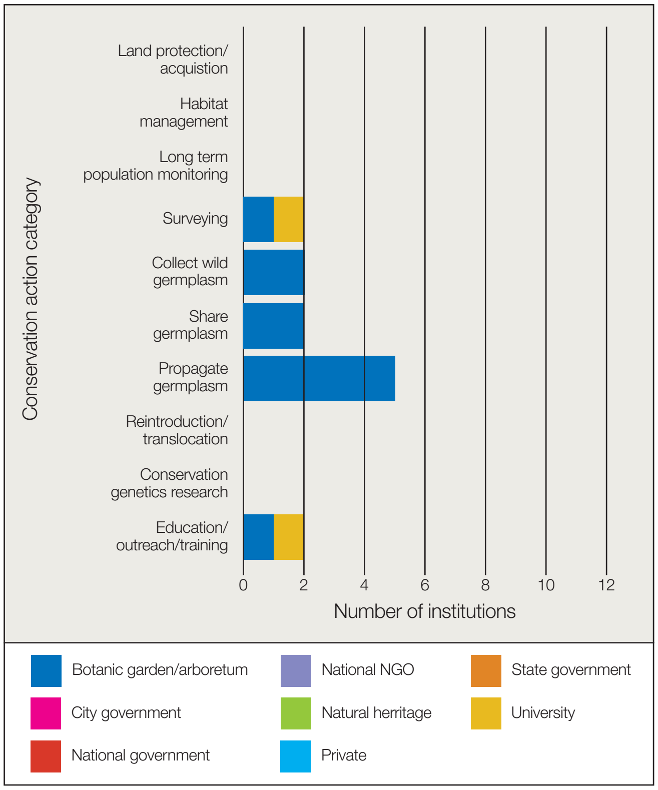


Figure 6. Number of institutions reporting conservation activities for *Quercus havardii* grouped by organization type. Seven of 252 institutions reported activities focused on *Q. havardii* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. havardii*, 30% of the land is covered by protected areas (Figure 7). Most of Harvard oak habitat in the eastern half of its range is on private lands, while much of the land in its western distribution is protected.

In the eastern portion of Harvard oak's range where most land is private, there are still a few noteworthy protected areas harboring the species. These include Black Kettle National Grassland (13,000 acres) and Packsaddle Wildlife Management Area (16,000 acres) in Oklahoma, as well as some areas in New Mexico. At the end of the 20th century New Mexico was estimated to have 1,200,000 acres of *Q. havardii* habitat managed by Bureau of Land Management (BLM), 500,000 acres covered by state trusts, and 21,000 acres managed by the New Mexico Department of Game and Fish.[1]

The majority of Harvard oak's western distribution is located on BLM or Navajo Nation lands. Additional populations occur on U.S. government lands including Arches National Park, Canyonlands National Park, Grand Staircase-Escalante National Monument, and Bears Ears National Monument. Close to 100% of the range in the West is on protected or public land. Some of these lands may be subject to disturbance from natural resource extraction, but this is likely minimal. Navajo Nation lands support most of the western *Q. havardii* populations, where land use is quite stable (S. Hoban & R. McCauley pers. comm., 2018).

Sustainable management of land: Some *Q. havardii* habitat is undergoing successful land management, as exemplified by the Lesser Prairie Chicken, a rare bird relying upon an ecosystem stabilized by Harvard oak. "In 2014, the Lesser Prairie Chicken was listed as Threatened under the Endangered Species Act; however, in 2016 a Texas judge ruled that this designation had been errant because voluntary conservation efforts had not been taken into account during the initial decision. Although some activists are against this decision, others believe it validates the work of public-private conservation partnerships in protecting the species."[12] Another at-risk wildlife species, the 'Mescalero Sands' White-tailed deer, is likely increasing the appropriate management of *Q. havardii* habitat, as "multiple land management agencies, conservation organizations and landowners are now coordinating a plan to balance the needs of the ecosystem with human use of the land."[13]

Population monitoring and/or occurrence surveys: Two institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Wild collecting and/or *ex situ* curation: With funding from a 2016 APGA-USFS Tree Gene Conservation Program grant, Sean Hoban of The Morton Arboretum drove 2,000 miles across the western U.S. to visit 36 populations of Harvard oak and collect 1,700 acorns, which were then distributed to ten institutions across the country. Partner institutions for the collecting expedition included Fort Lewis College Herbarium, Texas Arboretum & LBJ Wildflower Center, Trees That Please Nursery, University of Colorado, and Texas Tech University. Although germination rates were high from this collection, seedling mortality was also high in greenhouse containers at several institutions, with unknown cause (S. Hoban pers. comm., 2018).[14,15]

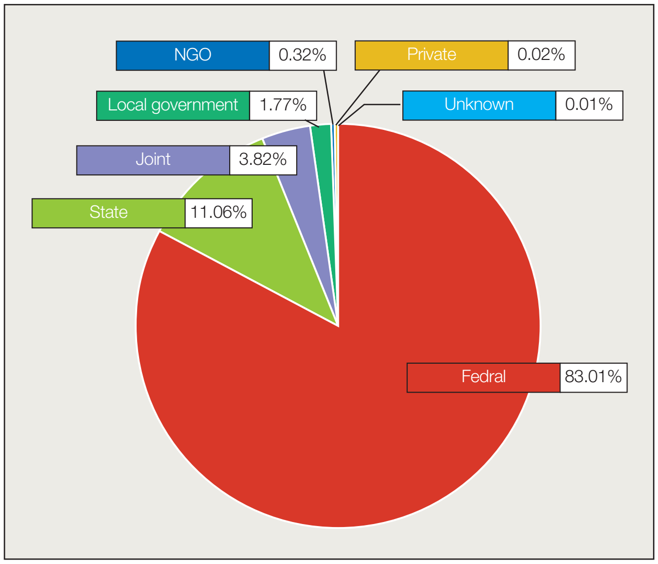


Figure 7. Management type of protected areas within the inferred native range of *Quercus havardii*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[9]

Sean Hoban

Propagation and/or breeding programs: With funding from the APGA-USFS Tree Gene Conservation Program, The Morton Arboretum and partner institutes have been propagating *Q. havardii* for placement of these specimens among their living collections. Before this conservation collection trip, Harvard oak was only present in one public garden (S. Hoban pers. comm., 2017).[14,15]

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: Davis (2013) found that current *Q. havardii* habitat restoration techniques are not sufficient, including activities such as removing oilfield infrastructure with the hope that the species will repopulate the area. The study proposes the use of Harvard oak rhizomes as a propagation source in the reestablishment of the species within disturbed areas, and found some success within trials. This is a technique that must be further researched, and could then be applied to areas of historic *Q. havardii* range that have been altered by ranchers and oilfields.[10] Hoban, McCauley, and colleagues are currently researching conservation genetic concerns for this species (S. Hoban pers. comm., 2018).

Education, outreach, and/or training: The *Q. havardii* ecosystem has gathered attention due to its unique wildlife, including the Dunes sagebrush lizard (Sceloporus arenicolus), which is only found in Harvard oak habitat and is listed as Vulnerable on the IUCN Red List.[16] The Lesser Prairie Chicken and 'Mescalero Sands' White-tailed deer have also received public attention.[17] With funding from the APGA-USFS Tree Gene Conservation Program in 2016, wild-collected *Q. havardii* acorns were placed in propagation, with the intention of display for public education (S. Hoban pers. comm., 2017).

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

Harvard Oak continues to be threatened by expanding agriculture and natural gas development, increasing aridity, lowering of the water table, and off-road vehicle use. Though, increased public recognition of this species' role in the ecosystem is a positive sign. Further actions should include continued outreach to the public regarding the importance of these communities, to encourage greater stewardship and consideration in development plans. Signage could be helpful in locations of high off-road vehicle use. Across the species range, conservation of lands is much greater in the West, therefore efforts should focus on Harvard oak communities in the eastern portion.

In addition to continued conservation of current communities, reintroduction and assisted migration should be considered. Range shifts caused by a changing climate are real for this species particularly due to changes in rainfall patterns. Initially, work should aim to generate predictive niche models in light of varying climate change scenarios. Using these models, Shinnery communities with the greatest chance to survive changes should be prioritized for restoration. Later, localities currently marginal for Shinnery communities but which show good potential for persistence in the future can be identified, and individuals with suitable genotypes could be introduced. In the western part of the range and on range edges in the East, very small and isolated populations could benefit from reinforcement. Reintroduction and assisted migration activities will also hinge on developing an understanding of Harvard oak's reproductive system, including information on seed viability, seedling survival rates under different conditions, and rhizome propagation.

The 2016 seed collection, supported by the APGA-USFS Tree Gene Conservation Partnership and lead by The Morton Arboretum, has increased the number of institutions safeguarding *Q. havardii* in *ex situ* collections. However, several institutions lost a high percentage of seedlings. Research may be needed into appropriate greenhouse care and long-term care of the species in a garden, especially in locations outside its natural range. Seed from the western part of the range was much less abundant, and therefore future seed collections may be needed from the western range. Finally, monitoring will be useful in small populations to confirm their stability.

Conservation recommendations for *Quercus havardii*

Highest Priority
- Education, outreach, and/or training
- Land protection
- Research (climate change modeling; reproductive biology/regeneration; restoration protocols/guidelines; taxonomy/phylogenetics)

Recommended
- Population monitoring and/or occurrence surveys
- Reintroduction, reinforcement, and/or translocation
- Sustainable management of land
- Wild collecting and/or *ex situ* curation

REFERENCES

1. **Peterson, R. S., & Boyd, C. S. (1998).** Ecology and management of sand shinnery communities: A literature review (Gen. Tech. Rep. RMRS-GTR-16). Fort Collins, CO: Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/treesearch/pubs/6048
2. **Dhillion, S. S., & Mills, M. H. (1999).** The Sand shinnery oak (*Quercus havardii*) communities of the Llano Estacado: History, structure, ecology, and restoration. In *Savannas, barrens and rock outcrop plant communities of North America* (pp. 262-274). Cambridge, UK: Cambridge University Press.
3. **U.S. Fish and Wildlife Service. (2012).** Endangered and threatened wildlife and plants: Withdrawal of the proposed rule to list Dunes sagebrush lizard. *Federal Register*, *77*, 36871-36899.
4. **Tucker, J. M. (1970).** Studies in the *Quercus undulata* complex. IV. The contribution of *Q. havardii. American Journal of Botany*, *57*, 71-84. doi:10.1002/j.1537-2197.1970.tb09792.x
5. **Welsh, S. L. (2003).** *Quercus welshii* R. A. Denham. A Utah Flora, 3, 317.
6. **Welsh, S. L. (1986).** *Q. havardii* var. *tuckeri*. *Great Basin Naturalist, 46*, 109.
7. **McCauley, R., Christie, B., Ireland, E., Landers, R., Nichols, H., & Schendel, M. (2012).** Influence of relictual species on the morphology of hybridizing oak complex: An analysis of the *Quercus x undulata* complex in the four corners region. *Western North American Naturalist*, 72(3), 296-310. Retrieved from https://doi.org/10.3398/064.072.0304
8. **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
9. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
10. **Davis, W. J. (2013).** *Shin-oak* (Quercus havardii, *Rydb.; Fagaceae*) *rhizome shoot production: possibilities for use in restoration*. Lubbock, TX: Wildlife, Aquatic, and Wildland Science and Management, Texas Tech University. Retrieved from http://hdl.handle.net/2346/58482
11. **U.S. EPA Office of Research & Development. (2013, April).** 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
12. **Lammi, G. G. (2016, August 1).** Regulators' delisting of Lesser prairie chicken a win, and a test, for voluntary conservation. *Forbes*. Retrieved from https://www.forbes.com/sites/wlf/2016/08/01/regulators-delisting-of-lesser-prairie-chicken-a-win-and-a-test-for-voluntary-conservation/#45121d5a7e52
13. **New Mexico Game and Fish. (n.d.).** Wildlife notes: Sand dune lizard. Retrieved from http://www.wildlife.state.nm.us/download/education/conservation/wildlife-notes/amphibians-reptiles/sand-dune-lizard.pdf
14. **Hoban, S., & Duckett, D. (2016).** *APGA/USFS Tree Gene Conservation Partnership: Report on scouting and collection efforts targeting* Quercus havardii. Lisle, IL: The Morton Arboretum. Retrieved from https://www.publicgardens.org/sites/default/files/2016%20Quercus_havardii_Final_w_permits.pdf
15. **American Public Gardens Association. (n.d.).** Tree Gene Conservation Partnership Showcase.
16. **Ryberg, W. A., Hill, M. T., Painter, C. W., & Fitzgerald, L. A. (2014).** Linking irreplaceable landforms in a self-organizing landscape to sensitivity of population vital rates for an ecological specialist. *Conservation Biology*, *29*(3), 888-898. doi:10.1111/cobi.12429
17. **Grisham, B. A., Zavaleta, J. C., Behney, A. C., Borsdorf, P. K., Lucia, D. R., Boal, C. W., & Haukos, D. A. (2016).** Ecology and conservation of Lesser prairie-chickens in sand shinnery oak prairies. In *Ecology and conservation of Lesser prairie-chickens* (pp. 315-344). CRC press.

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus hinckleyi***

Emily Beckman, Janet Rizner Backs, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, ***Quercus hinckleyi****, Quercus robusta, Quercus tardifolia*

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U S DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus hinckleyi C.H.Müll.

Synonyms: N/A **Common Names:** Hinckley's oak

Species profile co-author: Janet Rizner Backs, Department of Biological Sciences, University of Illinois at Chicago

Suggested citation: Beckman, E., Rizner Backs, J., Meyer, A., & Westwood, M. (2019). *Quercus hinckleyi* C.H.Müll. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 128-133). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-hinckleyi.pdf

DISTRIBUTION AND ECOLOGY

In the late Wisconsin or early Holocene period, *Quercus hinckleyi*, or Hinckley's oak, was widespread across the more mesic region that we now call the Chihuahuan Desert in western Texas, U.S., and north-central Mexico. Today, over 10,000 years later, this scrub oak exists in a few suitable patches within Presidio County, Texas. *Quercus hinckleyi* has become restricted and isolated as the area's climate moves in an increasingly xeric direction. There remains a chance that pockets of this species still exist within the northern Mexican states of Coahuila and Chihuahua, but no current confirmation exists. Hinckley's oak can be found in the northeastern part of Big Bend Ranch State Park as well as near the town of Shafter, Texas, just northwest of the state park's limits. The distance between these two main sites is about 60 kilometers. Hinckley's oak is found in a dry, subtropical landscape on limestone and sandstone slopes between about 1,000 and 1,400 meters above sea level. It grows as a shrub less than one meter tall and usually forms dense bunches with thick, grey-green leaves that possess a holly-like form. Although this species can reproduce both clonally and sexually, clonal reproduction is much more prevalent. Growth rings on individual aerial stems have been found to show a seven to nine year lifespan. However, the clonal bunches themselves cannot be dated and are simply known to be much older than above-ground individuals, perhaps by thousands of years.[1,2]

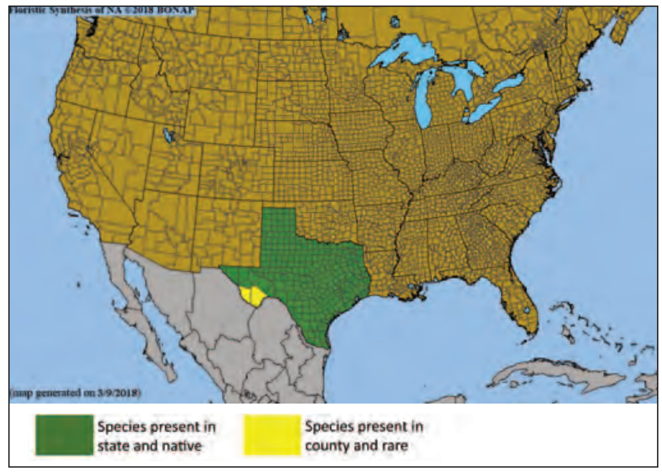


Figure 1. County-level distribution map for *Quercus hinckleyi*. Source: Biota of North America Program (BONAP).[3]

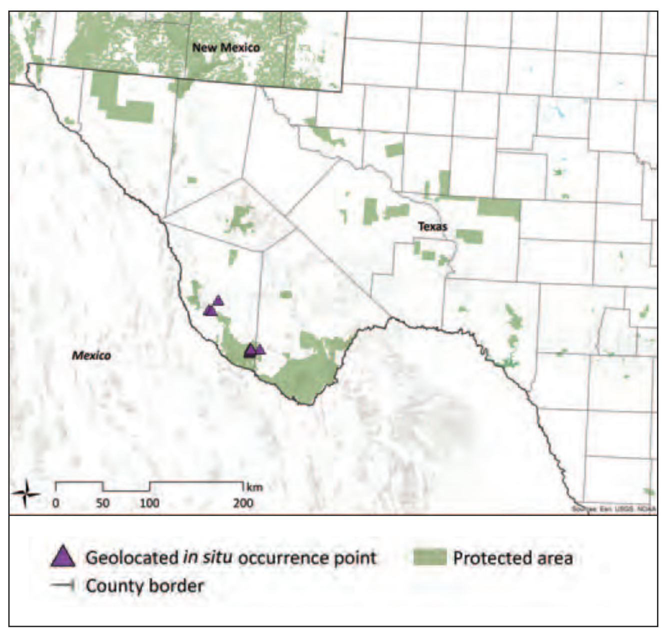


Figure 2. Documented *in situ* occurrence points for *Quercus hinckleyi*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus hinckleyi*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	20
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	20
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
Average vulnerability score							14.2
Rank relative to all U.S. oak species of concern (out of 19)							3

THREATS TO WILD POPULATIONS

High Impact Threats

Extremely small and/or restricted population: There are multiple concerns regarding the small, fragmented range of Hinckley's oak, which magnify through time if not addressed.[1]

Moderate Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: It is also possible that land development has caused changes to the environment that hinder the ability of *Q. hinckleyi* to successfully reproduce sexually and recruit saplings.[1] The smaller of the species' two populations, the Shafter site, is within the path of a proposed pipeline (J. Backs pers. comm., 2018).

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: As the climate shifts and landscapes change, *Q. hinckleyi* may have a difficult time adapting, mostly due to its small population size and small amount of sexual regeneration. Although some acorns were found at the larger sites within Big Bend Ranch State Park and there appears to be evidence of recruitment, there is no current evidence of recruitment at the smaller Shafter site. Clonal reproduction prevents continued diversification of genotypes, as well as the species' ability to populate new areas by the natural transportation of acorns. These are both important factors in determining the persistence of species as the climate shifts and landscapes change.[1]

Genetic material loss — inbreeding and/or introgression: Genetic threats should be considered for the smaller of the two subpopulations because the current reproduction method is overwhelmingly clonal; this stunts diversification of genotypes and population of new areas. Too few individuals cannot respond positively to natural selection. It has also been observed that as clones increase in size, flowers become surrounded with more of the same genetic entity and therefore may produce less viable seed.[1] Hybridization with *Q. pungens* and *Q. vaseyana* could also be a possible future threat, but does not seem to be extensive at this time and genetic swamping has not occurred.[5] Recent research also indicates that the effects of hybridization can sometimes be positive rather than negative, so more investigation is needed in this area.[6]

Low Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: It is possible that ranching activities in the area have caused habitat degradation, which hinders the ability of *Q. hinckleyi* to successfully reproduce sexually and recruit saplings.

Human use of landscape — tourism and/or recreation: Within Big Bend Ranch State Park, recreation has the potential to disturb Hinckley's oak populations.

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figure 3). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 5).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	6
Number of plants in *ex situ* collections:	10
Average number of plants per institution:	2
Percent of *ex situ* plants of wild origin:	20%
Percent of wild origin plants with known locality:	50%

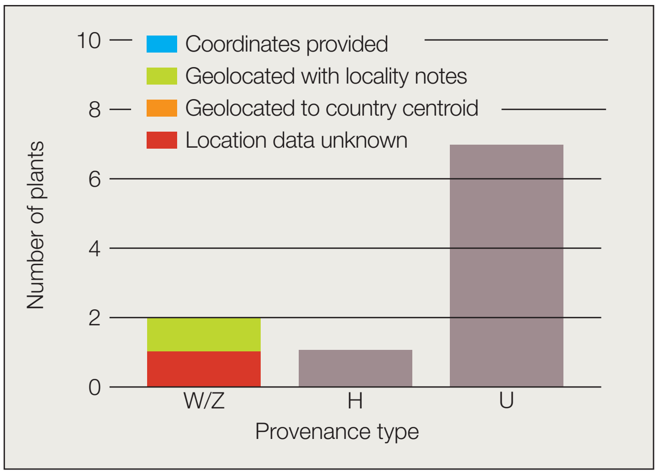


Figure 3. Number and origin of *Quercus hinckleyi* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 4). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	50%
Ecological coverage:	100%

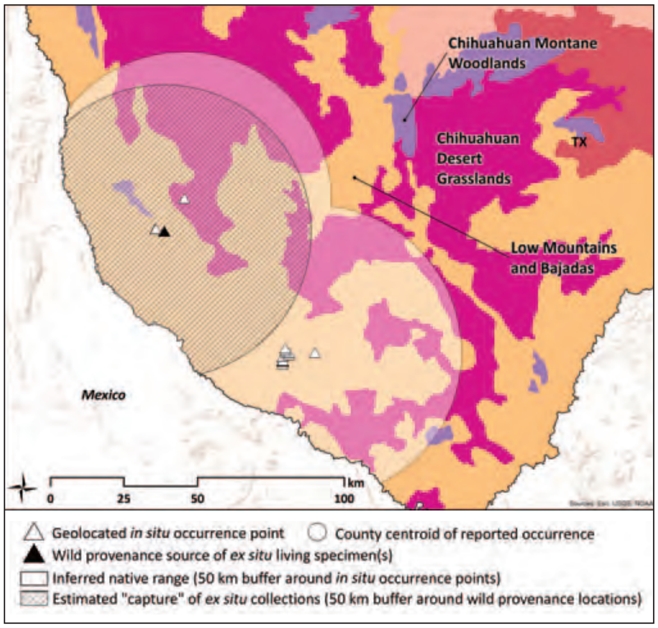


Figure 4. *Quercus hinckleyi in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level IV Ecoregions are colored and labelled.[7] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

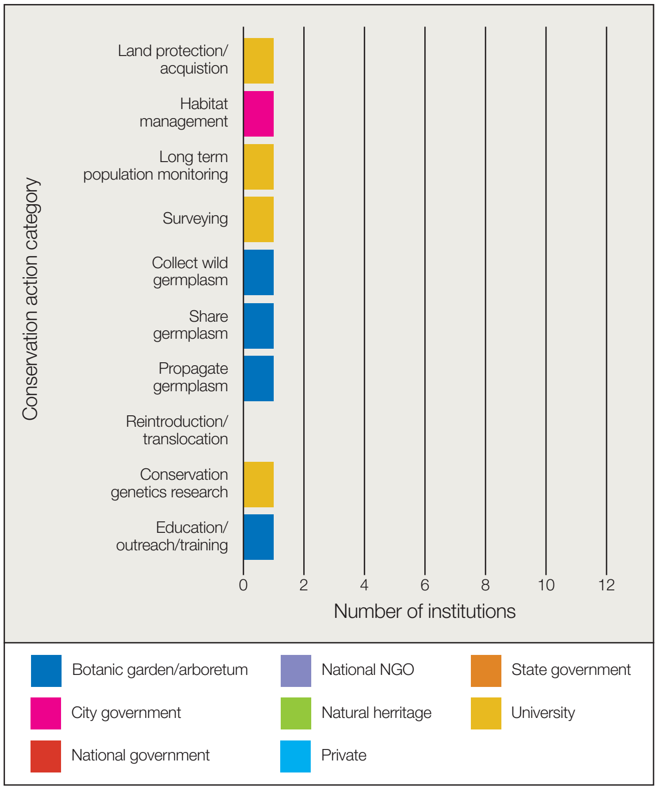


Figure 5. Number of institutions reporting conservation activities for *Quercus hinckleyi* grouped by organization type. One of 252 institutions reported activities focused on *Q. hinckleyi* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. hinckleyi* in the U.S., 62% of the land is covered by protected areas (Figure 6). One of the two known Hinckley's oak populations is protected within Big Bend Ranch State Park and the other is on privately owned land. Genetic analysis found the protected population to harbor more diversity (116 unique genotypes), while high clonality was determined at the unprotected Shafter site (seven unique genotypes). The protected site is also more frequently reproducing sexually.[1,5]

Sustainable management of land: The Texas Parks and Wildlife Department's 2012 ecoregions handbook for the Chihuahuan Desert and Arizona-New Mexico Mountains outlines general trends and needs in the region as a whole, including Big Bend Ranch State Park. There is no specific mention of *Q. hinckleyi* outside the "Species of Greatest Conservation Need" list.[8]

Population monitoring and/or occurrence surveys: In accordance with the requirements for species listed on the Endangered Species Act (ESA), a Hinckley Oak Recovery Plan was created upon listing in 1992. This document laid out criteria for removal from the ESA: "attain at least 20 viable self-sustaining populations in at least 4 geographically distinct population centers and attain a total of at least 10,000 individual plants. Demonstrate population viability at recovery levels for 10 consecutive years."[9] Within the species' five year review, which did not occur until 2008, it was found that little new information about *Q. hinckleyi* had been collected and few recovery actions had been implemented.[5] Big Bend Ranch State Park has also performed surveys of *Q. hinckleyi* within other parts of their preserve, but have not yet been successful.[1]

Wild collecting and/or *ex situ* curation: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Propagation and/or breeding programs: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: Within their 2015 and 2016 research, Backs *et al*. list the fulfillment of three high priority tasks within the recovery plan: #3212 to assess genetic viability and needs, #3231 to determine types of reproduction and contribution to population, and #3213 to assess incidence of (and potential threat from) hybridization with nearby oak species and develop management strategies to address any problems. They found that overall, remnant populations of *Q. hinckleyi* exhibit strong population differentiation, and do not act as fringe pioneers with founder effects or genetic bottlenecks. Backs et al. also used genetic analysis of *Q. hinckleyi* to further understand the potential conservation concern of hybridization and subsequent genetic swamping. It was concluded that although genetic swamping can be a threat to rare species, "it is not always the case, and rather than focusing on hybridization, conservation management may be better served by protecting threatened habitat that may include hybrids. To preserve the *Q. hinckleyi* genetic variability that may be stored in the neighboring oak species, protection of the cryptic *Q. pungens* should be included as part of *Q. hinckleyi's* conservation strategy."[1,6]

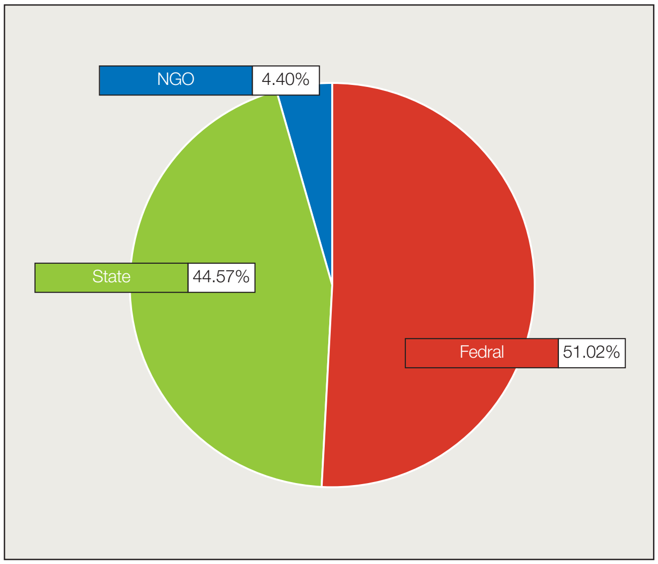


Figure 6. Management type of protected areas within the inferred native range of *Quercus hinckleyi*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

Emily Griswold

Education, outreach, and/or training: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Species protection policies: *Quercus hinckleyi* is the only native U.S. oak protected under the Endangered Species Act, which, by law, triggered the creation of a recovery plan.[9] The species is also considered Threatened by the state of Texas, as overseen by Texas Parks and Wildlife Department's Wildlife Diversity Program. Texas state Threatened or Endangered plants gain protection from humans taking, possessing, transporting, or selling the species.[10]

PRIORITY CONSERVATION ACTIONS

There have been limited conservation initiatives for Hinckley's oak. Although one of its subpopulations is now protected in a state park, recreational use of this area has the potential of threatening its numbers. The other subpopulation, located on private land, is within the path of a proposed pipeline. Climate is projected to become more xeric, which will further stress populations. Protecting surrounding habitat of wild individuals would be an ideal solution, but reality suggests that *ex situ* conservation is critical to the ultimate survival of this species. Although the species itself may appear insignificant, it has survived thousands of years of an increasingly arid environment. The persistence of the genetic adaptations to these conditions may be invaluable in understanding how plants cope with climate change as we are now experiencing it.

Because the species often reproduces clonally, genetic identification is needed to ensure that unique individuals are used for *ex situ* programs. Programs could include hand pollination and translocating genets or, less invasively, ramets of existing plants. Collecting acorns may be possible in some of its locations, but removing these from native habitat then limits survival there through loss of genetic diversification. Removal of acorns should be done with care; propagation programs could play an important role in sustainably distributing Hinckley's oak germplasm among *ex situ* institutions.

Protection of the Shafter site should be considered, as well as subsequent reinforcement and/or reintroduction to increase genetic diversity. Because *Q. hinckleyi* populations are very small and reproduce sporadically, population monitoring should continue on a regular basis to determine if decline is occurring. Finally, public outreach and education on the threats to this endangered species will help to raise awareness of the vulnerability of plant species in general. *Quercus hinckleyi* is a rather charismatic little oak, which has the potential to capture the support of locals, non-profits, and governing bodies alike.

Conservation recommendations for *Quercus hinckleyi*

Highest Priority
- Land protection
- Propagation and/or breeding programs
- Wild collecting and/or *ex situ* curation

Recommended
- Education, outreach, and/or training
- Population monitoring and/or occurrence surveys
- Reinforcement / Reintroduction / Translocation
- Research (climate change modeling; reproductive biology/regeneration; restoration protocols/guidelines)

REFERENCES

1. **Backs, J. R., Terry, M., Klein, M., & Ashley, M. V. (2015).** Genetic analysis of a rare, isolated species: A tough, little West Texas oak, *Quercus hinckleyi* C.H. Müller. The Journal of The Torrey Botanical Society, 142(4), 302-313. doi:10.3159/TORREY-D-14-00091.1
2. **Müller, C. H. (1951).** The oaks of Texas. Contributions Texas Research Foundation. *Botanical Studies*, 1, 21-323.
3. **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
4. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
5. **U.S. Fish and Wildlife Service. (2008).** Hinckley oak (*Quercus hinckleyi*) 5-Year review. Alpine, TX: Trans-Pecos Sub-Office.
6. **Backs, J. R., Terry, M., & Ashley, M. V. (2016).** Using genetic analysis to evaluate hybridization as a conservation concern for the threatened species *Quercus hinckleyi* CH Müller (Fagaceae). *International Journal of Plant Sciences*, 177(2), 122-31. Retrieved from https://doi.org/10.1086/684177
7. **U.S. EPA Office of Research & Development. (2013, April).** 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
8. **Texas Parks and Wildlife Department. (2012).** *Texas conservation action plan: Chihuahuan Desert and Arizona-New Mexico mountains ecoregions handbook.* Connally, W. (Ed.). Austin, TX. Retrieved from https://tpwd.texas.gov/landwater/land/tcap/documents/chih_tcap_2012.pdf

9 **Kennedy, K. (1992).** *Hinckley oak* (Quercus hinckleyi) *recovery plan*. Albuquerque, NM: U.S. Fish and Wildlife Service, Region 2. Retrieved from https://catalog.hathitrust.org/Record/002862480

10. T**exas Parks and Wildlife Department. (n.d).** Federal and State Listed Species in Texas. Retrieved from https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/listed-species/

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus inopina***

Emily Beckman, Adam black, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, ***Quercus inopina****, Quercus pumila*

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus inopina Ashe

Synonyms: N/A **Common Names:** Sandhill oak, Florida oak

Species profile co-author: Adam Black, Peckerwood Garden
Contributors: Michael Jenkins, Florida Forest Service, Florida Department of Agriculture and Consumer Services; Ron Lance, North American Land Trust

Suggested citation: Beckman, E., Black, A., Meyer, A., & Westwood, M. (2019). *Quercus inopina* Ashe. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 134-139). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-inopina.pdf

DISTRIBUTION AND ECOLOGY

Quercus inopina, or Sandhill oak, is endemic to south-central peninsular Florida, U.S. At its discovery in 1929, the species was considered to have characteristics intermediate between those of *Q. myrtifolia* and *Q. arkansana* var. *caput-rivuli* Ashe, though regional floras did not include *Q. inopina* until after the mid-80s.[1] Sandhill oak is abundant in upland ridge scrub, scrubby flatwoods, and open oak scrub communities of central Florida. In these habitats *Q. inopina* dominates along with other xerophytic scrub oaks (*Q. geminata, Q. myrtifolia, Q. chapmanii*), Florida rosemary (Ceratiola ericoides), and occasionally limited Sand pine (Pinus clausa) overstory. Patches of bare white sand and an open canopy are key characteristics of the ecosystem, and represent crucial habitat for the federally threatened Florida Scrub jay (Aphelocoma coerulescens).[2] Intermittent fires are characteristic and necessary to maintain the ecosystem's open canopy. *Quercus inopina* is an evergreen shrub averaging about one meter in height, sometimes reaching up to five meters. It rows clonally from an extensive underground rhizome, sending up unbranched shoots. This underground structure allows for rapid resprouting after fire.[3]

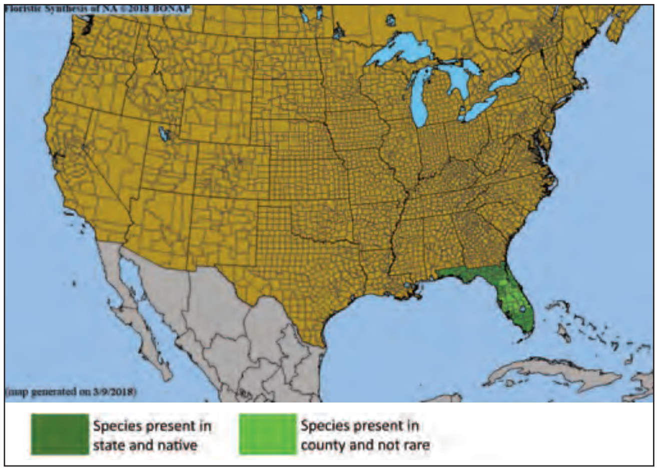


Figure 1. County-level distribution map for *Quercus inopina*. Source: Biota of North America Program (BONAP).[4]

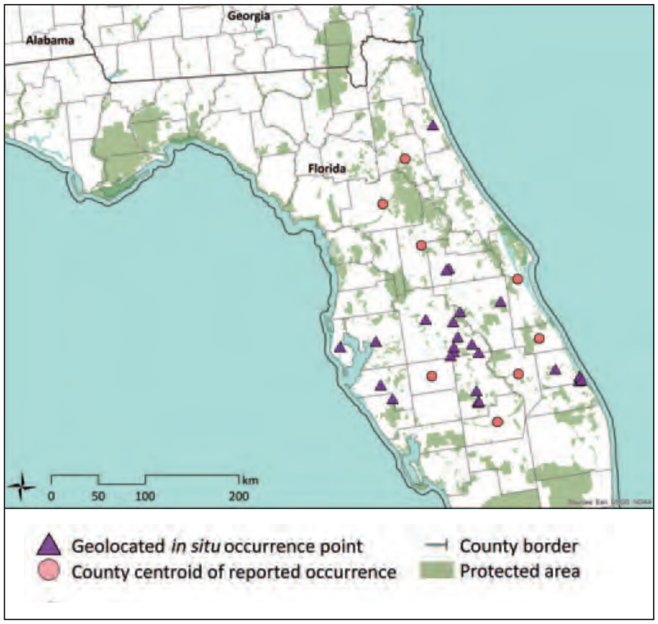


Figure 2. Documented *in situ* occurrence points for *Quercus inopina*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus inopina*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km^2 or AOO < 10 km^2 or 2-4 locations	EOO < 5,000 km^2 or AOO < 500 km^2 or 5-9 locations	EOO < 20,000 km^2 or AOO < 2,000 km^2 or 10+ locations	EOO > 20,000 km^2 or AOO > 2,000 km^2	Unknown	5
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	10
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	-
Average vulnerability score							6.0
Rank relative to all U.S. oak species of concern (out of 19)							13

High Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Many populations have been extirpated due to poor land management. Infrequent, or complete lack of, prescribed burns gives aggressive colonizers the opportunity to dominate. Therefore regular land management is critical for *Q. inopina* (A. Black pers. comm., 2017).

Moderate Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: Anthropogenic threats to *Q. inopina* habitat include conversion to residential and commercial uses, which also results in the fragmentation of remaining upland habitat. These developments, in addition to roads and railroads, often restrict the natural dispersal, intensity, and/or frequency of fire.[6]

Low Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: Conversion of habitat to agricultural land threatens *Q. inopina* in some areas (R. Lance pers. comm., 2018).[7]

Human use of landscape — tourism and/or recreation: Scrub habitat is readily damaged by off-road vehicle traffic or even foot traffic, which destroys the delicate ground cover and allows the loose sand to erode.[8]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Scrub communities are known to be sensitive to disturbance regime changes, which are altered by a changing climate. Further research is necessary regarding the the effects of climate change on the fluctuation of fire regimes.[9] No climate change projections are known for *Q. inopina* specifically.

Pests and/or pathogens: Because *Q. inopina* is a member of the red oak clade (Sect. Lobatae), it has the potential to be affected by oak wilt, Sudden oak death (SOD), and Goldspotted oak borer.[10,11,12] No serious damage has been reported to-date, though continued monitoring is necessary. Based on SOD's current distribution in California and the environmental conditions at these locations, models "indicated highest potential for establishment [of SOD] in the southeastern USA;" therefore, Sandhill oak is at particular risk should the pathogen spread throughout the Southeast.[11]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey	
Number of *ex situ* collections reporting this species:	5
Number of plants in *ex situ* collections:	14
Average number of plants per institution:	3
Percent of *ex situ* plants of wild origin:	79%
Percent of wild origin plants with known locality:	100%

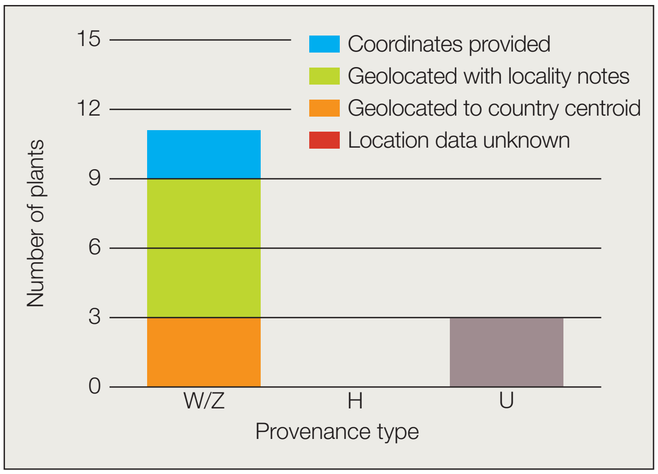


Figure 3. Number and origin of *Quercus inopina* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

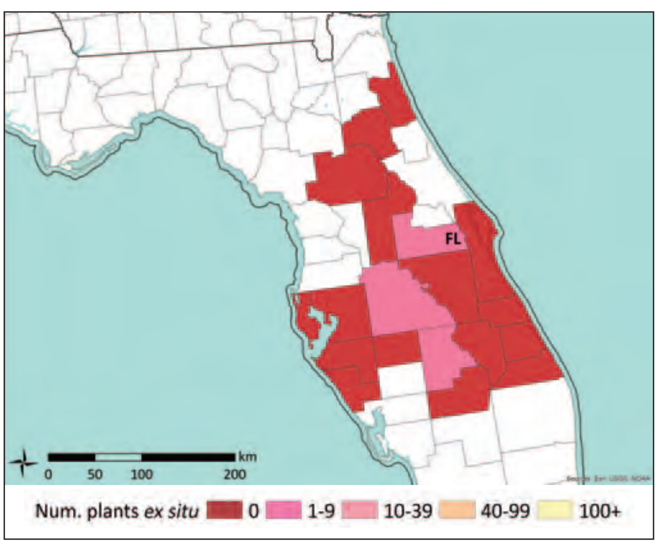


Figure 4. *Quercus inopina* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation	
Geographic coverage:	36%
Ecological coverage:	50%

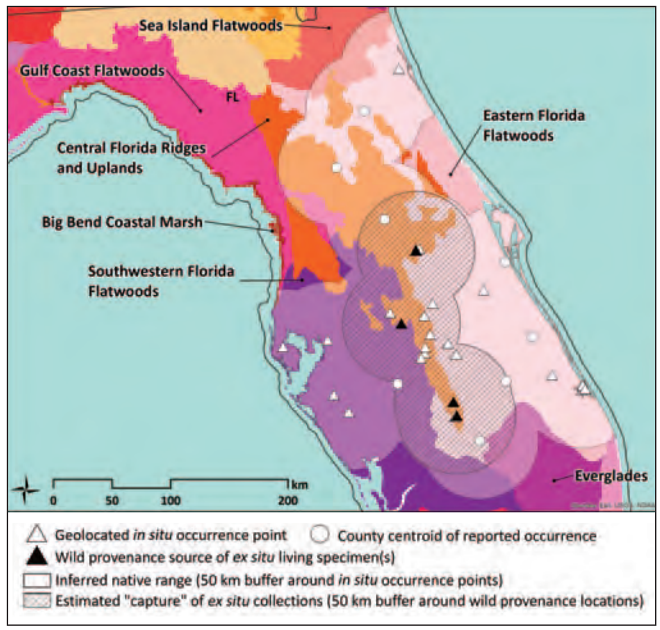


Figure 5. *Quercus inopina in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[13] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

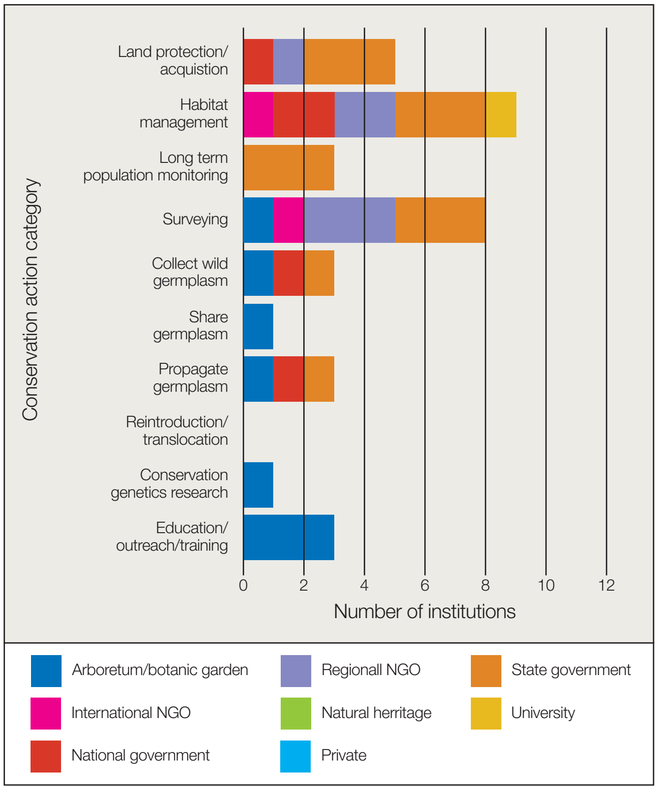


Figure 6. Number of institutions reporting conservation activities for *Quercus inopina* grouped by organization type. Fourteen of 252 institutions reported activities focused on *Q. inopina* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. inopina*, 25% of the land is covered by protected areas (Figure 7). In 2010 Moekstra *et al*. estimated that about 35% of the upland ridge and scrub communities of central Florida are formally protected. Ocala National Forest and Archbold Biological Station protect significant blocks of upland scrub habitat, including important *Q. inopina* populations.[14]

Lake Wales Ridge is the oldest of the beach and sand dune systems under protection and extends south from Orange County to Highlands County. Housing development and agriculture are the main threat to this habitat. A study of Lake Wales Ridge found that more than 85% of original scrub and other upland habitats on the Ridge are currently developed. Efforts to purchase scrub habitat in this area have been carried out by state and federal governments, in addition to non-profit organizations such as The Nature Conservancy. A network of more than 16,000 acres have been brought into protection since 1980. Lake-June-in-Winter State Park in southern Highlands County is an excellent example of *Q. inopina* original scrub habitat.[7,14] *Quercus inopina* has also been reported within the Savannas Preserve State Park and Tilton conservation area.[15]

Sustainable management of land: Archbold Biological Station burns at an intermediate frequency, about once every five to 20 years.[16] The Sand Lakes Conservation Area (approximately 1300 acres) has dictated the use of fire management, invasive plant removal, and forest management (silviculture) through a management plan.[17] In general, many public and private land managers in Florida practice prescribed burning (M. Jenkins pers. comm., 2017).

Population monitoring and/or occurrence surveys: The Institute for Regional Conservation tracks *Q. inopina* and has determined it to be Critically Imperiled in southern Florida.[15]

Wild collecting and/or *ex situ* curation: Three institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Propagation and/or breeding programs: Three institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

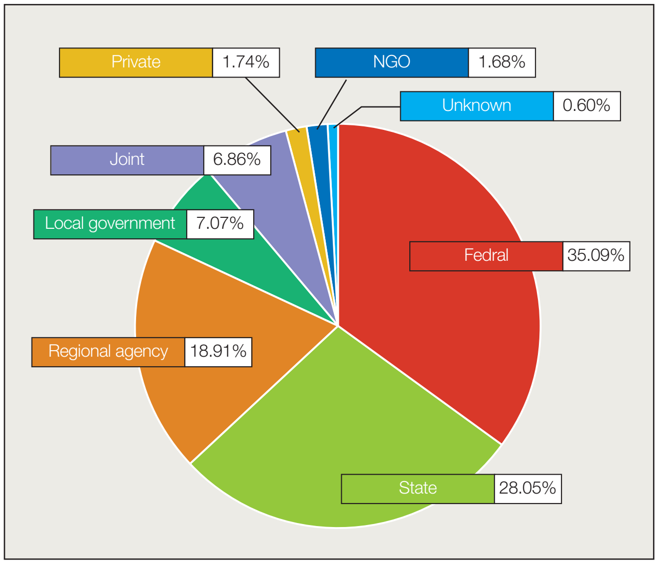


Figure 7. Management type of protected areas within the inferred native range of *Quercus inopina*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

Research: A study of acorn production in south-central Florida found that the smallest individuals (0.3–0.8 meters) of *Q. inopina* produced very few acorns (<5%), with each individual never generating more than five acorns.[18] The optimal fire return interval has also been studied for scrub habitat housing Sandhill oak. A general value could not be determined, but rather a variable prescribed fire interval was recommended due to "the high degree of variation in scrub types and site conditions, including an individual site's burn history. For example, fire return intervals between 8 and 15 years have been recommended as optimal for maintaining Florida scrub-jay populations in *Quercus inopina*-dominated scrub."[19]

Education, outreach, and/or training: Three institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

Proper land management is critical for Sandhill oak to prosper, including prescribed fire as dictated by site conditions, and further rehabilitation of once-suitable habitat contiguous with remaining fragmented preserved and/or maintained habitats. This restoration could include reintroduction and/or reinforcement where populations are small or fragmented. Emphasis should also be placed on *ex situ* conservation of germplasm from throughout the species' range, especially from isolated populations or those persisting on poorly managed land or private lands with uncertain future. Further land protection could be carried out where possible, but it is likely that education and training of land managers and/or owners, both public and private, will be the most effective solution. Populations should continue to be monitored for health and losses to land development. Research regarding appropriate land management techniques including fire and other replications of natural disturbance regimes should be furthered, to better understand best management practices.

Conservation recommendations for *Quercus inopina*

Highest Priority
- Sustainable management of land

Wild collecting and/or *ex situ* curation

Recommended
- Education, outreach, and/or training
- Land protection
- Population monitoring and/or occurrence surveys
- Reintroduction, reinforcement, and/or translocation
- Research (climate change modeling; demographic studies/ecological niche modeling; land management/disturbance regime needs; pests/pathogens; population genetics)

Ron Lance

REFERENCES

1. **Johnson, A. F. & Abrahamson, W. G. (1982).** *Quercus inopina*: A species to be recognized from South-central Florida. *Bulletin of the Torrey Botanical Club*, 109(3), 392- 395. Retrieved from https://www.jstor.org/stable/2995985
2. **Dinerstein, E., Weakley, A., Noss, R., Snodgrass, R., & Wolfe, K. (n.d.).** Florida sand pine scrub. Retrieved from https://www.worldwildlife.org/ecoregions/na0513
3. **Florida Fish and Wildlife Conservation Commission & Florida Natural Areas Inventory. (2009, June).** *Scrub management guidelines for peninsular Florida: Using the Scrub-jay as an umbrella species*. Tallahassee, FL. Retrieved from https://www.partnersinflight.org/wp-content/uploads/2017/03/Partners-in-Flight-Scrub-Mgmt-Guidelines-for-Peninsular-Florida.pdf
4. **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
5. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
6. **U.S. Fish and Wildlife Service. (1999).** *Multi-species recovery plan for south Florida*. Vero Beach, FL: South Florida Ecological Services Field Office. Retrieved from https://www.fws.gov/verobeach/ListedSpeciesMSRP.html
7. **LandScope America. (n.d.).** Featured endemic ecosystem: The Lake Wales Ridge scrub. Retrieved from http://www.landscope.org/florida/ecosystems/featured_ecosystems/endemic_ecosystems/
8. **Florida Natural Areas Inventory. (2010).** *Guide to the natural communities of Florida: 2010 edition*. Tallahassee, FL. Retrieved from: https://www.fnai.org/naturalcommguide.cfm
9. **Defenders of Wildlife. (n.d.).** Climate change and Florida scrub jays. Retrieved from http://www.landscope.org/article/FL/climate_scrub_jays/1/
10. **Canadian Food Inspection Agency (2019).** *Bretziella fagacearum* (previously known as *Ceratocystis fagacearum* (Oak Wilt) - Fact Sheet. Retrieved from http://www.inspection.gc.ca/plants/plant-pests-invasive-species/diseases/oak-wilt/fact-sheet/eng/1325629194844/1325632464641
11. **Kluza, D. A., Vieglais, D. A., Andreasen, J. K., & Peterson, A. T. (2007).** Sudden oak death: geographic risk estimates and predictions of origins. *Plant Pathology*, 56(4), 580-587. doi:10.1111/j.1365-3059.2007.01602.x
12. **Colman, T. W., Jones, M. I., Smith, S. L., Venette, R. C., Flint, M. L., & Seybold, S. J. (2017).** Goldspotted Oak Borer. Forest Insect & Disease Leaflet 183. U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf
13. **U.S. EPA Office of Research & Development. (2013, April).** 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
14. **Hoekstra, J. M., Molnar, J. L., Jennings, M., Revenga, C., Spalding, M. D., Boucher, T. M., Robertson, J. C., Heibel, T. J., & Ellison, K. (2010).** *The atlas of global conservation: Changes, challenges, and opportunities to make a difference*. Berkeley, CA: University of California Press.
15. **The Institute for Regional Conservation. (n.d.).** Natives for your neighborhood. Delray Beach, FL. Retrieved from https://regionalconservation.org/beta/nfyn/default.asp
16. **Archbold Biological Station. (n.d.).** Principal habitats: Excellent examples of Lake Wales Ridge upland habitats. Retrieved from http://www.archbold-station.org/html/aboutus/habitats.html
17. **St. Johns River Water Management District. (2008).** *Sand Lakes Conservation Area land management plan*. Retrieved from https://www.sjrwmd.com/static/lands/management/plans/2008_Sand_Lakes_CA.pdf
18. **Abrahamson, W. G., & Layne, J. N. (2002).** Relation of ramet size to acorn production in five oak species of xeric upland habitats in south-central Florida. *American Journal of Botany*, *89*(1), 124-131. doi:10.3732/ajb.89.1.124
19. **Florida Fish and Wildlife Conservation Commission & Florida Natural Areas Inventory. (2009, June).** *Scrub management guidelines for peninsular Florida: Using the Scrub-jay as an umbrella species.* Tallahassee, FL. Retrieved from https://www.partnersinflight.org/wp-content/uploads/2017/03/Partners-in-Flight-Scrub-Mgmt-Guidelines-for-Peninsular-Florida.pdf

Conservation Gap Analysis of Native

U.S. Oaks

Species profile: ***Quercus laceyi***

Emily Beckman, Chuck Cannon, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, ***Quercus laceyi***

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum®
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus laceyi Small

Synonyms: *Quercus breviloba* subsp. *laceyi* (Small) A.Camus, *Q. glaucoides* auct. non Mart. & Gal., *Q. microlepis* Trel. & C.H.Müll., *Q. porphyrogenita* Trel. **Common Names:** Lacey oak, Texas blue oak

Species profile co-authors: Chuck Cannon, The Morton Arboretum

Suggested citation: Beckman, E., Cannon, C., Meyer, A., & Westwood, M. (2019). *Quercus laceyi* Small. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 140-145). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-laceyi.pdf

DISTRIBUTION AND ECOLOGY

Quercus laceyi, or Lacey oak, is restricted to southern and southwestern parts of the Edwards Plateau in Texas, U.S., and mountainous regions in the Mexican states of Coahuila, Nuevo León, and Tamaulipas. Lacey oak is known to be associated with limestone outcrops, along with other flora unique to the ecosystem. It is found among woodland and riparian zones with mixed stands of ash, basswood and other oaks.[1] Lacey oak has been noted horticulturally for its leathery blue-gray mature leaves, light reddish-pink new growth, and fall color ranging from peach to gold. Its leaves can also be lobed or unlobed.[2] In Texas, *Q. laceyi* usually occurs at elevations between 350–600 meters above sea level, while its Mexican distribution occurs at higher elevations between 1,830-2,500 meters. It is a component of the pine-juniper-madrone-oak forest type of northern Mexico. *Quercus laceyi* is a small to medium tree, reaching a maximum height of 18 to 19 meters.[1,3,4]

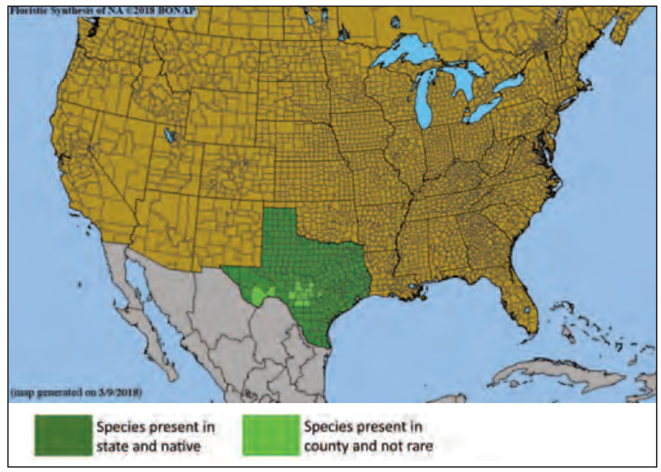


Figure 1. County-level distribution map for the U.S. distribution of*Quercus laceyi*. Source: Biota of North America Program (BONAP).[5]

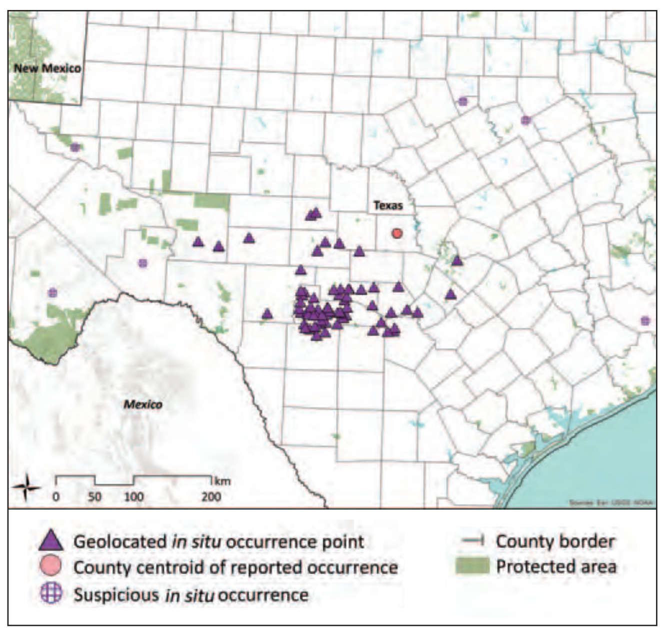


Figure 2. Documented *in situ* occurrence points for the U.S. distribution of *Quercus laceyi*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[6]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus laceyi*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km^2 or AOO < 10 km^2 or 2-4 locations	EOO < 5,000 km^2 or AOO < 500 km^2 or 5-9 locations	EOO < 20,000 km^2 or AOO < 2,000 km^2 or 10+ locations	EOO > 20,000 km^2 or AOO > 2,000 km^2	Unknown	0
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	10
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	5
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	-
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	-
Average vulnerability score							3.8
Rank relative to all U.S. oak species of concern (out of 19)							18

THREATS TO WILD POPULATIONS

High Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Threats to *Q. laceyi* are not well known, but climate change modeling has recently brought potential concern. In 2016 a 25.61% decrease in suitable range area was projected for *Q. laceyi* by 2050 using the Hadley global climate model and B1 (Lower) emissions scenario.[7] A recent analysis of U.S. tree vulnerability to climate change used species-specific intrinsic traits to asses trees' 1) exposure to climate change, including projected area change by 2050 and distance to future habitat; 2) sensitivity to threat, including rarity, area of distribution, dispersal ability, and disturbance tolerance; and 3) adaptability to threat, including regeneration, genetic variability, and ecological requirements. *Quercus laceyi* was found to have high vulnerability in all three categories.[8]

Moderate Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: *Quercus laceyi* is a common component of habitat vital to the federally endangered Black-capped vireo, which is known to face habitat loss through land use conversion and browsing by livestock. Though, it is noted that most of these threats have "decreased in magnitude or are adequately managed."[9]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	17
Number of plants in *ex situ* collections:	47
Average number of plants per institution:	3
Percent of *ex situ* plants of wild origin:	62%
Percent of wild origin plants with known locality:	66%

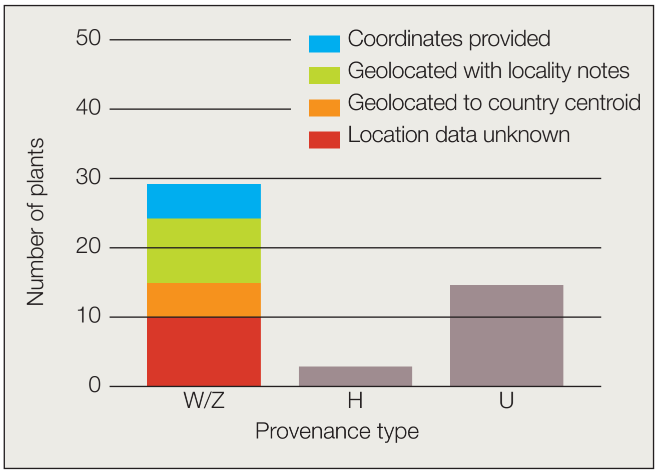


Figure 3. Number and origin of *Quercus laceyi* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

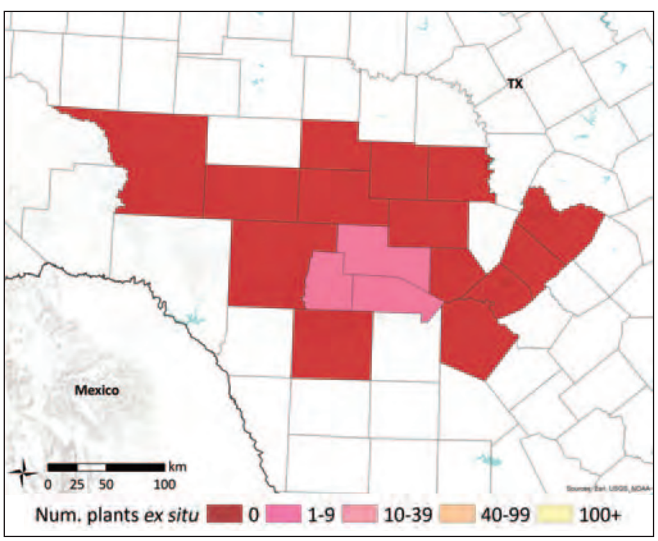


Figure 4. *Quercus laceyi* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Only the native U.S. distribution of the species was considered in this analysis, due to availability of ecoregion maps. Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	20%
Ecological coverage:	27%

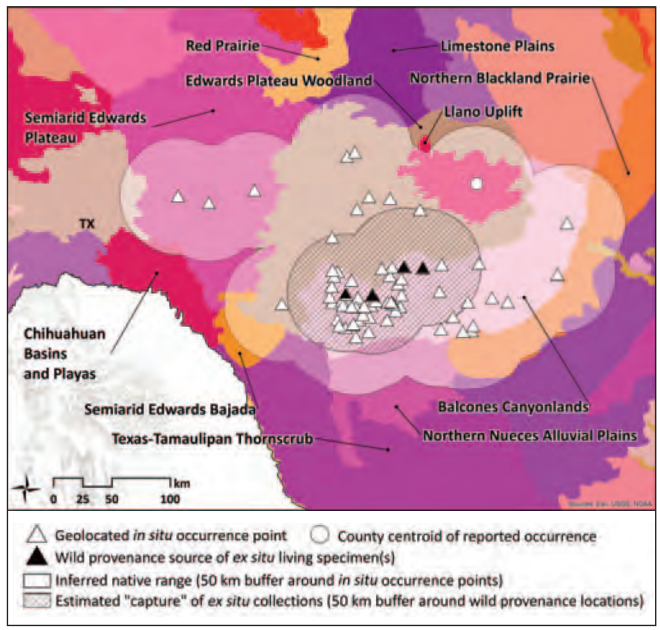


Figure 5. *Quercus laceyi in situ* occurrence points and *ex situ* collection source localities within the United States. U.S. EPA Level IV Ecoregions are colored and labelled.[10] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

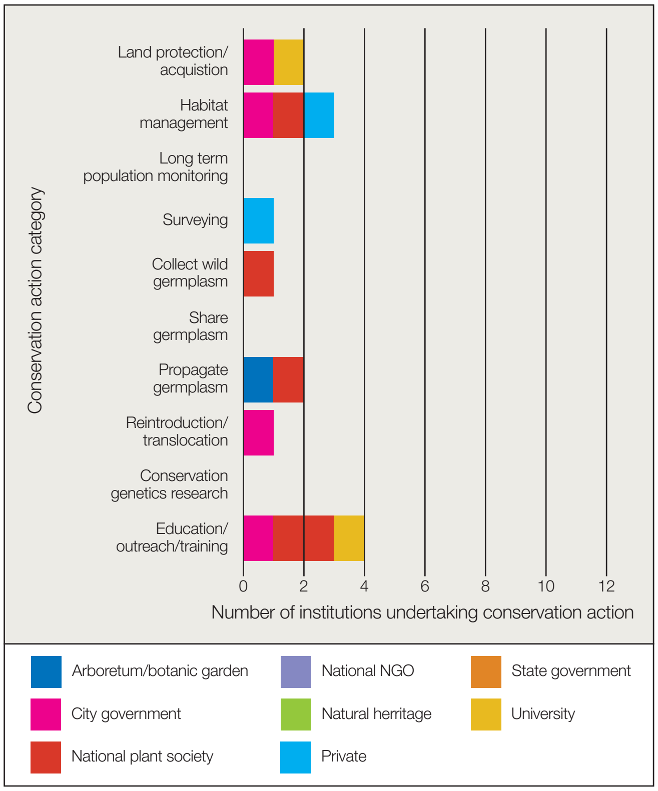


Figure 6. Number of institutions reporting conservation activities for *Quercus laceyi* grouped by organization type. Six of 252 institutions reported activities focused on *Q. laceyi* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. laceyi* in the U.S., 3% of the land is covered by protected areas (Figure 7). There is very little protected land in eastern Texas, rather the vast majority is privately owned and utilized as rangeland or cropland.

Quercus laceyi is a common component of habitat vital to the federally Endangered Black-capped vireo. This songbird underwent a thorough review by the U.S. Fish and Wildlife Service in 2016, which assessed health and ongoing conservation needs. The review determined that the majority of the Black-capped vireo's U.S. range covers privately owned land, and the small portion distributed on public land or land under a conservation easement do not generally experience threatening land use changes. This is likely the case through most of Lacey oak's U.S. range.[9]

Sustainable management of land: In general, land managed by federal, state, county or municipal entities, or under conservation easement for the purpose of managing other rare species, are thought to have stable land management practices.[9]

Population monitoring and/or occurrence surveys: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Wild collecting and/or *ex situ* curation: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Propagation and/or breeding programs: Although Lacey oak is not widely propagated in nurseries, some do offer the species, and it is gaining attention as a good choice for lawns and other suburban landscapes. It's noted for "blue-green mature foliage, peach-colored new growth and similar fall color."[2]

Reintroduction, reinforcement, and/or translocation: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Research: No known initiatives at the time of publication.

Education, outreach, and/or training: The Native Plant Society of Texas created the Operation NICE! (Natives Insead of Common Exotics) program to help nurseries offer natives that are right for the local environment. Lists of appropriate species have been compiled, including specific care instructions that are easy to access online.[11] The Boerne Chapter of the Native Plant Society of Texas selected Lacey oak as the NICE! Plant of the Month for October in both 2007 and 2011. Other chapters list *Q. laceyi* within their recommended plant lists.[12]

Species protection policies: No known initiatives at the time of publication.

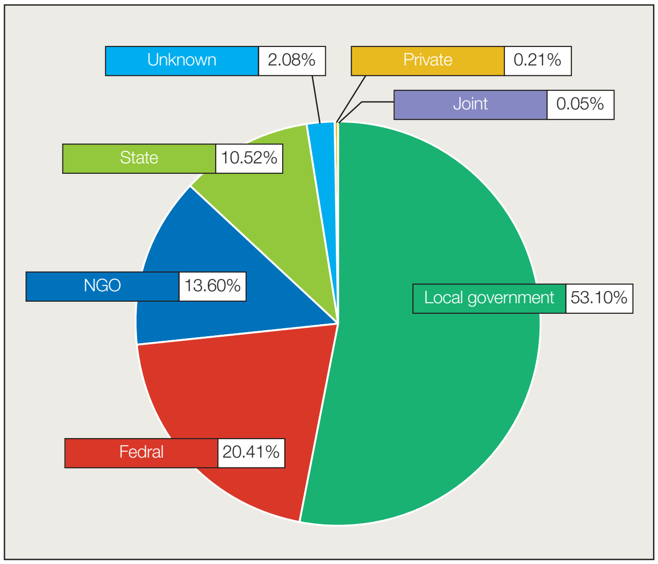


Figure 7. Management type of protected areas within the inferred native range of *Quercus laceyi*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[6]

Adam Black

PRIORITY CONSERVATION ACTIONS

While Lacey oak is currently not threatened, it does have a relatively narrow geographic distribution and is found most commonly in a specialized habitat with limestone-derived soils. Only a small fraction of its distribution has protected status and it occurs overwhelmingly on private land. These factors make the species especially vulnerable to climate change and/or changes in land use patterns in the region. The specialization of the species on limestone soils will greatly limit its ability to migrate and adapt to environmental conditions elsewhere, indicating that the best strategy will be conservation approaches that involve local *in situ* conservation. An increase in protected area coverage could be pursued through collaborations with landowners, for example establishing conservation easements. Land owners and managers could also be engaged regarding the importance of *Q. laceyi* in its ecosystem, its unique aesthetic qualities, and land management needs.

Quercus laceyi remains a poorly known species with few individuals found in *ex situ* living collections, capturing a small fraction of the natural genetic diversity. Few conservation activities directly focus on this tree species. More effort to bring wild seed into well-managed and documented collections should be made. Because of its current low conservation profile but ecological characteristics making it potentially vulnerable to rapid change in viability, continued monitoring and awareness of the status of common populations and their response to climate conditions in the future should be maintained; this will prevent Lacey oak from declining substantially without any conservation action.

Conservation recommendations for *Quercus laceyi*

Highest Priority
- Land protection
- Wild collecting and/or *ex situ* curation
- Education, outreach, and/or training

Recommended
- Population monitoring and/or occurrence surveys
- Research (climate change modeling)

REFERENCES

1. **Nixon KC, Müller CH. (1992).** The taxonomic resurrection of *Quercus laceyi* Small (Fagacae). *SIDA, contributions to botany*, 15, 57–69. Retrieved from https://www.jstor.org/stable/41967538
2. **Garrett, H. (2017, August).** These two oak trees should be used more often in North Texas yards. *The Dallas Morning News*. Retrieved from https://www.dallasnews.com/life/gardening/2017/08/01/two-oak-trees-used-often-north-texas-yards
3. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
4. **Stein, J., Binion, D., & Acciavatti, R. (2003).** *Field guide to native oak species of eastern North America.* Forest Service, U.S. Department of Agriculture.
5. **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
6. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
7. **Hargrove, W. W., & Potter, K. M. (2016).** The ForeCASTS project: Forecasts of climate-associated shifts in tree species. Version 5 Tree Atlas. Retrieved from https://www.geobabble.org/ForeCASTS/index.html
8. **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
9. **U.S. Fish and Wildlife Service. (2016, July).** S*pecies status assessment report for the Black-capped vireo* (Vireo atricapilla). Arlington, Texas: Ecological Services Field Office. Retrieved from https://www.fws.gov/southwest/es/ArlingtonTexas/pdf/Final BCVI SSA revised 2_03302018.pdf
10. **U.S. EPA Office of Research & Development. (2013, April).** 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
11. **Native Plant Society of Texas. (n.d.).** Operation NICE!. Retrieved from https://npsot.org/wp/resources/nice/
12. **Cain, D. (2011, October 7).** Lacey oak, a NICE! little tree for Hill Country yards. TX: Boerne Chapter, Native Plant Society of Texas. Retrieved from https://npsot.org/wp/boerne/publications/native-grown-articles/ lacey-oak-revisited/


Adam Black

Conservation Gap Analysis of Native U.S. Oaks

Species profile: *Quercus lobata*

Emily Beckman, Rosi Dagit, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
***Quercus lobata**, Quercus parvula, Quercus sadleriana*

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum®
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus lobata Née

Synonyms: *Quercus hindsii* Benth., *Q. hindsiana* Benth. ex Dippel, *Q. longiglanda* Frém., *Q. lyrata* Spreng.
Common Names: Valley oak, California white oak

Species profile co-author: Rosi Dagit, Resource Conservation District (RCD) of the Santa Monica Mountains
Contributors: Jessica Wright, Pacific Southwest Research Station, USDA Forest Service

Suggested citation: Beckman, E., Dagit, R., Meyer, A., & Westwood, M. (2019). *Quercus lobata* Née. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 146-151). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-lobata.pdf

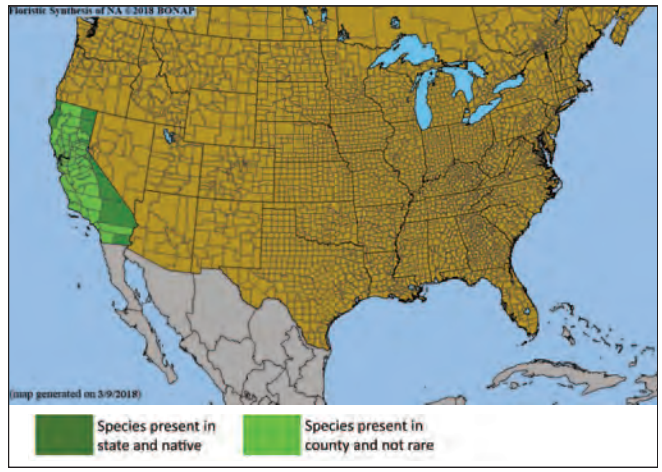


Figure 1. County-level distribution map for *Quercus lobata*. Source: Biota of North America Program (BONAP).[7]

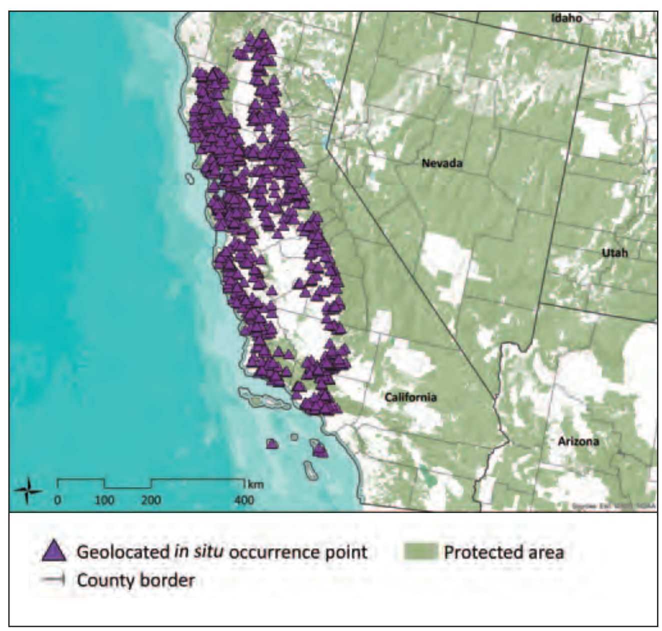


Figure 2. Documented *in situ* occurrence points for *Quercus lobata*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[8]

DISTRIBUTION AND ECOLOGY

Quercus lobata, or Valley oak, is endemic to California, U.S., with a distribution south from Shasta County to the Central Valley, including the foothills and valleys of the Sierra Nevada and Coast Ranges leading to Los Angeles.[1] Due to their naturally wide spacing, current mapping underrepresents occurrences, especially at the southern end of their range in Los Angeles County.[2] They are also found on Santa Cruz and Santa Catalina Islands. *Quercus lobata* is the dominant species in both Valley oak woodland and Valley oak riparian forest. Often, the species is the only tree found within Valley oak woodland, where it lives widely spaced with grasses stretching between each individual. Within the riparian community, Valley oak historically extended one to eight kilometers on each side of major rivers, along with other trees such as Interior live oak, Blue oak, Coast live oak, Black walnut, Sycamore, California bay laurel, White alder, numerous willow species, and Gray pine. These two dominant ecosystems have deep, rich soils that provide some of the best farmland in the world.[3] Valley oak is a deciduous tree that is both flood and drought tolerant, withstanding cool, wet winters and hot, dry summers. It is is reported to be the largest and longest lived oak species in North America, reaching ten to 30 meters tall and 400 to 600 years old, with a rounded, spreading crown.[4,5] The species can occur from sea level to 1,200 meters above sea level.[3] Valley oak also comprises necessary habitat for multiple state-threatened species such as Swanson's hawk, Sandhill crane, and Yellow-billed cuckoo, as well as the federally-threatened Elderberry longhorn beetle.[6]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus lobata*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	0
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	20
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	10
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	20
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	0
						Average vulnerability score	8.3
						Rank relative to all U.S. oak species of concern (out of 19)	11

THREATS TO WILD POPULATIONS

High Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: Much of *Q. lobata* habitat has been cleared for agriculture. In central California, the loss of large parcels of Valley oaks to vineyard development has fueled heated debates between private landowners and public interest groups. Soil compaction by cattle may be affecting regeneration.[9] It has also been found that oak tree removal increases ranch income through livestock use, though benefits drop after the first few years following removal (J. Wright pers. comm., 2018).[10]

Human use of landscape — residential/commercial development, mining, and/or roads: Over the last 150 years, Valley oaks have been the victims of widespread residential development in lowland areas. Over 90% of Valley oak woodlands have been lost due to conversion to development or agriculture.[9] Where groundwater pumping has drastically lowered the water table, Valley oaks have become slow-growing and haggard.[5] Expanding urban areas have also destroyed many stands in the Coast Ranges.[11]

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Remaining stands of Valley oak primarily occur on private lands, and are threatened by fire suppression.[1,9] Hydrologic processes such as periodic, low intensity floods that help maintain this vegetation have also been greatly altered.[11]

Pests and Diseases: Valley oaks are known reproductive hosts for the invasive Polyphagous and Kuroshio shot-hole borers, which carry the symbiotic fungus fusarium that infects the tree. The beetles are spreading north and threatening a larger number of trees.[12]

Moderate Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Valley oak is likely to experience habitat shifting and contracting due to climate change, leading to a decrease in both the quality and extent of its habitat. The decline of the species will not be consistent across its range, therefore a conservative estimate of 27% decrease in suitable habitat by 2099 has been projected.[13,14] A recent analysis of U.S. tree vulnerability to climate change found *Q. lobata* to be within the lowest climate change vulnerability category based on species-specific traits, as compared to other U.S. trees.[15]

Low Impact Threats

Human modification of natural systems — invasive species competition: Exotic plant species are present within Valley oak woodland and somewhat perturb the ecosystem.[16] Significant threat has not been noted at this time.

Human use of species — wild harvesting: Remaining *Q. lobata* stands primarily occur on private lands, and are sometimes threatened by fuelwood cutting.[1,9]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	44
Number of plants in *ex situ* collections:	1369
Average number of plants per institution:	31
Percent of *ex situ* plants of wild origin:	86%
Percent of wild origin plants with known locality:	99%

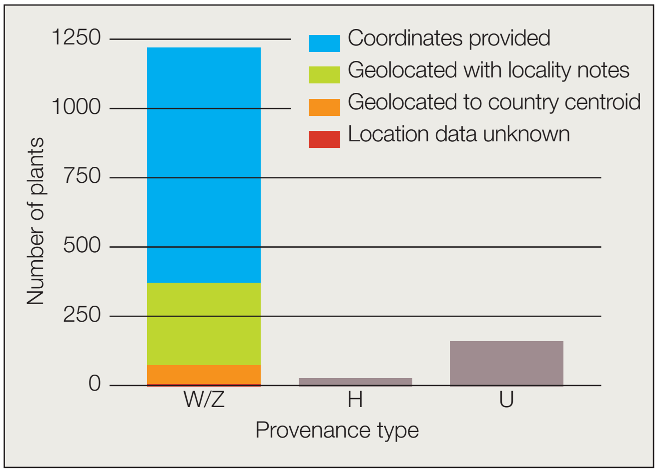


Figure 3. Number and origin of *Quercus ajoensis* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

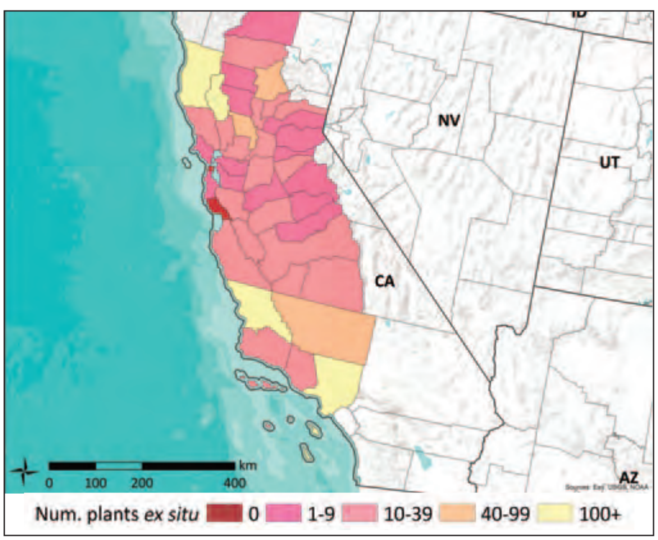


Figure 4. *Quercus lobata* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	91%
Ecological coverage:	95%

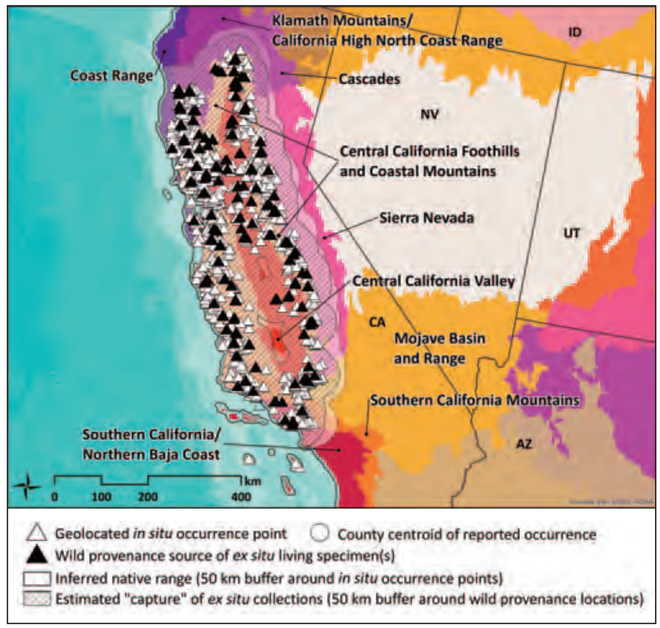


Figure 5. *Quercus lobata in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[17] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

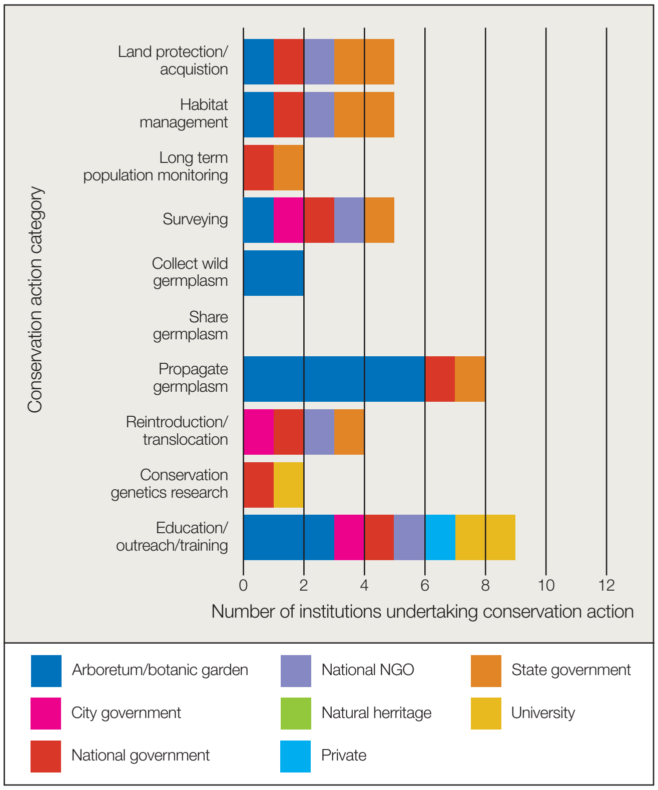


Figure 6. Number of institutions reporting conservation activities for *Quercus lobata* grouped by organization type. Nineteen of 252 institutions reported activities focused on *Q. lobata* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. lobata* in the U.S., 35% of the land is covered by protected areas (Figure 7). Although this is not a significant proportion, many counties and communities already work towards the protection of Valley oak on private land. Expansion of protected areas is unlikely, therefore collaboration with stakeholders is key.

Los Angeles County is aiming for no net loss of oak woodlands and has incorporated protections for both individual trees and woodland areas in their General Plan and other supporting land use plans.[18] Many other counties in California also have such goals for expanding protections on private lands through conservation easements and fee acquisition. Multiple federal and state agencies such as the Bureau of Land Management, National Park Service, USDA Forest Service, and California Department of Parks and Recreation are all working towards preservation and expansion of existing valley oak woodlands throughout the state (R. Dagit pers. comm., 2018).

Sustainable management of land: Of the 58 counties in California, roughly half have established protection ordinances or conservation plans to conserve their oak resources, including through proper land management. Los Angeles, Santa Barbara, San Luis Obispo, and Yolo counties have plans that are good examples of these efforts (R. Dagit pers. comm., 2018).[19]

Population monitoring and/or occurrence surveys: Current mapping scales and polygons are available, but routinely miss existing stands of Valley oaks due to the species' low density within a given spatial area, especially in savannah ecosystems.[2]

Wild collecting and/or *ex situ* curation: Since 2011, Wright (USDA Forest Service) and Sork (University of California, LA) have been working to establish a fully-replicated provenance trial from a range-wide collection, representing 95 populations of Valley oak at two outplanting sites: the Institute of Forest Genetics (IFG) in Placerville, California and the USDA-FS Chico Seed Orchard in Chico, California (J. Wright pers. comm., 2017).[20]

Propagation and/or breeding programs: Wright and Sork describe their provenance trial: "Over 10,000 acorns were planted at the Institute of Forest Genetics, PSW, Placerville. 9115 of these acorns germinated, representing an 89% germination rate...In the December 2014, 3500 trees were planted at the IFG site, and in January, 3500 seedlings were outplanted at the GRCC [now the Chico Seed Orchard] in Chico."[20] Height growth has been recorded every year since planting in 2012, and bud burst data have been collected since 2015. Analyses associating growth performance, climate, and each individual's site of origin are ongoing (J. Wright pers. comm., 2018).

Reintroduction, reinforcement, and/or translocation: There is great interest among public and private managers to restore as much Valley oak woodland and riparian forest as possible, and revegetation projects are numerous. Due to heavy acorn and seedling predation, however, mortality of newly-established populations often approaches 100% on project sites. Enclosing plants in a protective device such as wire caging is recommended until tree height exceeds the browse line.[4]

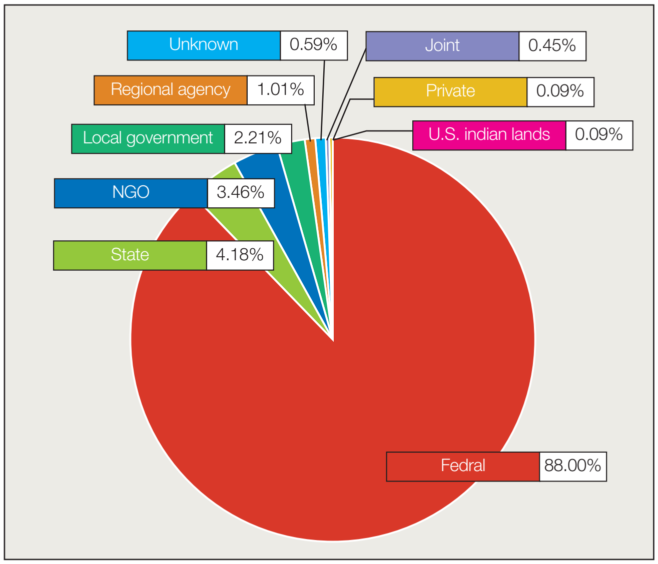


Figure 7. Management type of protected areas within the inferred native range of *Quercus lobata*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[8]

Research: Ecosystem and landscape level research is limited. To develop a comprehensive conservation plan for Valley oaks, certain critical information is lacking. Knowledge of the species' current range and distribution, and current rates of land conversion are needed to assess loss of habitat. Information on stand structure, population dynamics, and minimum viable population size will help identify conservation priorities.[9]

In response to ongoing fragmentation and loss of Valley oaks due to drought and invasive beetles, Los Angeles County embarked on a collaborative effort with federal, state, and local land agencies to identify potential climate-appropriate areas for restoration and planting. Sites within the Santa Monica Mountains National Recreation Area were studied using remote sensing data, to identify criteria and locations for priority planting sites. Maps and guidance for priority planting and restoration areas are in progress and expected to be available by the end of 2019 (R. Dagit pers. comm., 2018).[21]

Wright and Sork's Valley oak provenance test is dedicated to assessing climate change vulnerability, linking climatic models with population response models, determining seed-zone and seed-transfer guidelines for current and future climates, gathering conservation genomics information, and providing easy access to sites for further research and project development (J. Wright pers. comm., 2017).[22]

Education, outreach, and/or training: The Integrated Hardwood Range Management Program—a partnership among the University of California, California Department of Forestry and Fire Protection, and California Department of Fish and Game, as well as numerous county and local programs—has focused efforts on educating landowners on multiple-use and sustainable-yield practices. Research regarding economic incentives, wildlife relationships, and tree reproduction and regeneration have been shared, and funding has been provided for further research informing an understanding of oak woodland ecology.[9] Wright and Sork's provenance trial provides educational outreach opportunities for students, postdocs, and the general public, as well as specific guidance for resource managers on ecotypic variation in Valley oak survival (J. Wright pers. comm., 2017).

Species protection policies: City and county ordinances often focus on heritage trees and set mitigation standards for removal of trees. Though these efforts are a step in the right direction, they may not result in the long-term survival of *Q. lobata*.[9] With help from Santa Barbara County, a group of citizens formed the Oak Working Group, which produces the basic recommendations that are applied in the Oak Tree Protection and Regeneration Program (adopted in 2003; includes *Q. agrifolia, Q. lobata, Q. douglasii, Q. chrysolepis, Q. kelloggii, Q. wislizenii*). This protection and regeneration program received support from both the agricultural and environmental communities, which is critical to the success of species protection and restoration programs.[23] In 2011, Los Angeles County also adopted an Oak Woodland Conservation Management Plan that provides a comprehensive road map for achieving no net loss of woodlands in the future. The plan outlines specific strategies for conserving the 17 oak species native to the county.[2] Counties throughout California have taken a variety of steps to protect oak woodlands and provide strategies for future preservation through the use of conservation easements, fee acquisition, and other land use planning tools.

PRIORITY CONSERVATION ACTIONS

The biggest challenge to ensuring a future for Valley oaks throughout their range is to increase understanding of current distribution patterns, population demographics, regeneration patterns, and potential response to changes in climate. Ongoing research by Wright and Sork will provide important understanding of genetic variability and guidance for successful restoration efforts. There is also a need for identifying optimal sites where planting can augment currently fragmented, mature, and senescing populations. Additional landscape-level analysis of potential suitable habitat based on projected climate change scenarios is critical to focus restoration efforts throughout the species' range. This analysis of ideal locations for planting, paired with the provenance data being gathered by Wright and Sork, will provide powerful tools for restoration and reforestation. Los Angeles County is tackling this need for the Santa Monica Mountains National Recreation Area in 2018-2019 by building upon the documentation of drought and beetle mortality and using remote sensing data to identify criteria and locations for prioritizing planting sites.[21] Improving protocols for restoration planting and maintenance are also needed, given the challenges of providing water in remote locations. Forward thinking analyses such as these will be needed to direct successful, scientifically sound, and collaborative regeneration efforts for the future. Valley oaks are iconic trees, often optimizing the rural beauty of California, and are much loved by many people. Developing a coordinated, comprehensive plan is the key to longevity of this species, and must include the engagement of all stakeholders in sharing the effort to ensure future generations are able to enjoy these trees.

Conservation recommendations for *Quercus lobata*

Highest Priority
- Reintroduction, reinforcement, and/or translocation
- Research (pests/pathogens; population genetics; reproductive biology/regeneration; restoration protocols/guidelines)

Recommended
- Education, outreach, and/or training
- Population monitoring and/or occurrence surveys
- Sustainable management of land

REFERENCES

1. **Gamen, T., & J. Firman. (2006).** *Oaks 2040: The status and future of oaks in California* (Gen. Tech. Rep. PSW-GTR-217). Retrieved from https://www.fs.fed.us/psw/publications/documents/psw_gtr217/psw_gtr217_603.pdf
2. **Los Angeles County. (2014).** Los Angeles County oak woodlands conservation management plan. Los Angeles, CA: Los Angeles County Oak Woodlands Strategic Alliance. Retrieved from http://planning.lacounty.gov/oakwoodlands
3. **Pavlik, B. M., Muick, P. C., Johnson, S. G., & Popper, M. (1991).** *Oaks of California*. Los Olivos, CA: Cachuma Press, Inc.
4. **NRCS. (n.d.).** Fact sheets & plant guides. PLANTS Database. Retrieved from http://plants.usda.gov/java/factSheet
5. **Tyler, C. M., Kuhn, B., & Davis, F. W. (2006).** Demography and recruitment limitations of three oak species in California. *The Quarterly Review of Biology*, 81(2).
6. **Howard, J. L. (1992).** *Quercus lobata*. In Fire Effects Information System [online]. CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from https://www.fs.fed.us/database/feis/plants/tree/quelob/all.html
7. **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
8. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
9. **Standiford, R. B. (2015).** Valley oak conservation. CA: University of California, Oak Woodland Management. Retrieved from http://ucanr.edu/sites/oak_range/Oak_Articles_On_Line/Oak_Woodland_Ecology_and_Monitoring/Valley_Oak_Conservation/
10. **Murphy, A. H., & Berry, L. J. (1973)**. Range pasture benefits through tree removal. *California Agriculture*, 8-9.
11. **NatureServe. (2017).** NatureServe Explorer: An online encyclopedia of life [online]. Version 7.1. Arlington, VA. Retrieved from http://explorer.natureserve.org
12. **Eskalen, A., Kabashima, J., Dimson, M., & Lynch, S. (2018).** *Invasive shot-hole borer and fusarium dieback field guide Identifying Polyphagous and Kuroshio shot-hole borer in California* (ANR Publication 8590). CA: University of California, Agriculture and Natural Resources. Retrieved from https://anrcatalog.ucanr.edu/pdf/8590.pdf
13. **Kueppers, L. M., Snyder, M. A., Sloan L. C., Zavaleta E. S., & Fulfrost, B. (2005).** Modeled regional climate change and California endemic oak ranges. *Proceedings of the National Academy of Sciences of the United States of America, 102*(45), 16281–16286. Retrieved from https://doi.org/10.1073/pnas.0501427102
14. **Sork, V. L., Davis, F. W., Westfall, R., Flint, A., Ikegami, M., Wang, H., & Grivet, D. (2010).** Gene movement and genetic association with regional climate gradients in California valley oak (*Quercus lobata* Nee) in the face of climate change. *Molecular Ecology*, 19, 3806–3823. Retrieved from https://doi.org/10.1111/j.1365-294X.2010.04726.x
15. **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
16. **Morrison, M. L., Block, W. M., & Verner, J. (1991).** Wildlife-habitat relationships in California's oak woodlands: Where do we go from here? *In Wildlife habitat & relationships of hardwood rangelands* (Gen. Tech. Rep. PSW-126). Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/treesearch/pubs/28406
17. **U.S. EPA Office of Research & Development. (2013, April).** 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
18. **Los Angeles County. (2015).** *Los Angeles County 2035 General Plan.* CA: Los Angeles County Department of Regional Planning. Retrieved from http://planning.lacounty.gov/generalplan/generalplan
19. **Yolo County. (2007, January).** *Yolo County oak woodland conservation and enhancement plan*. Woodland, CA: Yolo County Parks and Natural Resources Management Division & Yolo County Planning, Resources, and Public Works Department Retrieved from http://www.yolocounty.org/home/showdocument?id=4040
20. **Mix, A. D., Wright, J. W., Gugger, P. F., Liang, C., & Sork, V. L. (2015).** Establishing a range-wide provenance test in Valley oak (*Quercus lobata* Née) at two California sites. In *Proceedings of the seventh California oak symposium: managing oak woodlands in a dynamic world* (Gen. Tech. Rep. PSW-GTR-251). Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/treesearch/pubs/50010
21. **Dagit, R., Contreras, S., Dauksis, R., Sprykia, A., Queally, N., Foster, K., Nickmeyer, A., Rousseau, N., Chang., E. (2017).** H*ow can we save our native trees? Drought and invasive beetle impacts on wildland trees and shrublands in the Santa Monica Mountains.* Retrieved from www.rcdsmm.org/wp-content/uploads/2016/04/Drought-and-Invasive-Beetle-impacts-RCDSMM-1.2.18.pdf
22. **Valley Oak Genome Project. (2016).** Valley oak phenology. Retrieved from https://valleyoak.ucla.edu/valley-oak-phenology/
23. **County of Santa Barbara. (2009).** *Santa Barbara County comprehensive general plan: Conservation element — Oak tree protection in the inland rural areas of Santa Barbara County.* Retrieved from http://longrange.sbcountyplanning.org/programs/conservationelement/conservation_element.php

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus oglethorpensis***

Emily Beckman, Matt Lobdell, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, ***Quercus oglethorpensis****, Quercus similis*

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U S DEPARTMENT AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus oglethorpensis W.H.Duncan

Synonyms: N/A **Common Names:** Oglethorpe oak

Species profile co-author: Matt Lobdell, The Morton Arboretum

Suggested citation: Beckman, E., Lobdell, M., Meyer, A., & Westwood, M. (2019). *Quercus oglethorpensis* W.H.Duncan. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 152-157). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-oglethorpensis.pdf

DISTRIBUTION AND ECOLOGY

Quercus oglethorpensis, or Oglethorpe oak, has a disjointed distribution across the southern U.S. Smaller clusters of localities exist in northeastern Louisiana, southeastern Mississippi, and southwestern Alabama, and a more extensive and well-known distribution extends from northeastern Georgia across the border into South Carolina. There has been relatively little research regarding the full distribution of this species, as it wasn't described until 1940 and has only recently received attention from the botanic community. From 1975 to 2013, about seven new localities were discovered. Oglethorpe oak is known to be locally uncommon, and previous sites have recently been found unoccupied upon the following visit (M. Lobdell pers comm., 2017). The species' most vigorous subpopulations exist within the distinctive Piedmont Gabbro Upland Depression Forest (PGUDF) ecosystem. This association consists of a patchy, wet hardwood forest that only occurs on gently sloping or slightly concave upland terrain in Georgia and South Carolina.[1] There is evidence that *Q. oglethorpensis* had a denser population before colonial settlement, but agriculture and other land alterations have restricted its distribution.[2] Across its range, *Q. oglethorpensis* is found in moist, heavy chalk or limestone soils that are rich and contain high clay content. The tree usually reaches about 18 meters, but can grow up to 25 meters in height.[3]

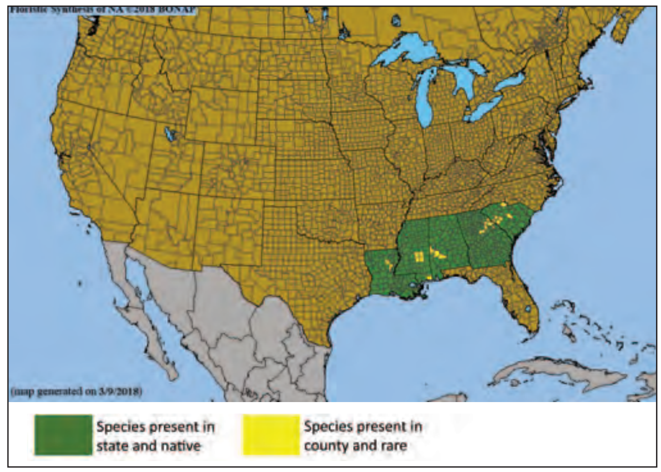


Figure 1. County-level distribution map for *Quercus oglethorpensis*. Source: Biota of North America Program (BONAP).[4]

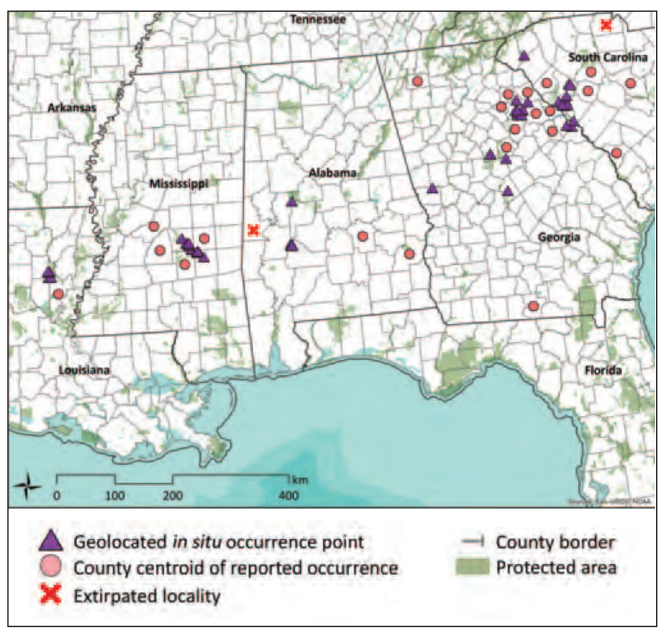


Figure 2. Documented *in situ* occurrence points for *Quercus oglethorpensis*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus oglethorpensis*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	10
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	5
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	20
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
						Average vulnerability score	11.7
						Rank relative to all U.S. oak species of concern (out of 19)	7

THREATS TO WILD POPULATIONS

High Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Damming and flooding in some areas have changed the floodplain ecosystems on which Oglethorpe oak relies.[6]

Moderate Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: Land use changes have posed a large threat to *Q. oglethorpensis* in the past, but most areas suitable for agriculture or silviculture have already been cleared, leaving wetter areas or roadside occurrences remaining.[2,7]

Human use of landscape — residential/commercial development, mining, and/or roads: Forest clearing for urban and suburban development shrunk the distribution of *Q. oglethorpensis*, but most areas suitable for development have already been converted.[2,7]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Dry-season fires render concern, since Oglethorpe oak seedlings and saplings are not fire-tolerant. Extreme drought and flooding have recently been experienced by the region, and further changes due to climate change are expected.[8]

Genetic material loss — inbreeding and/or introgression: Genetic research has found that some populations of *Q. oglethorpensis* exhibit moderate to high levels of inbreeding, compared to other wind-pollinated species.[9] As with other rare oaks, genetic introgression may also be a problem.

Pests and/or pathogens: Changes in the hydrology of the region have led to insubstantial regeneration and serious losses due to chestnut blight (*Cryphonectria parasitica*), which cannot survive in wetland sites but attacks upon drainage.[8] In Louisiana, there is initial evidence of disease caused by a member of the Botryosphaeriaceae family. A sample was collected by Adam Black and cultured at the University of Florida; further collection from the infected *Q. oglethorpensis* population has been planned, to confirm the pathogen's identity (M. Lobdell pers. comm., 2018).

Low Impact Threats

Human modification of natural systems — invasive species competition: Invasive plants such as Japanese honeysuckle (*Lonicera japonica*), Autumn olive (*Elaeagnus umbellata*), and Chinese privet (*Ligustrum sinense*) compete with seedlings.[6] In transitional forests where the species occurs, including some districts of Bienville National Forest, successional species such as Liquidambar styraciflua and Nyssa sylvatica may also be a source of competition by shading out establishing seedlings and saplings (M. Lobdell pers. comm., 2018).

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	30
Number of plants in *ex situ* collections:	392
Average number of plants per institution:	13
Percent of *ex situ* plants of wild origin:	93%
Percent of wild origin plants with known locality:	98%

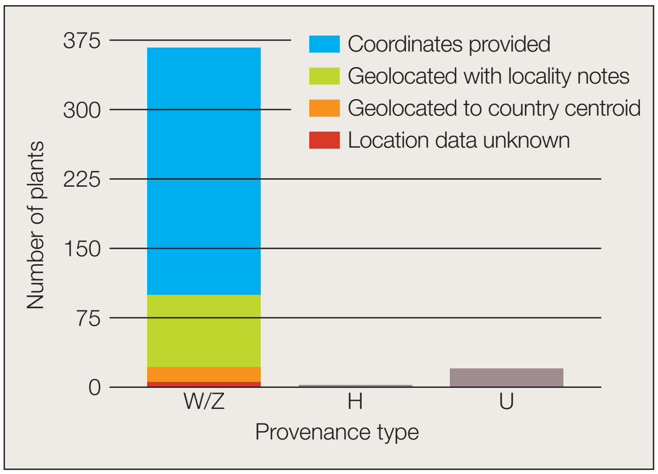


Figure 3. Number and origin of *Quercus oglethorpensis* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

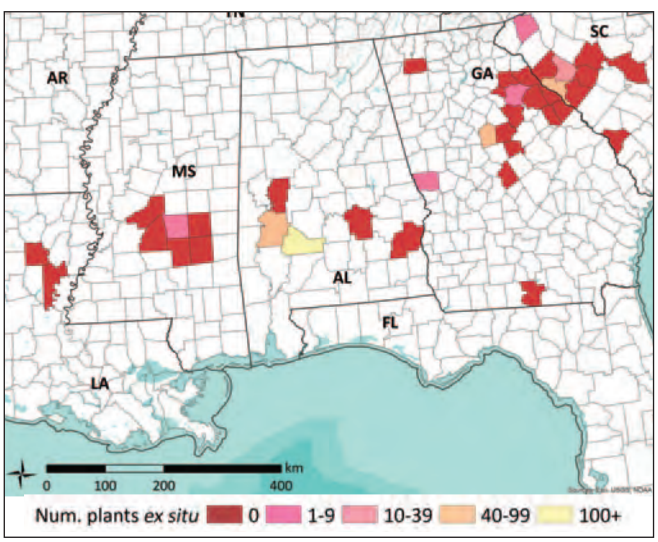


Figure 4. *Quercus oglethorpensis* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	38%
Ecological coverage:	33%

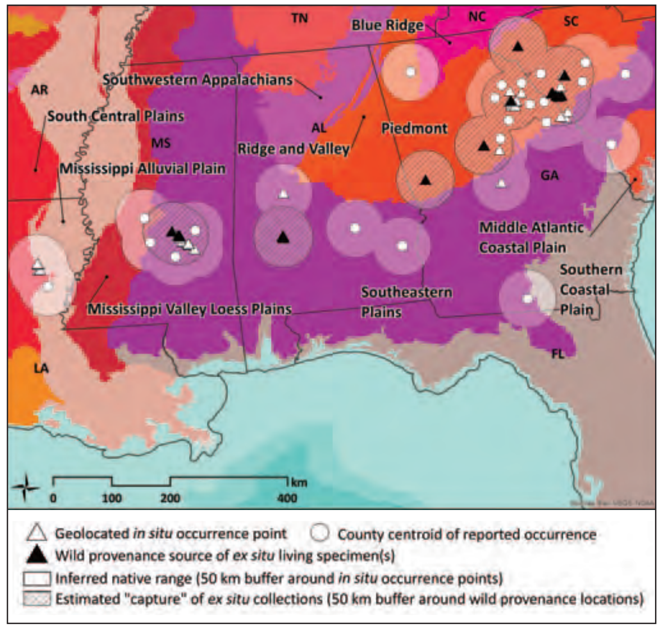


Figure 5. *Quercus oglethorpensis in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[10] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

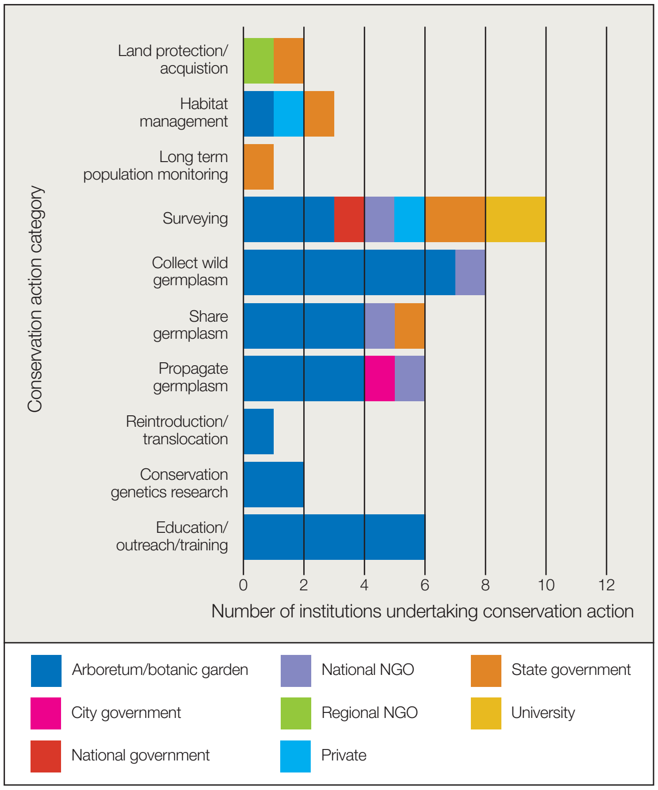


Figure 6. Number of institutions reporting conservation activities for *Quercus oglethorpensis* grouped by organization type. Twenty-four of 252 institutions reported activities focused on *Q. oglethorpensis* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. oglethorpensis*, 9% of the land is covered by protected areas (Figure 7). Some relatively healthy populations are known in protected areas, but the majority of Oglethorpe oak habitat is privately owned.

The non-profit regional land trust Broad River Watershed Association preserves natural areas within Georgia's Broad River basin and lists *Q. oglethorpensis* as a rare species within the area.[11] Oglethorpe oak is also known from Bienville National Forest in Mississippi, Oconee National Forest and George L. Smith State Park in Georgia, and Sumter National Forest in South Carolina (M. Lobdell pers. comm., 2017).

Sustainable management of land: Three protected areas are known to currently monitor and manage *Q. oglethorpensis* within their boundaries, performing controlled burns and selective clearing; these include Bienville National Forest, Oconee National Forest, and Sumter National Forest (M. Lobdell pers. comm., 2017). The Georgia Department of Natural Resources manages George L. Smith State Park, approximately 87 hectares, with prescribed fire.[12]

Population monitoring and/or occurrence surveys: A 2014 floristic inventory of the Piedmont Gabbro Upland Depression Forests was administered at three sites, approximately 600 acres each, in Oconee National Forest in Jasper County, Georgia. The survey documented 541 vascular plant species in 319 genera and 111 families, including *Q. oglethorpensis*.[1] Extensive scouting was performed before and during germplasm collections in 2017, lead by The Morton Arboretum, in partnership with Tulsa Botanic Garden and Peckerwood Garden, and supported by a 2017 APGA-USFS Tree Gene Conservation grant. These surveys continued in 2018 (M. Lobdell pers. comm., 2018).[13]

Wild collecting and/or *ex situ* curation: With funding from a 2015 APGA-USFS Tree Gene Conservation Partnership grant, The Morton Arboretum led a collecting trip which gathered a total of 287 acorns from 28 populations of *Q. oglethorpensis* in Alabama, Georgia, and South Carolina. No fruiting individuals were located in Bienville National Forest, Mississippi, but scion wood was collected for grafting. One fruiting tree was observed in Sumter National Forest (South Carolina), from which about 40 acorns were collected. The population near Catherine, Alabama was the most extensively sampled, with 274 acorns collected. Acorns were propagated at The Morton Arboretum and, following the first growing season, a portion was shipped to three botanic gardens and arboreta with Nationally Accredited Collections of oaks: The Holden Arboretum, Chicago Botanic Garden, and Starhill Forest Arboretum. This distributes the germplasm over an area approximately 635,000 kilometers squared.[14] Another APGA-USFS Tree Gene Conservation Partnership grant was awarded in 2017 for the collection of *Q. oglethorpensis* populations within Mississippi and Louisiana, which were not covered by the first project. Unfortunately, no acorns were found during this expedition (M. Lobdell pers. comm., 2018).[13]

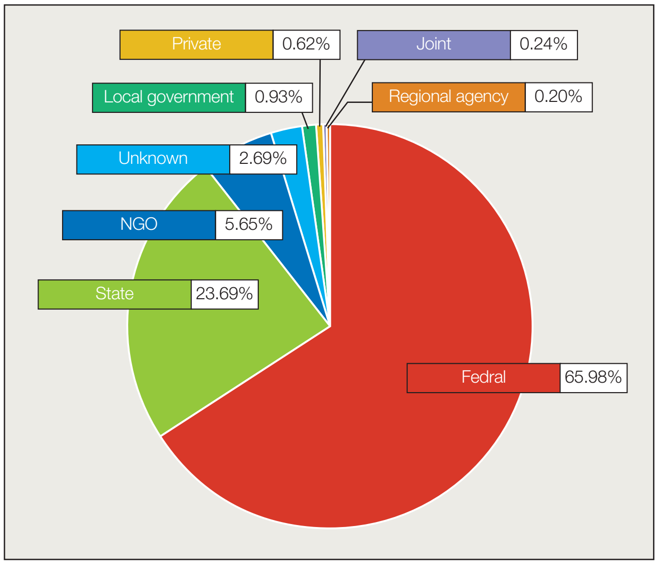


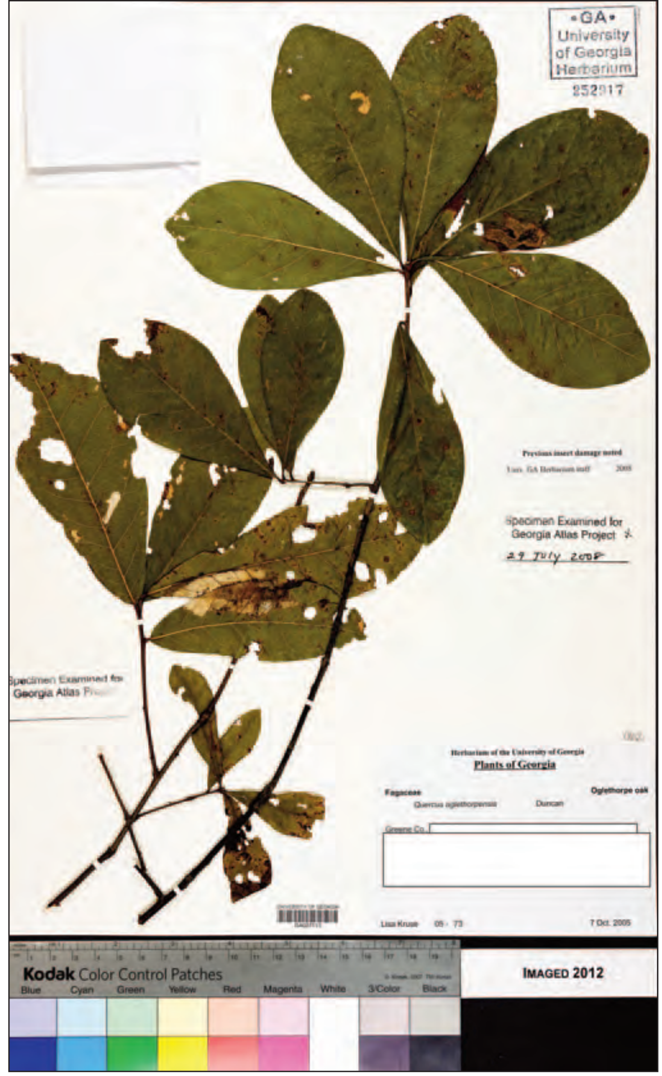
Figure 7. Management type of protected areas within the inferred native range of *Quercus oglethorpensis*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

Propagation and/or breeding programs: Acorns collected during the 2015 expedition are in propagation at four botanic gardens and arboreta within the U.S. "By cultivating and evaluating the species in the collections of botanical gardens and arboreta, a better understanding of its ideal growing conditions will be gained, and the success rate for *Q. oglethorpensis* in cultivation will likely increase."[14] Acorns collected in 2017 are in propagation at The Morton Arboretum. Following germination, a determination will be made as to their species. Resulting *Q. oglethorpensis* seedlings will be divided among Bartlett Tree Research Laboratories and Arboretum, Chicago Botanic Garden, The Morton Arboretum, Peckerwood Garden, Polly Hill Arboretum, US National Arboretum, and Tulsa Botanic Garden.[13]

Reintroduction, reinforcement, and/or translocation: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Research: Oglethorpe oak coexists with many other rare species and has experienced a significant decrease in healthy habitat, prompting ecosystem-focused research. For example, a floristic inventory and site quality assessment was completed for the Piedmont Gabbro Upland Depression Forests plant association, which is ranked as globally Imperiled by NatureServe. This habitat is endemic to a few scattered locations in the Piedmont regions of Georgia and South Carolina, and houses *Q. oglethorpensis*.[1] Research focused on propagation and provenance tests of Oglethorpe oak is underway through a APGA-USFS Tree Gene Conservation Partnership grant.[14]

Wood (2018) sampled populations of *Q. oglethorpensis* in South Carolina, Georgia, Alabama, Mississippi and Louisiana to examine population structure and compare the genetic diversity found among *in situ* populations versus *ex situ* collections. He found that Bienville National Forest had the highest allelic diversity, Monticello Glades and Buffalo Mills Road harbored the most unique alleles, and Louisiana harbors the only two populations that did not show significant inbreeding. In his examination of all possible *ex situ* sampling combinations, Wood showed that "to capture 90% of the globally common alleles would require collecting samples from between 15 and 20 trees from at least 6 of the 7 populations, while capturing 90% of locally common alleles would require 5 trees from 6 of the 7 populations." At the start of the study, Wood found that *ex situ* collections contained less than 63% of the total alleles found in wild samples of Oglethorpe oak from across its range. After collecting samples for the study and distributing them to *ex situ* collections, genetic capture within *ex situ* collections rose to 86%.[9]



Education, outreach, and/or training: Oglethorpe oak is rarely available from nurseries, but plants can be obtained from Woodlanders, Inc nursery.[15]

Species protection policies: Oglethorpe oak is listed as Threatened in Georgia, "rare" in South Carolina, and S1 (state-level Critically Imperiled) in Louisiana. One example of the effect state listing has in Georgia can be seen in the environmental review for a proposed hydroelectric dam project; the review reports the presence of *Q. oglethorpensis* and any effects the company may have on its population, which is required before moving forward with the project.[16] Athens-Clarke County has created a Tree Species List that aims to "support the development code, site planning and design activities for tree conservation and establishment, and tree maintenance planning and decision-making;" this list includes *Q. oglethorpensis*.[17]

PRIORITY CONSERVATION ACTIONS

Further conservation efforts for Oglethorpe oak should be two-fold, focusing on both *in situ* and *ex situ* efforts. Floristic surveys should continue on a semi-regular basis with the goal of locating potentially undocumented populations, as well as confirming the continued existence of narrow disjuncts. Reported losses of populations such as those in Sumter County, Alabama, a mere few years after their initial documentation, indicates the urgency of conservation activities in many sites, particularly those located on private or unprotected land. Depending on the site, a combination of various conservation activities could be pursued: acquiring land for protection; engaging landowners and land managers in training regarding Oglethorpe oak identification and/or appropriate habitat management; providing resources for sustainable management of land within areas already protected; reinforcing or translocating populations that are dwindling or threatened by land use changes, especially those with unique genetic diversity.

The relative hardiness of the species as demonstrated by cultivation at The Morton Arboretum (Lisle, IL) suggests *ex situ* conservation could also play a valuable role in the long-term preservation of the species. Material in cultivation is still heavily skewed towards specimens with provenance of the type locality in Oglethorpe County, Georgia or large populations in Greenwood County, South Carolina. Further collection of material from the western portion of the species distribution would be valuable. In addition, it may prove useful to engage in ecological niche and climate change modeling for *Q. oglethorpensis*. These data could help identify areas for further scouting that may harbor unknown populations of the species, as well as aid in planning for future habitat changes, which would inform current *in situ* and *ex situ* conservation activities.

Conservation recommendations for *Quercus oglethorpensis*

Highest Priority

- Population monitoring and/or occurrence surveys
- Sustainable management of land
- Wild collecting and/or *ex situ* curation

Recommended

- Education, outreach, and/or training
- Land protection
- Reintroduction, reinforcement, and/or translocation
- Research (climate change modeling; demographic studies/ecological niche modeling; land management/disturbance regime needs; pests/pathogens; restoration protocols/guidelines)

REFERENCES

1. **Sewell, S. Y., & Zomlefer, W. B. (2014).** Floristics of Piedmont Gabbro Upland Depression Forests in Jasper County, Georgia. Castanea, 79(3), 195-220. doi:10.2179/14-019
2. **Haehnle, G. G., & Jones, S. M. (1985).** Geographical distribution of *Quercus oglethorpensis*. *Castanea*, 50(1), 26-31. Retrieved from https://www.jstor.org/stable/4033102
3. **Louisiana Department of Wildlife and Fisheries. (n.d.).** *Quercus oglethorpensis* Duncan: Rare plant fact sheet PDFAG051M0. Natural Heritage Program. Retrieved from http://www.wlf.louisiana.gov/sites/default/files/pdf/fact_sheet_plant/31897-Quercus%20oglethorpensis/quercus_oglethorpensis.pdf
4. **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
5. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
6. **Chafin, L. G. (2007).** *Field guide to the rare plants of Georgia*. Athens, GA: The State Botanical Garden of Georgia and University of Georgia Press.
7. **Lobdell, M., & Thompson, P. (2017).** *Ex-situ* conservation of *Quercus oglethorpensis* in living collections of arboreta and botanical gardens. In Sniezko, R. A., Man, G., Hipkins, V., Woeste, K., Gwaze, D., Kliejunas, J. T., & McTeague, B. A. (Tech. coords.), *Gene conservation of tree species—banking on the future workshop proceedings* (Gen. Tech. Rep. PNW-GTR-963). Portland, OR: Pacific Northwest Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/treesearch/pubs/55112
8. **Coder, K. D. (2003, December).** *Oglethorpe oak: Sunset of a species*. Athens, GA: University of Georgia Warnell School of Forest Resources.
9. **Wood, J. (2018).** *Conservation genetics and* ex situ *management for living collections for endangered plants* (Unpublished master's thesis). Northwestern University & Chicago Botanic Garden.
10. **U.S. EPA Office of Research & Development. (2013, April).** 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
11. **Broad River Watershed Association. (2013).** Trees/shrubs. Retrieved from http://www.brwa.org/natural-guide/plants/plants—-trees/
12. **Long, J. M., & Schenk, J. (2017).** *Comparative floristic studies of Georgian Sandhill ecosystems reveals a dynamic composition of endemics and generalists.* Georgia Southern University Honors Program Theses. 247. Retrieved from http://digitalcommons.georgiasouthern.edu/honors-theses/247
13. **Lobdell, M. (2017).** *APGA/USFS Tree Gene Conservation Partnership report on 2017 scouting and collection efforts targeting* Quercus oglethorpensis. Lisle, IL: The Morton Arboretum. Retrieved from https://www.publicgardens.org/sites/default/files/2017%20Quercus%20oglethorpensis%20II%20report.pdf
14. **Lobdell, M., & Thompson, P. (2015, December).** *APGA/USFS Tree Gene Conservation Partnership: Report on scouting and collection efforts targeting* Quercus oglethorpensis. Retrieved from https://publicgardens.org/sites/default/files/images/documents/OglethorpeReport_LobdellMandThompsonP_2015-12-17.pdf
15. **Coombes, A. J., & Coates, W. N. (1997).** Oglethorpe and the Oglethorpe oak. *Arnoldia*, (Summer), 25-30. Retrieved from http://arnoldia.arboretum.harvard.edu/pdf/articles/1997-57-2-oglethorpe-and-the-oglethorpe-oak.pdf
16. **Georgia Power. (2015, February).** Pre-application document: Wallace Dam Hydroelectric Project FERC, project number 2413.
17. **Athens-Clarke County. (n.d.).** The Athens-Clarke County tree species list. Retrieved from https://www.athensclarkecounty.com/DocumentView.aspx?DID=281

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus pacifica***

Emily Beckman, Mario B. Pesendorfer, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, *Quercus tomentella*

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum®

BOTANIC GARDENS CONSERVATION INTERNATIONAL

FOREST SERVICE U S DEPARTMENT AGRICULTURE

FAUNA & FLORA INTERNATIONAL

Quercus pacifica Nixon & C.H.Müll.

Synonyms: *Quercus dumosa* var. *polycarpa* Greene **Common Names:** Island scrub oak, Channel Island scrub oak, Pacific oak

Species profile co-author: Mario B. Pesendorfer, Cornell Lab of Ornithology/Smithsonian Conservation Biology Institute, National Zoological Park
Contributors: Janet Rizner Backs, Department of Biological Sciences, University of Illinois at Chicago; Lyndal Laughrin, Santa Cruz Island Reserve, UC Santa Barbara Natural Reserve System

Suggested citation: Beckman, E., Pesendorfer, M. B., Meyer, A., & Westwood, M. (2019). *Quercus pacifica* Nixon & C.H.Müll. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 158-165). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-pacifica.pdf

DISTRIBUTION AND ECOLOGY

Quercus pacifica, or Island scrub oak, is endemic to three of the California Channel Islands, U.S.: Santa Cruz, Santa Catalina, and Santa Rosa. The species is not present on the California mainland, but did previously bear the name *Quercus dumosa*, as was applied to a few shrub oaks in the "*Q. dumosa* complex." At least five taxa within this complex are now recognized as distinct species, based on acorn morphology, leaf vestiture, and habitat. *Quercus pacifica* occurs from 0 to 700 meters above sea level, and grows most often as a shrub reaching two meters tall, but can also appear in a small tree form, five or more meters. This species is the dominant component of Island scrub oak chaparral, covering a variety of surfaces including ridges, open slopes, and canyons.[1] Also present in oak woodland, grassland margins, and closed-pine understory, this species is mainly limited by its occurrence on only three islands, rather than a need for very specialized habitat. Trees mature at about 40 years of age, and live up to 100 years or longer.[2]

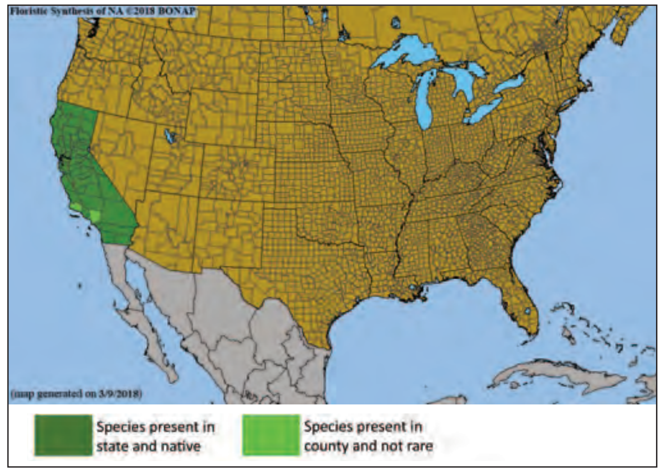


Figure 1. County-level distribution map for *Quercus pacifica*. Source: Biota of North America Program (BONAP).[3]

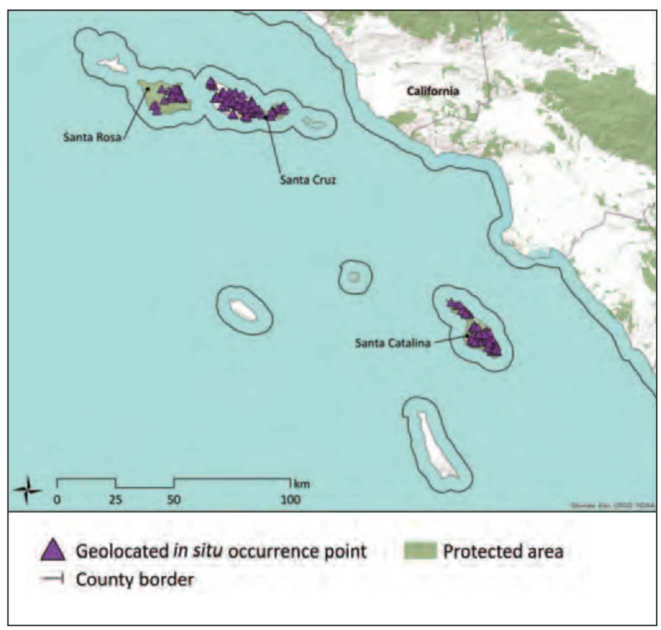


Figure 2. Documented *in situ* occurrence points for *Quercus pacifica*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus pacifica*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	Score
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	20
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	0
						Average vulnerability score	8.3
						Rank relative to all U.S. oak species of concern (out of 19)	11

THREATS TO WILD POPULATIONS

High Impact Threats

Human Use of Landscape - e.g. agriculture, ranching, grazing, silviculture: Ranching and subsequent decimation by introduced herbivores (feral pigs, goats, sheep) occurred for more than a century on all of the Channel Islands. Feral goats and pigs were removed from Santa Catalina Island by the Catalina Island Conservancy in the early 2000s.[5] The Nature Conservancy successfully eradicated feral sheep from 90% of Santa Cruz Island by 1988 and pigs by 2008.[6,7] Sheep and cattle were removed from Santa Rosa Island by 1998, however remaining trees struggled to reproduce in the dry, eroding soils that are no longer sheltered by a shrub layer.[8,9] Past wood harvesting could have also decimated large areas of oak habitat on all three islands.

Moderate Impact Threats

Human Modification of Landscape - e.g. fire and fire suppression, eradication, pollution: Air pollution has the potential strain *Q. pacifica* stands, but fire regime alteration is known to stress Santa Catalina Island's native ecosystem. On the Island, "fire is a natural disturbance...however, high fire frequency can eliminate woody plants and cause a type conversion to non-native annual grassland."[11,12] Pond core samples from Santa Rosa Island suggest that fire frequency was generally low before human arrival and likely increased due to active habitat management by Chumash Native Americans.[9,13] Natural ignition rates are thought to be relatively low in coastal areas.[14]

Human Modification of Landscape - e.g. invasive species competition: Non-native annual grasses likely contribute to reduced acorn germination and survival of oak seedlings through a combination of competition, nutrient cycling shifts, insect facilitation, and disturbance regime alteration on the Channel Islands; experiments utilizing prescribed burning or mechanical removal of invasive plants are necessary to confirm these hypotheses. Burns may prove difficult though, since the grasses seem to "act as ladder fuels, carrying fire into the canopy of oaks."[2,5] On Santa Cruz Island, non-native fennel (*Phoeniculus vulgare*) has spread extensively, particularly after the removal of pigs.[15,16,17] Non-native black-tailed deer have recently achieved record densities on Santa Rosa Island, and *Q. pacifica* leaves form an integral part of their diet. Oak seedlings were also found to be strongly affected by physical destruction and trampling by non-native bison (*Bos bison*).[18]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figure 3). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 5).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	11
Number of plants in *ex situ* collections:	80
Average number of plants per institution:	7
Percent of *ex situ* plants of wild origin:	85%
Percent of wild origin plants with known locality:	96%

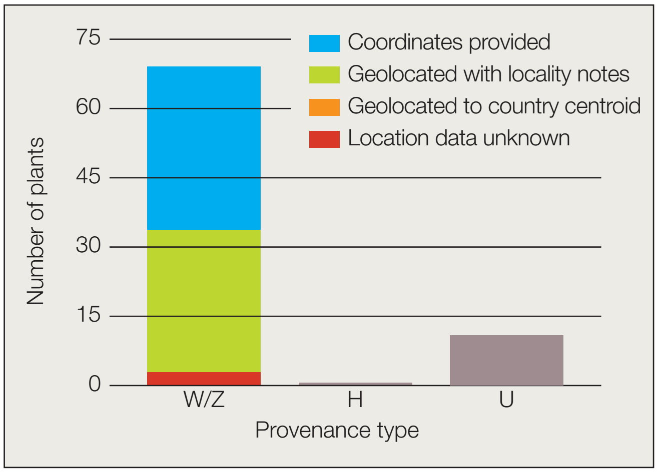


Figure 3. Number and origin of *Quercus pacifica* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 4). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	67%
Ecological coverage:	100%

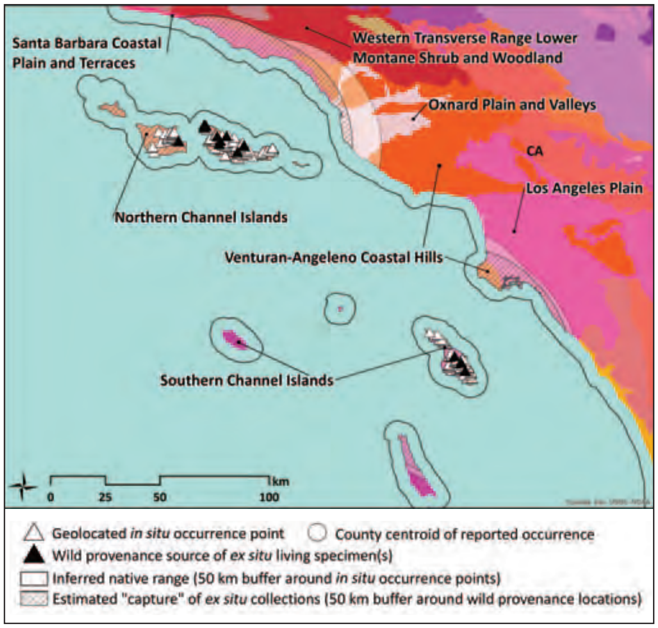


Figure 4. *Quercus pacifica in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level IV Ecoregions are colored and labelled.[22] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

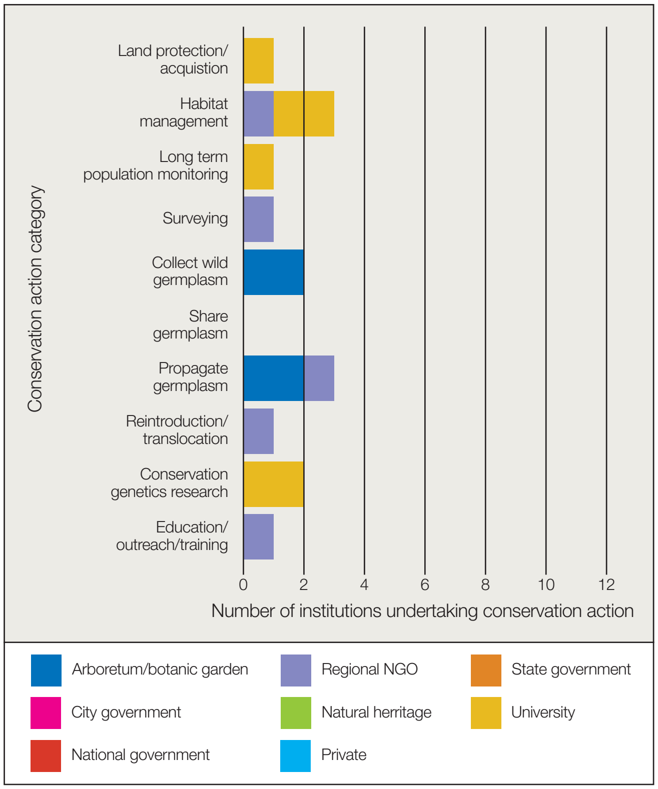


Figure 5. Number of institutions reporting conservation activities for *Quercus pacifica* grouped by organization type. Six of 252 institutions reported activities focused on *Q. pacifica* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. pacifica*, 46% of the land is covered by protected areas (Figure 6). However, because this species' distribution is small and well-documented, we know that nearly 100% of the species' potential occurrences within the U.S. are within protected areas.

The Catalina Island Conservancy owns and manages 88% of the Island, The National Park Service owns all of Santa Rosa Island and the eastern 24% of Santa Cruz Island, and The Nature Conservancy owns the remaining 76% of Santa Cruz Island. Little protection has been necessary on Santa Rosa and Santa Cruz following the removal of non-native ungulates.[19,23] Island scrub oak groves that burned during the 1999 Goat Harbor fire on Santa Catalina Island were fenced due to decimation of basal sprouts by deer.[11]

Sustainable management of land: The Catalina Island Conservancy has developed and implemented a comprehensive management program for the Island, entitled Catalina Habitat Improvement and Restoration Program (CHIRP). The Conservancy uses both chemical and manual techniques for removing invasive plants, which began with "mapping of all manageable invaders then eradication of high-impact, low-abundance species and control of high-impact, high-abundance taxa in priority areas;" preventative treatment along dispersal corridors is also a high priority.[5,24] A draft fire management plan was created for Santa Catalina Island in 2003, but "the mosaic rotational burning may not be appropriate for the habitat types and conditions on Catalina Island."[5]

Since the removal of non-native livestock led to a rebound of Island scrub oak on Santa Cruz, many hope that the other two islands will soon recover as well.[2] However, a recent study simulated the observed oak habitat recovery on Santa Cruz and suggests that the absence of seed dispersal by birds has a stifling effect on the spatial extent of recovery, as movement by gravity only allows recovery of areas down-hill from current stands.[10] A potential management for Santa Rosa Island therefore includes the reintroduction of the recently-extinct Island scrub-jay (*Aphelocoma insularis*).[7]

Population monitoring and/or occurrence surveys: Within-stand densities, tree sizes, and acorn production of *Q. pacifica* populations on all three islands of occurrence have recently been surveyed, and subpopulations on Santa Cruz Island are experiencing a strong recovery from past decline.[21] Long-standing vegetation monitoring has also been in place, such as a study between 1984 and 2005 on Santa Cruz Island, which observed the response of endemic plant species to the eradication of feral sheep.[6] Recent studies have found that passive recovery of Santa Cruz Island has resulted in an increase of woody vegetation overstory from 27% to 53%, yet a decline in oak cover on their transects was recorded between 1980 and 2012.[25] Because *Q. pacifica* is a late-successional species, however, the effects of herbivore removal will likely take time to affect oak distributions.

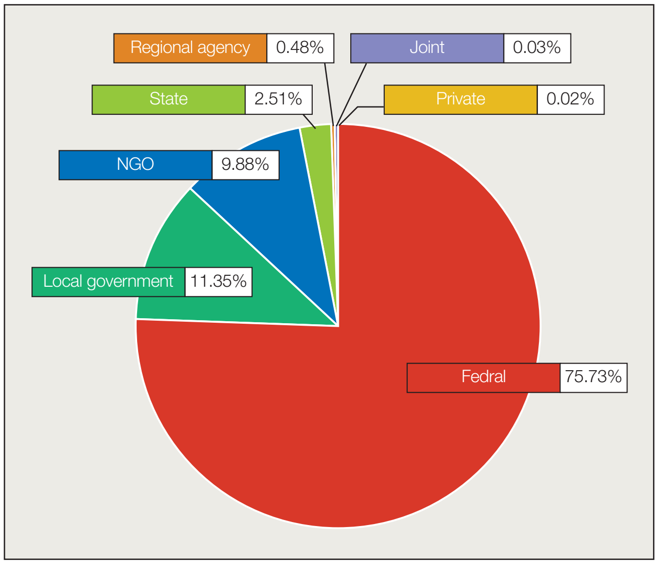


Figure 6. Management type of protected areas within the inferred native range of *Quercus pacifica*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

Based on remote-sensing data of vegetation patterns, spatial autocorrelation of woody vegetation in the landscape is likely a consequence of seed dispersal by Island scrub-jays and Island foxes (*Urocyon littoralis santacruzae*).[26] An ongoing long-term study (Santa Cruz: 2008 – current; Santa Rosa: 2012 – current) of ~400 *Q. pacifica* individuals is tracking growth, survival, and seed production; the data suggest low mortality of adults (M. Pesendorfer, unpublished data).[21] The Santa Catalina Conservancy also closely monitors populations of *Q. pacifica* on the Island.[12]

Wild collecting and/or *ex situ* curation: Two institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Propagation and/or breeding programs: The Catalina Island Conservancy has participated in active restoration of *Q. pacifica* habitat, including propagation and planting of young oaks; this initiative began with a pilot monitoring study in 2001. Another project, this time focused on Santa Cruz Island, recently planted over 600 acorns within a greenhouse to determine the possible role of acorn size in *Q. pacifica* regeneration.[27] *Quercus pacifica* is available for public purchase at Ackerman Native Plant Nursery.[28]

Reintroduction, reinforcement, and/or translocation: Subpopulations on Santa Cruz Island have experienced a strong recovery from past decline, but the subpopulations on Santa Rosa and Santa Catalina islands are still of conservation concern, with active management occurring through acorn planting in disturbed oak habitat.[27] Following a 258-acre fire on Santa Cruz Island in March 2018, Pesendorfer and colleagues have initiated restoration trials aimed to increase acorn hoarding by Island scrub-jays in target areas along the fire perimeter (M. Pesendorfer pers. comm., 2018).

Research: Many research initiatives exist for species and ecosystems on the California Channel Islands; the following paragraphs give a sample of these activities.

Backs & Ashley (2016) took samples from all three islands where *Q. pacifica* is found and assessed their genetic makeup: "Genetic differentiation of *Q. pacifica* among islands is small but significant. Both recent and historical gene flow were surprisingly high considering the disjunct distribution of *Q. pacifica* on islands separated by as much as 125 km of open ocean...We found no evidence for recent bottlenecks, suggesting that the overgrazing and vegetation loss of the 20th century did not have a negative genetic impact on *Q. pacifica*. We did find evidence that bottlenecks took place at some time in the past, perhaps associated with the original colonization of the islands."[30]

Pesendorfer *et al*. (2014) "sampled within-stand densities, tree sizes, and acorns in 3 island populations that have been exposed to different herbivores, seed predators, and climate conditions" on Santa Cruz Island. Findings revealed that "trees at higher elevations produced more acorns, but the roles of temperature and precipitation were unclear." Long-term monitoring across the California Channel Islands would be necessary to better understand the acorn production drivers for *Q. pacifica*.[21] A subsequent study found that "larger acorns are more likely to germinate," and "acorn mass had strong effects on root mass, shoot mass, seedling height and leaf surface area." Therefore, they suggest that managers plant larger acorns within restoration projects.[27] Klinger *et al*. (2002) also studied Santa Cruz Island, focusing on the complex effects of removing non-native grazers (e.g., goats, cheep, cows): "It is often assumed that removing nonnative grazers from islands will lead to recovery of native specie. This assumption can be justified to a certain degree, but as a general expectation it is probably overly simplistic. As the patterns showed on [Santa Cruz Island], removing feral animals from islands will lead to a range of complex effects, many of which will be beneficial to native species and many of which may not."[6]

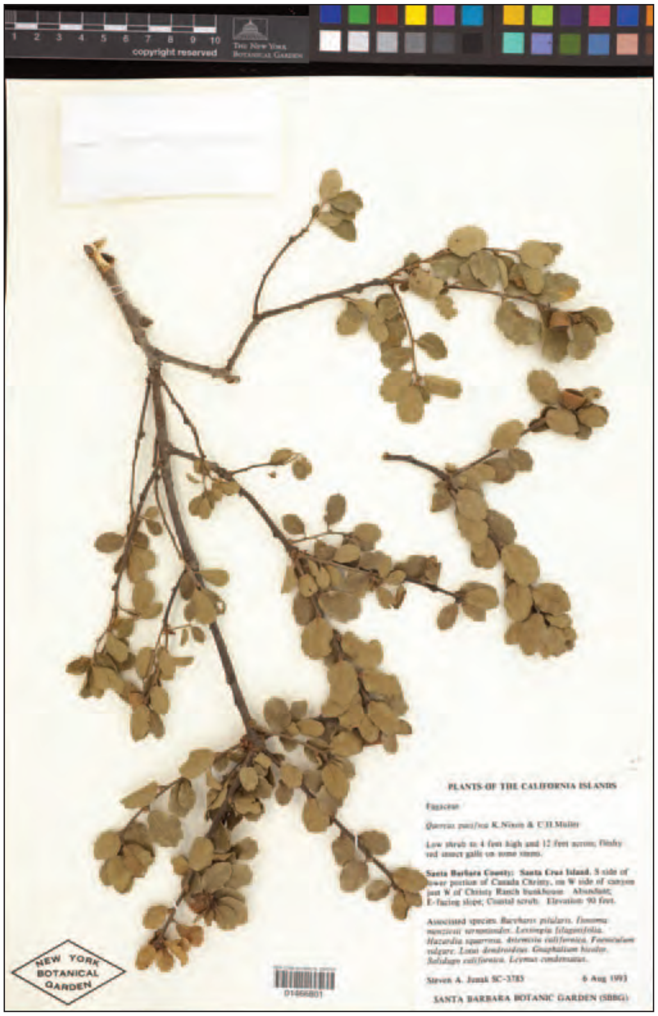
In 2001 a pilot study was conducted by Catalina Island Conservancy, which mapped oak individuals in eight 30 by 6 meter transects; data gathered included age class, number of stems/trunks, basal diameter of the largest three trunks, overall health, acorn production, and animal/pest damage. Half of the transects were located on the western end of the Island, where all feral animals except deer have been removed since the mid to late 1990's, and the other half were in the north-central portion of the Island where non-native animal removal has been more recent. The study found an average 26% of trees in each transect to be dead, saplings within only two of the eight transects, and seedlings in three of the eight transects. Acorns were seldom found, though many trees were ranked as having good or very good overall health; but no trees were ranked as excellent.[29]

In partnership with the National Park Service, Dr. McEachern and colleagues are studying the cloud forest recovery on Santa Rosa Island, which includes stands of Island scrub oak. They are utilizing "artificial structures to slow erosion, capture fog, increase soil moisture and establish plants from nursery-grown stock and seeds. The project's long-term goals are to create self-sustaining stands of trees and shrubs that can re-start the upland hydrologic cycle, and demonstrate the local effects of fog on plant growth, soil moisture, erosion rates, sustainability and ecological complexity."[31]

Steve Matson

Education, outreach, and/or training: A description of *Q. pacifica* care and uses within gardens and patios is available online at learn2grow.com. It has also been pointed out that, "some of the Island's constraints are also key assets. The high level of visitation to Santa Catalina makes it an ideal educational and outreach center. The Conservancy's Nature Center and Botanical Garden are perfect venues to educate about the uniqueness of the islands, the threats that face them, and the benefits of restoration."[24] In collaboration with UC Santa Barbara's Office of Education Partnerships, Pesendorfer and Sillett have initiated annual conservation experience workshops, which introduce undergraduate students from underrepresented minority background to basic techniques of field ecology. In addition, students from the Smithsonian Scholars Program have been conducting oak restoration trials in the 2018 fire scar (M. Pesendorfer pers. comm., 2018).

Species protection policies: No known initiatives at the time of publication.



PRIORITY CONSERVATION ACTIONS

While Island scrub oak has received more attention from managers and scientists than other western North American scrub oak species, there are substantial gaps in our understanding; these gaps include population dynamics and regeneration across its range, potential vulnerabilities to changes in abiotic conditions and threats from non-native pests, as well as effective management tools to ensure the long-term persistence of the species. Specifically, research and management efforts would benefit from coordination across institutions and populations, so that biotic and abiotic drivers of die-off and recruitment can be identified. Annual oak surveys should be incorporated into a long-term monitoring program across the California Channel Islands. Such information would be crucial to project potential impacts of changes in temperature and precipitation, and to gain a better understanding of *Q. pacifica* acorn production drivers. Furthermore, in light of potential threats by non-native pests such as the goldspotted oak borer (*Agrilus coxalis*), which has devastated *Q. agrifolia* population in southern California, systematic exposure trials of mainland individuals could provide insights that could prevent large-scale mortality. These research activities will play an important role in continuing to develop effective land management plans for the islands.

In addition, wild germplasm should be gathered from population not yet represented in *ex situ* collections, for long-term preservation as living specimens in gardens and arboreta globally. A coordinated effort of managers to develop protocols for cost-effective restoration and propagation techniques should also be carried out. This will allow for landscape-scale management, particularly in areas where non-native plant populations are currently being removed or combatted (e.g., Eucalyptus groves on Santa Cruz Island).

Conservation recommendations for *Quercus pacifica*

Highest Priority

- Population monitoring and/or occurrence surveys
- Research (pests/pathogens; reproductive biology/regeneration; restoration protocols/guidelines)
- Wild collecting and/or *ex situ* curation

Recommended

- Propagation and/or breeding programs
- Reintroduction, reinforcement, and/or translocation
- Sustainable management of land

REFERENCES

1. **Junak, S., Ayers, T., Scott, R., Wilken, D., & Young, D. (1995).** *A flora of the Santa Cruz Island*. Santa Barbara, CA: Santa Barbara Botanic Garden/California Native Plant Society.
2. **de Gouvenain, R.C. and Ansary, A.M. (2010).** Island scrub oak (*Quercus pacifica*) population structure and dynamics on Santa Catalina Island. In D.A. Knapp (ed.), *Oak ecosystem restoration on Santa Catalina Island, California: Proceedings of an on-island workshop*, February 2-4, 2007 (pp. 111-124). Avalon, CA: Catalina Island Conservancy.
3. **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
4. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
5. **Knapp, D. A. (2014).** Ecosystem restoration on Santa Catalina Island: A review of potential approaches and the promise of bottom-up invader management. *Monographs of the Western North American Naturalist, 7*, 421-434. Retrieved from https://www.jstor.org/stable/24870248
6. **Klinger, R. C., Schuyler, P., & Sterner, J. D. (2002).** The response of herbaceous vegetation and endemic plant species to the removal of feral sheep from Santa Cruz Island, California. In Veitch, C. R. & Clout, M. N. (Eds.). *Turning the tide: The eradication of invasive species* (pp. 141-154). Gland, Switzerland & Cambridge, United Kingdom: IUCN SSC Invasive Species Specialist Group.
7. **Morrison, S. A., Sillett, T. S., Ghalambor, C. K., Fitzpatrick, J. W., Graber, D. M., Bakker, V. J., Bowman, R., Collins, C. T., Collins, P. W., Delaney, K. S., Doak, D. F., Koenig, W. D., Laughrin, L., Lieberman, A. A., Marzluff, J. M., Reynolds, M. D., Scott, J. M., Stallcup, J. A., Vickers, W., & Boyce, W. M. (2011).** Proactive conservation management of an island-endemic bird species in the face of global change. *BioScience, 61*(12), 1013-1021. doi:10.1525/bio.2011.61.12.11
8. **McEachern, K., Atwater, T., Collins, P. W., Faulkner, K., & Richards, D. V. (2016).** Chapter 34: Managed island ecosystems. In Mooney, E. & Zavaleta. E. (Eds.), *Ecosystems of California*.
9. **Anderson, R. S., Starratt, S., Jass, R. M. B., & Pinter, N. (2010).** Fire and vegetation history on Santa Rosa Island, Channel Islands, and long‐term environmental change in southern California. *Journal of Quaternary Science, 25*(5), 782-797. doi:10.1002/jqs.1358
10. **Pesendorfer, M. B., Baker, C. M., Stringer, M., McDonald‐Madden, E., Bode, M., McEachern, A. K., Morrison, S. A., & Sillett, T. S. (2018).** Oak habitat recovery on California's largest islands: Scenarios for the role of corvid seed dispersal. *Journal of Applied Ecology, 55*(3), 1185-1194. doi:10.1111/1365-2664.13041
11. **Knapp, D. A. (2005).** Rare plants in the Goat Harbor burn area, Santa Catalina Island, California. pp. 205–211 in *Proceedings of the 5th California Islands Symp*., C.A. Schwemm (ed.). National Park Service Technical Publications CHIS-05- 01, Institute for Wildlife Studies, Arcata, CA.
12. **Knapp, D. A. (2002).** The status of Island scrub oak (*Quercus pacifica*) on Catalina Island, California. General Technical Report (PSW-GTR-184). USDA Forest Service.
13. **Hardiman, M., Scott, A. C., Pinter, N., Anderson, R. S., Ejarque, A., Carter-Champion, A., & Staff, R. A. (2016).** Fire history on the California Channel Islands spanning human arrival in the Americas. *Philosophical Transactions of the Royal Society B: Biological Sciences, 371*(1696). doi:10.1098/rstb.2015.0167.
14. **Minnich, R. A. (1983).** Fire mosaics in southern California and northern Baja California. *Science, 219*(4590), 1287-1294. doi:10.1126/science.219.4590.1287
15. **Beatty, S. W., & Licari, D. L. (1992).** Invasion of fennel (Foeniculum vulgare) into shrub communities on Santa Cruz Island, California. *Madroño, 39*(1), 54-66. Retrieved from https://www.jstor.org/stable/41424886
16. **Hanna, C., Naughton, I., Boser, C., & Holway, D. A. (2017).** Aphid‐tending ants on introduced fennel: can resources derived from non‐native plants alter the trophic position of higher‐order consumers?. *Ecological Entomology, 42*(1), 61-66. Retrieved from https://doi.org/10.1111/een.12359
17. **Power, P. J., Stanley, T., Cowan, C., & Roberts, J. R. (2014).** Native plant recovery in study plots after fennel (Foeniculum vulgare) control on Santa Cruz Island. *Monographs of the Western North American Naturalist, 7*(32) 465-476. Retrieved from https://scholarsarchive.byu.edu/mwnan/vol7/iss1/32
18. **Manuwal, T., & Sweitzer, R. (2010).** Impacts of introduced mule deer to island scrub oak habitats of Santa Catalina Island, California. In Knapp, D. A. (Ed.) (2010), *Oak ecosystem restoration on Santa Catalina Island, California: Proceedings of an on-island workshop, February 2-4, 2007* (pp. 19-34). Avalon, CA: Catalina Island Conservancy.
19. **National Park Service. (2015).** Channel Islands National Park, Final general management plan, Wilderness study, Environmental impact statement. https://parkplanning.nps.gov/showFile.cfm?projectID=11063&MIMEType=application%252Fpdf&filename=Channel%20Islands%20National%20Park%20Final%20General%20Management%20Plan%20Wildrness%20Study%20Environmental%20Impact%20Statement%2Epdf&sfid=208534
20. **Aguirre-Muñoz, A., Samaniego-Herrera, A., Luna-Mendoza, L., Ortiz-Alcaraz, A., Rodríguez-Malagón, M., Méndez-Sánchez, F., Félix-Lizárraga, M., Hernández-Montoya, J. C., González-Gómez, R., Torres-García, F., Barredo-Barberena, J. M., & Latofski-Robles, M. (2011).** Island restoration in Mexico: Ecological outcomes after systematic eradications of invasive mammals. In Veitch, C. R., Clout, M. N. & Towns, D. R. (Eds.), *Island invasives: eradication and management* (pp. 250-258). Gland, Switzerland: IUCN. Retrieved from http://issg.org/pdf/publications/Island_Invasives/pdfHQprint/3Aguirre-Munozl.pdf
21. **Pesendorfer, M. B., Langin, K. M., Cohen, B., Principe, Z., Morrison, S. A., & Sillett, T. S. (2014).** Stand structure and acorn production of the Island scrub oak (*Quercus pacifica*). *Monographs of the Western North American Naturalist, 7*(1), 246-259. doi:10.3398/042.007.0119.
22. **U.S. EPA Office of Research & Development. (2013, April).** 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
23. **Southern California Botanists. (2003).** *2003 SCB Symposium, Back From the Brink: Conservation Success Stories.* Retrieved http://www.socalbot.org/symposia/2003.php
24. **Knapp, J. (2010).** Catalina Island's invasive plant management program, with an emphasis on invasion and protection of oak ecosystems. In Knapp, D. A. (Ed.) (2010), *Oak ecosystem restoration on Santa Catalina Island, California: Proceedings of an on-island workshop, February 2-4, 2007.* Avalon, CA: Catalina Island Conservancy.
25. **Beltran, R. S., Kreidler, N., Van Vuren, D. H., Morrison, S. A., Zavaleta, E. S., Newton, K., Tershy, B. R., & Croll, D. A. (2014).** Passive recovery of vegetation after herbivore eradication on Santa Cruz Island, California. *Restoration Ecology, 22*(6). doi:10.1111/rec.12144.
26. **Dahlin, K. M., Asner, G. P., & Field, C. B. (2014).** Linking vegetation patterns to environmental gradients and human impacts in a mediterranean-type island ecosystem. Landscape Ecology, 29(9). doi:10.1007/s10980-014-0076-1
27. **Pesendorfer, M.B. (2015).** The Effect of Seed Size Variation in *Quercus pacifica* on Seedling Establishment and Growth. In *Proceedings of the seventh California oak symposium: managing oak woodlands in a dynamic world* (Gen. Tech. Rep. PSW-GTR-251). Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/treesearch/pubs/50010
28. **California Native Plant Society. (2017).** Island Scrub Oak, *Quercus pacifica*. Retrieved 2017, from http://calscape.org/Quercus-pacifica-()
29. **Catalina Island Conservancy. (2017).** Island Scrub Oak Regeneration. Retrieved 2017, from https://www.catalinaconservancy.org/index.php?s=wildlife&p=island_scrub_oak_regeneration
30. **Backs, J. R., & Ashley, M. V. (2016).** Evolutionary history and gene flow of an endemic island oak: *Quercus pacifica. American Journal of Botany, 103*(12), 2115-2125. doi:10.3732/ajb.1600259
31. **McEachern, K. (n.d.).** Drivers of ecosystem recovery on Santa Rosa Island. USGS, Western Ecological Research Center (WERC). Retrieved from https://www.usgs.gov/centers/werc/science/drivers-ecosystem-recovery-santa-rosa-island?qt-science_center_objects=0#qt-science_center_objects

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus palmeri***

Emily Beckman, Paul Manos, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, ***Quercus palmeri****, Quercus toumeyi*

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum® · BOTANIC GARDENS CONSERVATION INTERNATIONAL · FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE · FAUNA & FLORA INTERNATIONAL

Quercus palmeri Engelm.

Synonyms: *Quercus chrysolepis* var. *palmeri* (Engelm.) Engelm.,   **Common Names:** Palmer oak, Dunn oak

Species profile co-authors: Paul Manos, Department of Biology, Duke University

Suggested citation: Beckman, E., Manos, P., Meyer, A., & Westwood, M. (2019). *Quercus palmeri* Engelm. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 166-171). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-palmeri.pdf

DISTRIBUTION AND ECOLOGY

Quercus palmeri, or Palmer oak, is distributed across California, Arizona, and New Mexico, U.S., as well as stretching slightly into Baja California, Mexico. The Mojave Desert in southeastern California forms a barrier between the California and Arizona populations; morphology is clearly distinct between these disjunct populations, with the eastern group exhibiting classic *Q. palmeri* characteristics. The populations furthest east, though, in southeastern Arizona and New Mexico, are also morphologically unique and there is disagreement regarding the classification of these individuals as *Q. chrysolepis* affinity *Q. palmeri*. More research would be necessary to confirm introgression in the region (P. Manos pers. comm., 2018).[1] In California, the Southern Coast Range is relatively sparsely populated, with a higher concentration of individuals located further south within the coastal Transverse and Peninsular Ranges. On the east side of the desert, *Q. palmeri* populates the strip just south of the Colorado Plateau, and is most populous in central Arizona. Much of this species' distribution is composed of isolated subpopulations that are presumed to be relicts from a once-larger range that shrunk as aridity increased after the Pleistocene period.[2] Many of the isolated occurrences north of Riverside County, California, have been found to be single clones, and there is speculation that more localities will follow this pattern upon inspection.[3] Palmer oak inhabits "canyons, mountain washes, dry thickets, and margins of chaparral communities."[4] The species is usually associated with mesic, semi-desert landscapes, but also grows well near springs and in deeper valley soils of pinyon-juniper woodlands. Tolerance for a gradient of ecological conditions is evident. Compared to other oaks within the region (*Q. hypoleucoides, Q. arizonica*), *Q. palmeri* generally occupies lower elevations. It usually takes the form of a shrub or small tree, between one and three meters tall, but can reach up to six meters.[5]

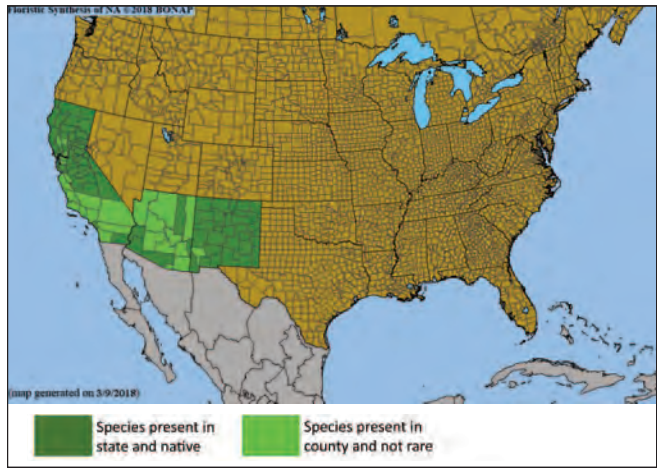


Figure 1. County-level distribution map for the U.S. distribution of *Quercus palmeri*. Source: Biota of North America Program (BONAP).[6]

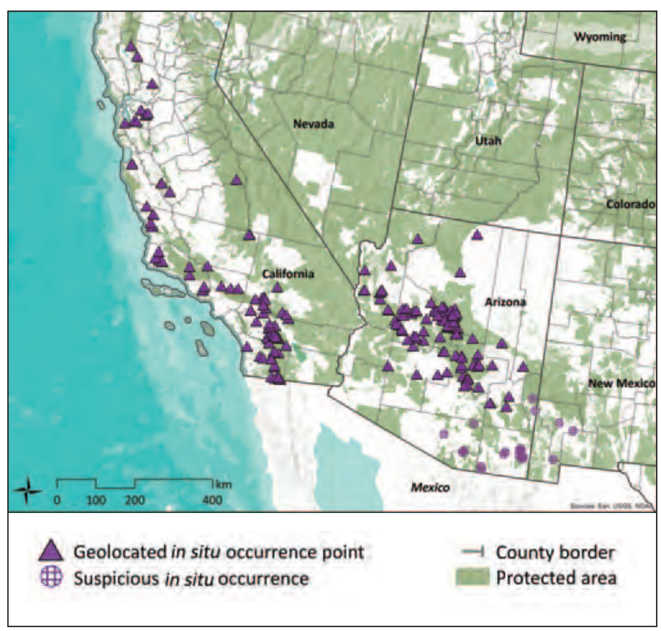


Figure 2. Documented *in situ* occurrence points for the U.S. distribution of *Quercus palmeri*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[7]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus palmeri*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	0
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	0
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	10
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	10
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
						Average vulnerability score	5.0
						Rank relative to all U.S. oak species of concern (out of 19)	15

THREATS TO WILD POPULATIONS

High Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: Specific threats to *Q. palmeri* have not been directly studied, but many of the threats facing the less common but well-studied oaks of southern California apply to Palmer oak as well. Continued recreational, commercial, and residential development in the region leads to habitat conversion and degradation. Some of the densest subpopulations of *Q. palmeri* are in Riverside County, which is one of the fastest growing counties in California.[8]

Moderate Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Altered fire regimes are thought to be affecting the regeneration success rate of Palmer oak.[8]

Genetic material loss — inbreeding and/or introgression: It has been proposed that morphologically aberrant populations identified as *Q. palmeri* in eastern Arizona and southwestern New Mexico are the result of hybridization with *Q. chrysolepis*. If true, this would significantly shrink *Q. palmeri's* extent of occurrence.[4]

Low Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: This oak may begin to experience the effects of severe fragmentation, including a depressed ability to adapt in response to climate change due to a smaller available gene pool.

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	18
Number of plants in *ex situ* collections:	41
Average number of plants per institution:	2
Percent of *ex situ* plants of wild origin:	66%
Percent of wild origin plants with known locality:	96%

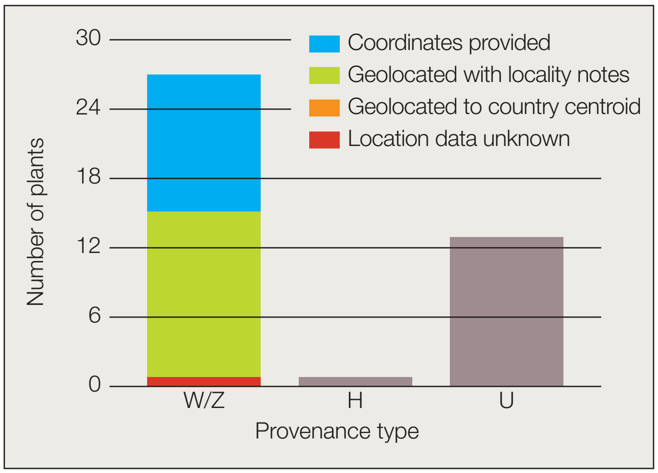


Figure 3. Number and origin of *Quercus palmeri* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

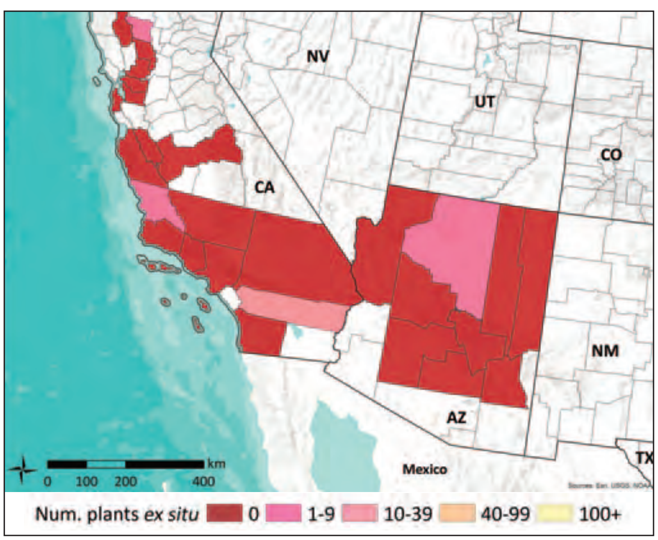


Figure 4. *Quercus palmeri* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Only the native U.S. distribution of the species was considered in this analysis, due to availability of ecoregion maps. Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	12%
Ecological coverage:	30%

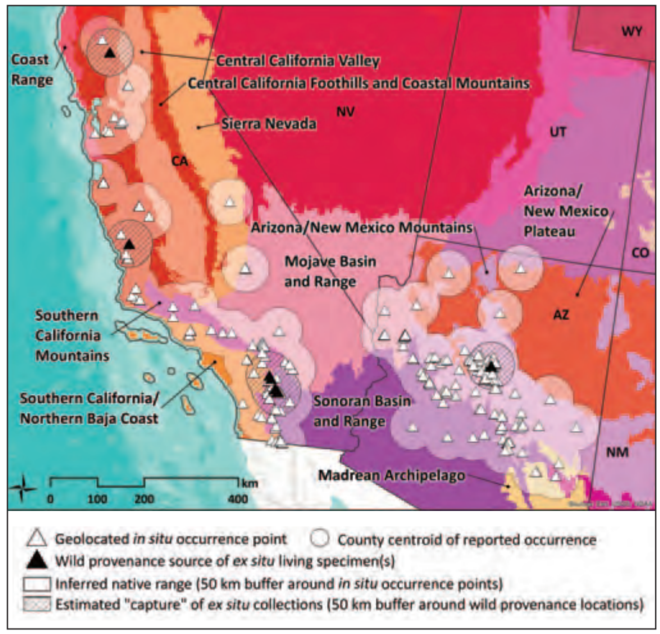


Figure 5. *Quercus palmeri in situ* occurrence points and *ex situ* collection source localities within the United States. U.S. EPA Level III Ecoregions are colored and labelled.[9] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

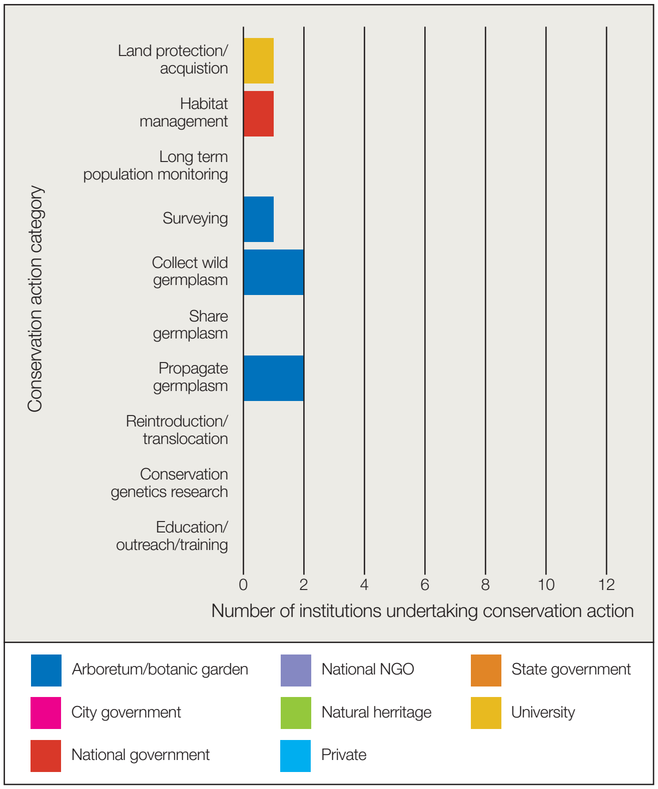


Figure 6. Number of institutions reporting conservation activities for *Quercus palmeri* grouped by organization type. Four of 252 institutions reported activities focused on *Q. palmeri* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. palmeri* in the U.S., 65% of the land is covered by protected areas (Figure 7). These areas seem to provide a good amount of protection for Palmer oak, though key populations in California could be impacted by land development; fire suppression within protected areas may interfere with sexual regeneration of *Q. palmeri*, which is necessary to maintain a diverse population.

A small population of Palmer oak was discovered in Ventura County in 2002, potentially harboring unique genetics: "a new species of oak was found by City Staff in the Sunset Hills Open Space in the northeastern portion of the City...The population in our open space consists of about 6 trees approximately 20' in height."[10] There is also one Candidate Special Interest Area—Garner Valley—within the San Bernardino National Forest, which hosts the most extensive actively reproducing subpopulation of *Q. palmeri* known in California (P. Manos pers. comm., 2018).[11,12]

Sustainable management of land: The Garner Valley Hazardous Fuels Reduction Project was listed within the San Bernardino National Forest Schedule of Proposed Actions for early 2017: "The project would introduce fire to chaparral areas to create a mosaic of age classes and will reduce fuels in the project area."[12] While searching for younger singleleaf pinyon trees, the Parry Pinyon Pine Protection Project found trees growing within a chaparral community alongside frequent *Q. palmeri*. They found that some areas being treated for fuels have not burned in many decades, causing dense vegetation cover over three meters tall. Pinyon seedlings are doing very well, but the status of Palmer oak reproduction in the area is unknown.[13]

Population monitoring and/or occurrence surveys: During the 39th Annual Southern California Botanists Symposium in 2013, Lark Canyon and McCain Valley were toured by members of the San Diego chapter of the California Native Plants Society. Rainfall seemed to have been adequate in the region, compared to most of California that year, and healthy *Q. palmeri* were observed.[14]

Wild collecting and/or *ex situ* curation: Two institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Propagation and/or breeding programs: Two institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: In western Riverside County, California, a 2005 joint study between the California Department of Fish and Wildlife and the California Native Plant Society was established to define and describe the vegetation types present; their motivation was "to provide data for future management of the plant communities." More than 2,000 kilometers squared of "core" undeveloped land has been classified and mapped, providing a baseline for management and conservation decisions in the future.[8]

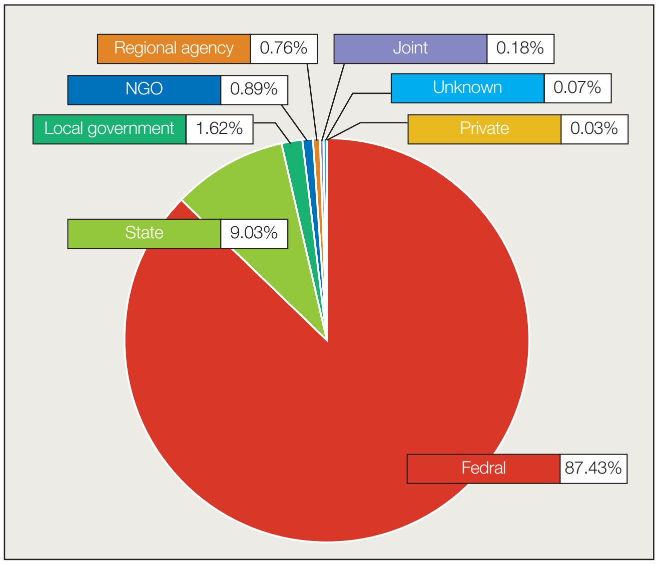


Figure 7. Management type of protected areas within the inferred native range of *Quercus palmeri*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[7]

Education, outreach, and/or training: The Rare Plants of Santa Barbara County list was created to "bring attention to those vascular plant taxa with a limited distribution in Santa Barbara County, irrespective of their status, whether they are common elsewhere or whether they are considered imperiled, threatened, or endangered by resource management agencies." The list was prepared from records maintained at the Santa Barbara Botanic Garden, and includes *Q. palmeri*.[15] The California non-profit Sustainable Conservation recently produced a publication entitled Beyond Drought-Tolerant, which educates residents about native, low-water gardening. *Quercus palmeri* is among "a selection of western trees that have low-water needs."[16]

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

Palmer oak consists of three main morphological groups: 1) populations in southern California as well as Baja California, Mexico; 2) populations in Arizona, and 3) putatively introgressed populations with *Q. chrysolepis* in New Mexico and eastern Arizona. The distinction between western and eastern populations of *Q. palmeri* is slight, and most apparent in leaf morphology, the latter with somewhat flatter and more deeply lobed leaves. Introgressed individuals are common in southeastern Arizona, and appear to have stronger affinities to *Q. chrysolepis* at the far eastern edge of its range. *In situ* conservation within California would begin with transplanting seedlings from proximal germplasm sources to several of the nearby populations known to harbor massive single clones. To better understand genetic and/or environmental effects on growth and development, *ex situ* efforts could include common garden experiments with germplasm representing the three morphological groups. Ideal locations would be botanical gardens in California and Arizona with conservation-based programs. Further representation of Palmer oak in *ex situ* collections should be pursued, since few of the species' wild populations are currently represented. Further effort should also be invested in population monitoring, including documenting losses to development or other land use changes as well as effects of fire suppression on *Q. palmeri* regeneration and overall ecosystem health within its habitat. It will be important to understand the ecosystem's appropriate disturbance regime, and use these data to inform sustainable land management practices in the future.

Conservation recommendations for *Quercus palmeri*

Highest Priority

- Reintroduction, reinforcement, and/or translocation
- Research (climate change modeling; land management/disturbance regime needs; population genetics; reproductive biology/regeneration; restoration protocols/guidelines)
- Wild collecting and/or *ex situ* curation

Recommended

- Population monitoring and/or occurrence surveys
- Sustainable management of land

REFERENCES

1. **Manos, P. S. (1993).** *Cladistic analyses of molecular variation in "higher" Hamamelididae and Fagaceae, and systematics of* Quercus *section Protobalanus* (Doctoral dissertation). Ithaca, NY: Cornell University.
2. **Rosatti, T. J., & Tucker, J. M. (2014).** *Quercus palmeri*, Palmer's oak. Berkeley. Retrieved from http://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=40584
3. **Russo, R. (2011).** Plant galls: Desert treasures. *Fremontia: Journal of the California Native Plant Society, 39*(1), 40-45. Retrieved from https://www.researchgate.net/publication/290193146_Rare_Plants_of_Griffith_Park_Los_Angeles
4. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
5. **Halstead, K. E., Pritchard, K. R., & Fischer, D. G. (2007).** The effects of environmental stress on *Quercus* morphology, physiology, and distribution in the Chiricahua Mountains. San Jose, CA: ESA/SER Joint Meeting, San Jose McEnery Convention Center. Retrieved from https://eco.confex.com/eco/2007/techprogram/P7924.HTM
6. **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
7. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
8. **Klein, A., & Evens, J. (2005, August).** Revised 2006. *Vegetation alliances of western Riverside County, California*. California Native Plant Society.
9. **U.S. EPA Office of Research & Development. (2013, April).** 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
10. **City of Thousand Oaks. (2013).** *Conservation element: Thousand Oaks general plan.* Retrieved from http://www.toaks.org/home/showdocument?id=332
11. **May, M. R., Provance, M. C., Sanders, A. C., Ellstrand, N. C., & Ross-Ibarra, J. (2009).** A Pleistocene clone of Palmers oak persisting in southern California. *PLOS ONE, 4*(12). doi:10.1371/journal.pone.0008346
12. **San Bernardino National Forest. (2017).** Schedule of Proposed Actions (SOPA) 01/01/2017 to 03/31/2017. Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.fed.us/sopa/components/reports/sopa-110512-2017-01.html
13. **McCarthy, D. (2012).** Perry pinyon pines protection project. In Haase, D. L., Pinto, J. R., & Riley, L. E. (Tech. coord.). *National proceedings: Forest and conservation nursery associations—2011*. Fort Collins, CO: Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture. Proceedings RMRS-P-68. pp. 96-101. Retrieved from https://npn.rngr.net/publications/proceedings/2011/perry-pinyon-pines-protection-project/at_download/file
14. **Roberts, F. (2013).** Fieldtrip reports: Lark Canyon, McCain Valley area, April 20th. *Leaflets of the Southern California Botanists*.
15. **Central Coast Center for Plant Conservation. (2012).** *Rare plants of Santa Barbara County*. Santa Barbara, CA: Santa Barbara Botanic Garden. Retrieved from https://www.sbbg.org/sites/default/files/pdfs/rare_list_santabarbara.pdf
16. **Sustainable Conservation. (n.d.).** *Beyond drought-tolerant: A California low-water gardening guide from Sustainable Conservation.* San Francisco, CA. Retrieved from https://www.gardenclubofsantabarbara.org/drought-tolerant-resource.html


Emily Beckman

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus parvula***

Emily Beckman, Ian Pearse, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
*Quercus lobata, **Quercus parvula**, Quercus sadleriana*

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum®
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus parvula Greene

Synonyms: *Quercus wislizenii* A. de Candolle **Common Names:** Santa Cruz Island oak, Shreve oak, Tamalpais oak

Species profile co-author: Ian Pearse, Fort Collins Science Center, USGS

Suggested citation: Beckman, E., Pearse, I., Meyer, A., & Westwood, M. (2019). *Quercus parvula* Greene. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 172-177). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-parvula.pdf

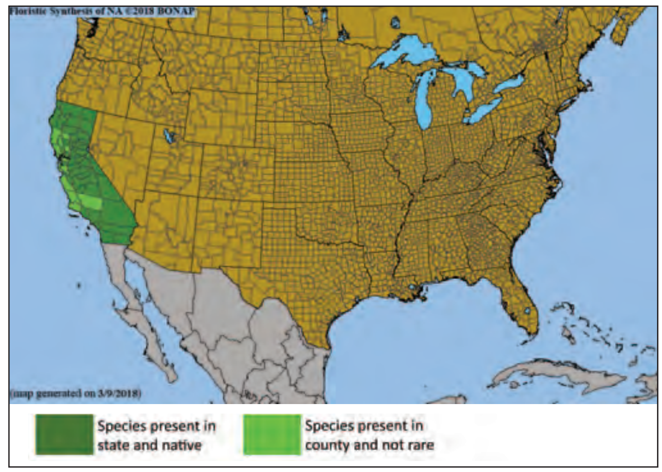


Figure 1. County-level distribution map for *Quercus parvula*. Source: Biota of North America Program (BONAP).[6]

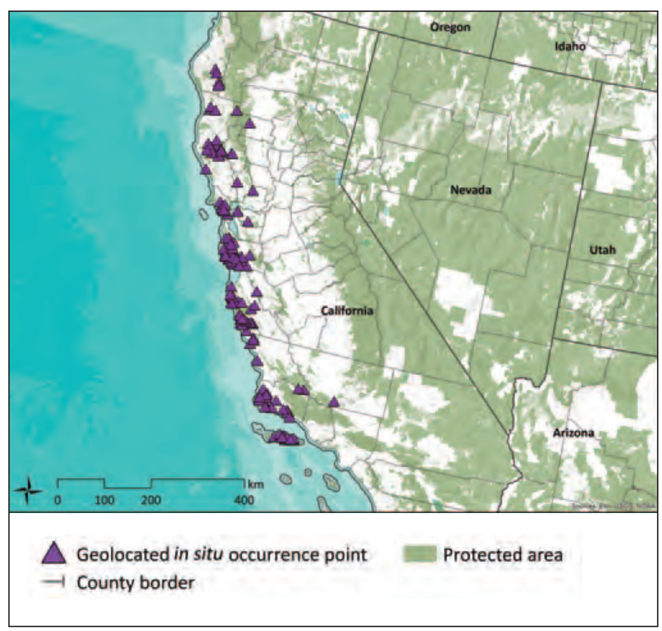


Figure 2. Documented *in situ* occurrence points for *Quercus parvula*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[7]

DISTRIBUTION AND ECOLOGY

Three varieties of *Quercus parvula* are currently recognized, all endemic to California, U.S.: *Q. parvula.* var. *parvula* (Santa Cruz Island oak), *Q. parvula* var. *shrevei* (Shreve oak), and *Q. parvula* var. *tamalpaisensis* (Tamalpais oak); though it has recently been asserted that *Q. parvula* var. *tamalpaisensis* is a hybrid between *Q. parvula* and *Q. wislizeni*.[1] Distribution of the Santa Cruz Island oak is limited to Santa Cruz Island and a few coastal localities in Santa Barbara County. It is associated with maritime chaparral and closed-cone pine forests. Shreve oak is the tree-like mainland variety of the shrubby, primarily insular variety. It is endemic to moist woodlands in the outer south-central California Coast Ranges from Santa Barbara County north to Mendocino County and west of the San Francisco Bay region. Tamalpais oak is endemic to Mount Tamalpais, located along the coast just north of San Francisco, growing in several small subpopulations. The USDA PLANTS Database recognizes all three varieties of *Q. parvula*, The Plant List only recognizes its shrevei variety, while Flora North America places all of these taxa in *Q. wislinzeni*.[2,3,4] Genetic evidence points to extensive hybridization between *Q. parvula* and other live oaks in the red oak clade (Sect. Lobatae), including *Q. agrifolia* and *Q. wislizeni*, suggesting more research is needed regarding *Q. parvula* and its distribution.[5]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus parvula*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	5
Range/endemism	Extremely small range or 1 location	EOO < 100 km^2 or AOO < 10 km^2 or 2-4 locations	EOO < 5,000 km^2 or AOO < 500 km^2 or 5-9 locations	EOO < 20,000 km^2 or AOO < 2,000 km^2 or 10+ locations	EOO > 20,000 km^2 or AOO > 2,000 km^2	Unknown	5
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	10
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	5
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	0
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	-
						Average vulnerability score	5.0
						Rank relative to all U.S. oak species of concern (out of 19)	15

THREATS TO WILD POPULATIONS

High Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Death of trees infected trees by sudden oak death has increased fuel loads and potential fire occurrence.[8]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Severe drought and multiple forest fires have reduced the size of some *Q. parvula* subpopulations. In 2015, it was estimated that 500 kilometers squared of *Q. parvula* habitat was affected, calculated by superimposing occurrence data points with the California Fire Map.[9,10]

Pests and/or pathogens: In 2002, *Q. parvula* was determined to be affected by sudden oak death, which is caused by the fungus Phytophthora ramorum.[11] At the time of this discovery, the the pathogen covered over 600 kilometers from central California to southern Oregon, and had spread at a faster rate than that of chestnut blight in the early 1900s.[12] Several other studies subsequently demonstrated that *Q. parvula* can die from infection, but that the pathogen cannot sporulate (reproduce) on oaks; instead it requires another host (usually Tanoak or California bay laurel) to persist and spread in the environment (I. Pearse pers. comm., 2018). Since 2002, *P. ramorum* has been found infecting oaks as far south as Santa Barbara County. Most *Q. parvula* subpopulations are found in areas known to be infected.[13] Because *Q. parvula* is a member of the red oak clade (Sect. Lobatae), it also has the potential to be affected by oak wilt and Goldspotted oak borer, the latter of which is currently distributed within the range of *Q. parvula*.[14,15] No serious damage is known to-date, though continued monitoring is necessary.

Moderate Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: *Quercus parvula* var. *tamalpaisensis* is an extremely localized endemic known only from the Mount Tamalpais area in Marin County. Some sites are on protected lands owned by the Marin County Water District, where the only threats are disturbance from hiking and perhaps firebreaks. The other sites have unknown ownership and unknown threats. There may be development and other serious threats to some sites since significant portions of the species' range are highly urbanized.[16]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	15
Number of plants in *ex situ* collections:	61
Average number of plants per institution:	4
Percent of *ex situ* plants of wild origin:	70%
Percent of wild origin plants with known locality:	77%

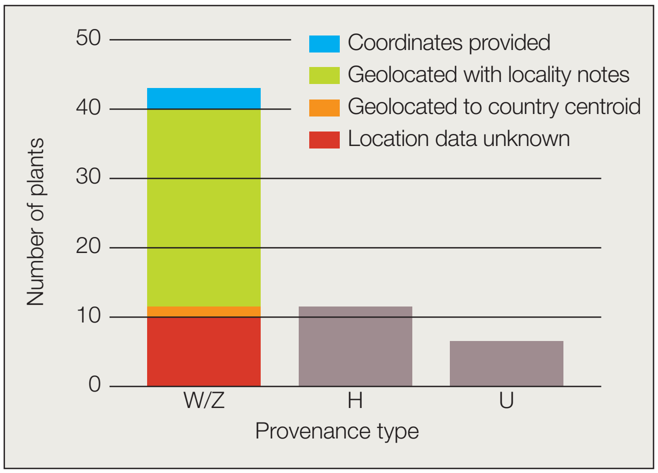


Figure 3. Number and origin of *Quercus parvula* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

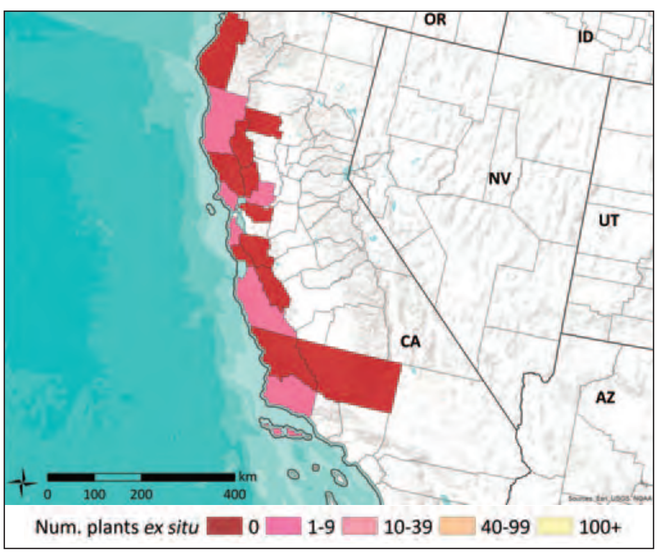


Figure 4. *Quercus parvula* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	39%
Ecological coverage:	64%

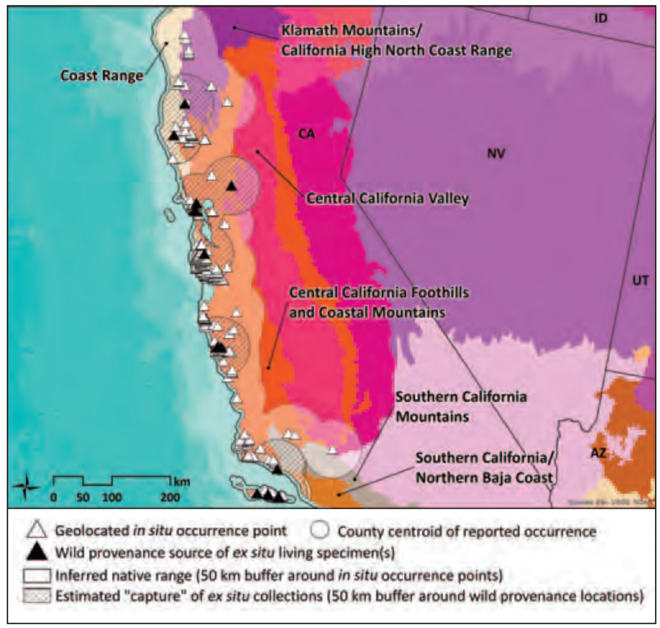


Figure 5. *Quercus parvula in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[17] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

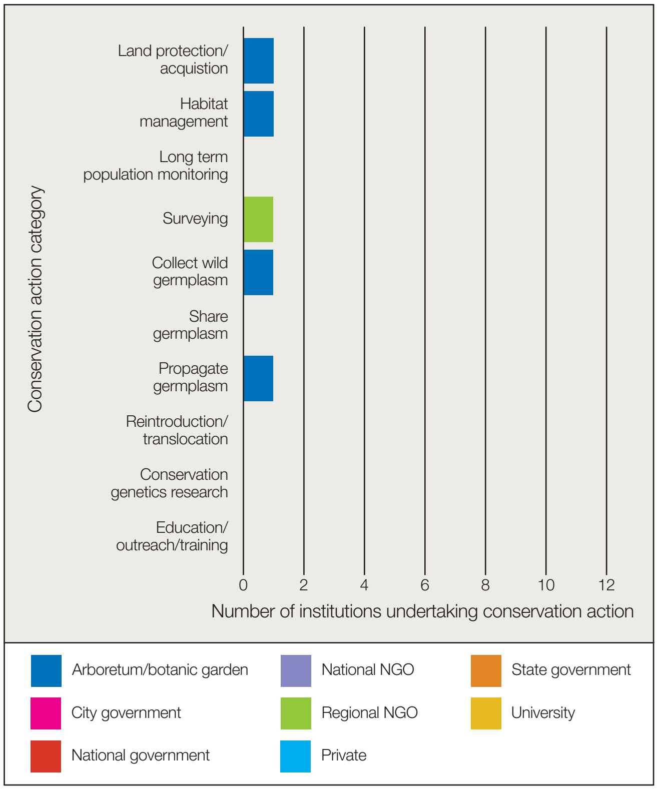


Figure 6. Number of institutions reporting conservation activities for *Quercus parvula* grouped by organization type. One of 252 institutions reported activities focused on *Q. parvula* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. parvula*, 33% of the land is covered by protected areas (Figure 7). Much of Santa Cruz Island oak's native distribution is composed of developed urban/suburban areas, rangeland, or unprotected wildland.

In 2016, the East Bay California Native Plant Society encouraged their members to sign a petition to preserve the Richmond Hills, an open space near Wildcat Canyon and San Pablo Dam Road, and prevent development of the land. They argue the land has "potential and documented botanical richness" and that "Northern Maritime Chaparral is a sensitive natural community." *Quercus parvula* var. *shrevei* is listed as one of the rare and unique plant species within the open space, "at it's only location in the East Bay."[18] The Richmond Hills Initiative was successfully adopted, but currently three of the speculative developers are suing the City of Richmond in an attempt to overturn the Initiative. The Sierra Club is helping the City respond to the lawsuits, and a specialist lawyer has been hired.[19] At UC Davis Arboretum Shields Oak Grove, a native *Q. parvula* stand is protected and monitored.[20]

Sustainable management of land: The Oak Woodlands Management Plan for Santa Clara County was adopted in 2005, and includes habitat for *Q. parvula* var. shrevei.[21]

Population monitoring and/or occurrence surveys: *Quercus parvula* var. *parvula* and *Q. parvula* var. *tamalpaisensis* are considered rare by the California Native Plant Society, and therefore their distribution, ecology, and conservation status are tracked as part of the society's Rare Plant Program. They use this information to promote science-based plant conservation in California.[22]

Wild collecting and/or *ex situ* curation: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Propagation and/or breeding programs: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: The University of California Santa Cruz (UCSC) Forest Ecology Research Plot, located in the UCSC Campus Natural Reserve, contains six hectares of mixed evergreen coastal forest with 8,180 tagged stems. The four dominant species are Douglas fir (*Pseudotsuga menziesii*), Coast live oak (*Quercus agrifolia*), Shreve's oak (*Q. parvula* var. *shrevei*), and Tanoak (*Lithocarpus densiflorus*). This research plot provides an opportunity to follow population dynamics across different soil types, and includes an area that has undergone significant canopy mortality in the last two decades with unknown cause.[23]

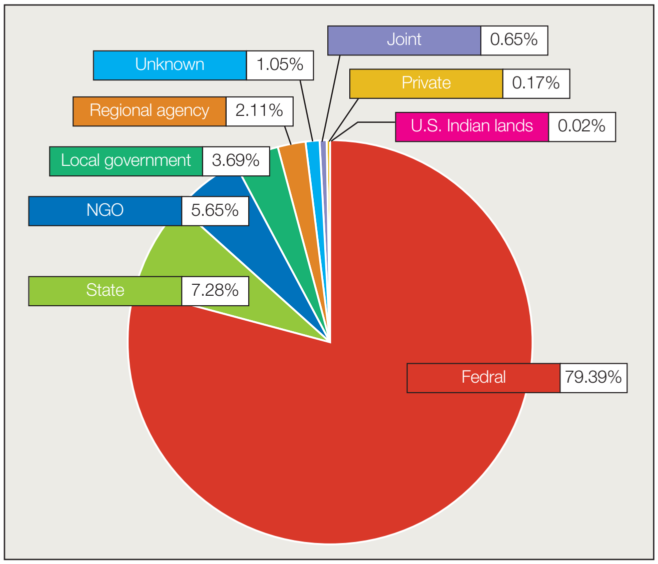


Figure 7. Management type of protected areas within the inferred native range of *Quercus parvula*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[7]

Through a network of 280 long-term forest monitoring plots, it is known that stands infested with sudden oak death are largely mixed evergreen forests with a specific plant composition of Bay laurel, Coast live oak, Tanoak, Madrone (*Arbutus menziesii*), and Shreve's oak (*Q. parvula* var. *shrevei*). A likely relationship was also uncovered between the pathogen's establishment and fire suppression: the pathogen more commonly establishes in mature stands, which have not been recently burned. These stands can also more easily spread the pathogen, due to increased connectivity stemming from a lack of fire.[13]

Education, outreach, and/or training: The East Palo Alto Tree Initiative, "a multi-year collaboration to enhance the urban forest in East Palo Alto and plant more than 1,200 trees," included *Q. parvula* as one of 20 species chosen for plantings. Between 2007 and 2008, the initiative, lead by the non-profit Canopy, collaborated with East Palo Alto City officials to spread the word and recruit partners and volunteers. School groups and community members helped prepare planting sites, plant acorns and seedlings, mulch, weed, and prune to keep the newly planted trees healthy. These volunteers contributed more than 4,000 hours of work. The City maintenance crews have now take over caring for the trees.[24]

The Oak Woodlands Management Plan for Santa Clara County was adopted in 2005 and informs forest management practices, including natural areas with populations of *Q. parvula* var. *shrevei*. Their listed Strategies for Conserving include improving knowledge, increasing outreach and education, promoting pilot projects, providing incentives for landowners, encouraging collaborative action, and planning for oak conservation on public lands.[21] Shipley Nature Center also protects a few young Island scrub oak specimens within their property, and hopes these trees will flourish so visitors can learn about and enjoy them.[25]

Species protection policies: No known initiatives at the time of publication.


Dean Taylor

PRIORITY CONSERVATION ACTIONS

Pressing challenges for the conservation of *Q. parvula* include the prevalence of sudden oak death throughout much of its range as well as habitat loss in coastal California due to development and fire. Preventing the spread of sudden oak death and understanding the degree of natural resistance to the pathogen that exists in *Q. parvula* will help mitigate this threat and clarify its importance. Long-term climate projections for coastal California still contain a great deal of uncertainty due to the importance of the fog layer in this region.

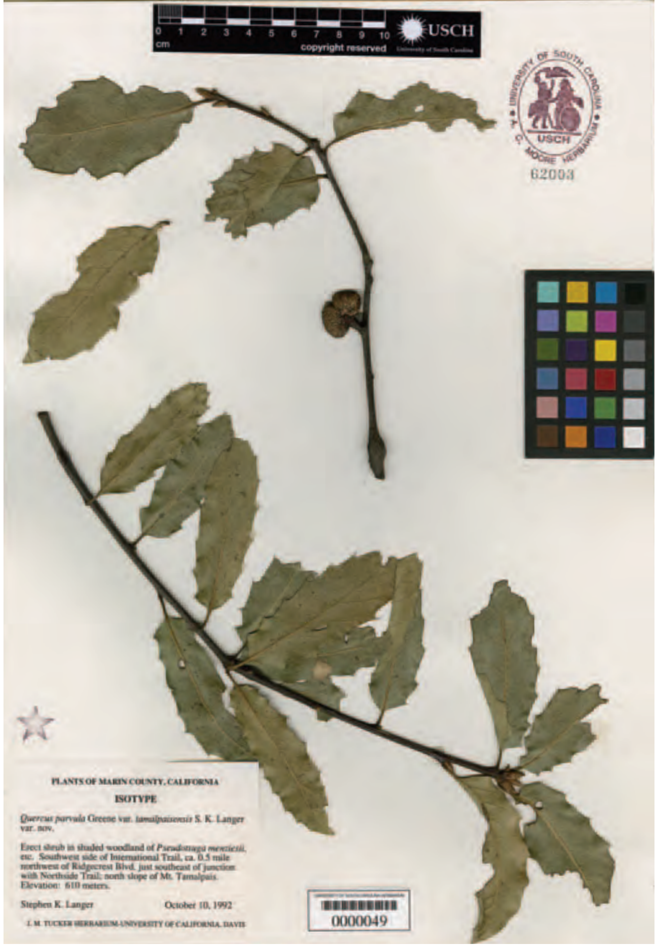
Imminent threat to *Q. parvula* from increased fire disturbance in California may be addressed with studies that track the survival of *Q. parvula* trees and regeneration post-fire. These studies will inform appropriate land management practices within *Q. parvula* habitat. Land owners and managers should be engaged in this process, and education and/or training will likely be an important step in applying research findings towards sustainable management of land. Land protection could also be considered in areas with pressure from development.

The species concept of *Q. parvula* has undergone numerous changes resulting in subspecies and populations that are treated differently by different scientists and conservation organizations. Moving forward, this concept should be tightened through genetic and morphological studies, which will be useful to conservation efforts that wish to preserve genetic resources of this species. The potential for important functional differences among *Q. parvula* populations is high because of the prevalence of disjunct populations such as those on the Channel Islands. Maintaining conservation efforts and *ex situ* collections of these populations can preserve that diversity.

Conservation recommendations for *Quercus parvula*

Highest Priority
- Population monitoring and/or occurrence surveys
- Research (climate change modeling; land management/disturbance regime needs; pests/pathogens; taxonomy/phylogenetics)
- Sustainable management of land

Recommended
- Education, outreach, and/or training
- Land protection
- Wild collecting and/or *ex situ* curation



REFERENCES

1. **Hauser, D. A., Keuter, A., Mcvay, J. D., Hipp, A. L., & Manos, P. S. (2017).** The evolution and diversification of the red oaks of the California Floristic Province (*Quercus* section Lobatae, series Agrifoliae). *American Journal of Botany, 104*(10), 1581-1595. doi:10.3732/ajb.1700291
2. **USDA, NRCS. (2018).** The PLANTS Database. Greensboro, NC: National Plant Data Team. Retrieved from http://plants.usda.gov
3. **The Plant List (2013).** Version 1.1. Retrieved from http://www.theplantlist.org/
4. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
5. **Dodd, R. S., & Afzal-Rafii, Z. (2004).** Selection and dispersal in a multispecies oak hybrid zone. *Evolution, 58*(2), 261-269. doi:10.1111/j.0014-3820.2004.tb01643.x
6. **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
7. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
8. **Forrestel, A. B., Ramage, B. S., Moody, T., Moritz, M. A., & Stephens, S. L. (2015).** Disease, fuels and potential fire behavior: Impacts of sudden oak death in two coastal California forest types. *Forest Ecology and Management, 348*, 23–30. Retrieved from https://doi.org/10.1016/j.foreco.2015.03.024
9. **Kua, C.-S. (2016).** *Quercus parvula*. The IUCN Red List of Threatened Species 2016: e.T62538A3116230. Retrieved from http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T62538A3116230.en
10. **Cal Fire. (2015).** California statewide fire map. Retrieved from http://www.fire.ca.gov/general/firemaps
11. **Rizzo, D. M., Garbelotto, M., Davidson, J. M., Slaughter, G. W., & Koike, S. T. (2002).** *Phytophthora ramorum* as the cause of extensive mortality of *Quercus* spp. and *Lithocarpus densiflorus* in California. *Plant Disease, 86*(3), 205-214. doi:10.1094/pdis.2002.86.3.205
12. **Davidson, J. M., Rizzo, D. M., Garbelotto, M., Tjosvold, S., & Slaughter, G. W. (2002).** *Phytophthora ramorum* and sudden oak death in California: II. Transmission and survival. In Standiford, R. B. (Ed.), *Proceedings of the fifth symposium on oak woodlands: Oaks in California's challenging landscape* (Gen. Tech. Rep. PSW-GTR-184). Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/treesearch/pubs/26170
13. **Metz, M. R., Frangioso, K. M., Wickland, A. C., Meentemeyer, R. K., & Rizzo, D. M. (2012).** An emergent disease causes directional changes in forest species composition in coastal California. *Ecosphere, 3*(10). doi:10.1890/es12-00107.1
14. **Canadian Food Inspection Agency (2019).** *Bretziella fagacearum* (previously known as *Ceratocystis fagacearum* (Oak Wilt) - Fact Sheet. Retrieved from http://www.inspection.gc.ca/plants/plant-pests-invasive-species/diseases/oak-wilt/fact-sheet/eng/1325629194844/1325632464641
15. **Colman, T. W., Jones, M. I., Smith, S. L., Venette, R. C., Flint, M. L., & Seybold, S. J. (2017).** Goldspotted Oak Borer. Forest Insect & Disease Leaflet 183. U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf
16. **NatureServe. (2017).** NatureServe Explorer: An online encyclopedia of life [online]. Version 7.1. Arlington, VA. Retrieved from http://explorer.natureserve.org
17. **U.S. EPA Office of Research & Development. (2013, April).** 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
18. **Whitestone, K. (2016, September 22).** Sign the Richmond Hills Initiative. Conservation & East Bay California Native Plant Society. Retrieved from https://ebcnps.wordpress.com/2016/09/22/sign-the-richmond-hills-initiative/
19. **Save the Richmond Hills. (n.d.).** The Richmond Hills Initiative has been adopted. Retrieved from https://www.savetherichmondhills.org/
20. **UC Davis Arboretum and Public Garden. (2011, June).** UC Davis oaks. Retrieved from http://arboretum.ucdavis.edu/oak-collection.aspx
21. **Santa Clara County. (2005, May).** *An oak woodlands management plan for Santa Clara County*. Retrieved from https://www.sccgov.org/sites/dpd/DocsForms/Documents/CEQA_OaksPlan.pdf
22. **California Native Plant Society. (2017).** Inventory of rare and endangered plants of California [online]. CA: Rare Plant Program. Retrieved from http://www.rareplants.cnps.org
23. **Center for Tropical Forest Science. (2011, December 14).** California temperate forest plot joins CTFS-SIGEO network. Retrieved from http://ctfsnews.blogspot.com/2011/
24. **Canopy. (n.d.).** East Palo Alto tree initiative. Retrieved from http://canopy.org/our-work/tree-planting/east-palo-alto-tree-initiative/
25. **Hoffman, J. (2008, October).** Native trees. *Friends of Shipley Nature Center, 5*(4). Retrieved from http://www.shipleynature.org/newsletters/2008october.pdf

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus pumila***

Emily Beckman, Tony Aiello, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, ***Quercus pumila***

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus pumila Walter

Synonyms: *Cyclobalanopsis sericea* (Aiton) Schottky, *Quercus elliottii* Wilbur, Q. *sericea* (Aiton) Willd. **Common Names:** Runner oak

Species profile co-authors: Tony Aiello, Morris Arboretum of the University of Pennsylvania
Contributors: Gerould Wilhelm, Conservation Research Institute

Suggested citation: Beckman, E., Aiello, T., Meyer, A., & Westwood, M. (2019). *Quercus pumila* Walter. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 178-183). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-pumila.pdf

DISTRIBUTION AND ECOLOGY

Quercus pumila, or Runner oak, occurs in the southeastern U.S., throughout peninsular Florida and along the Coastal Plain north to North Carolina and west to Mississippi. There is recent uncertainty regarding the species' name, since the discovery that no original 1788 herbarium specimen exists, and Walter's accompanying description is not precise enough to confirm the species' identity. *Quercus pumila* is certainly a distinctive species, but *Q. elliottii* has been proposed as the correct name, given by Wilbur in 2002 after deeming Walter's description inadequate. However, some believe the herbarium specimen chosen by Wilber is actually a hybrid between *Q. falcata* and *Q. phellos*, causing further confusion.[1,2,3] Runner oak grows as a small shrub, deciduous or partially-deciduous, and reaches about one meter in height, sometimes two meters in ideal conditions. Its leaves are unlobed and slightly revolute with white pubescence beneath. Runner oak is highly clonal, producing shoots from a stolon or "runner," and grows primarily horizontally. This species is found on dry sandy to loamy soils of pine flatwoods, oak-pine scrub, savannas and ridges. Adapted to fire, *Q. pumila* re-sprouts quickly with increased acorn production once burned.[1,4,5]

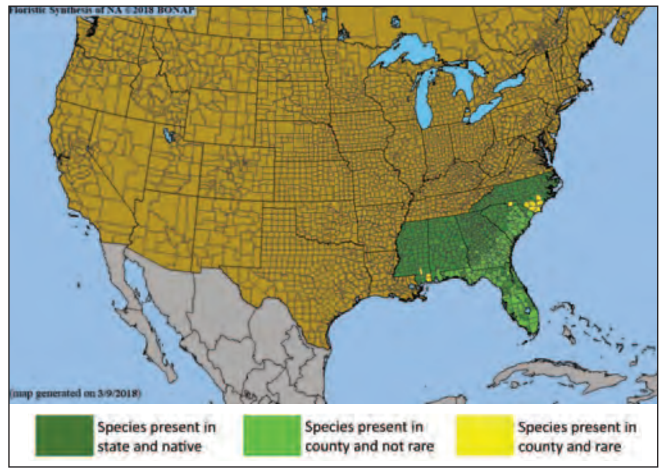


Figure 1. County-level distribution map for *Quercus pumila*. Source: Biota of North America Program (BONAP).[6]

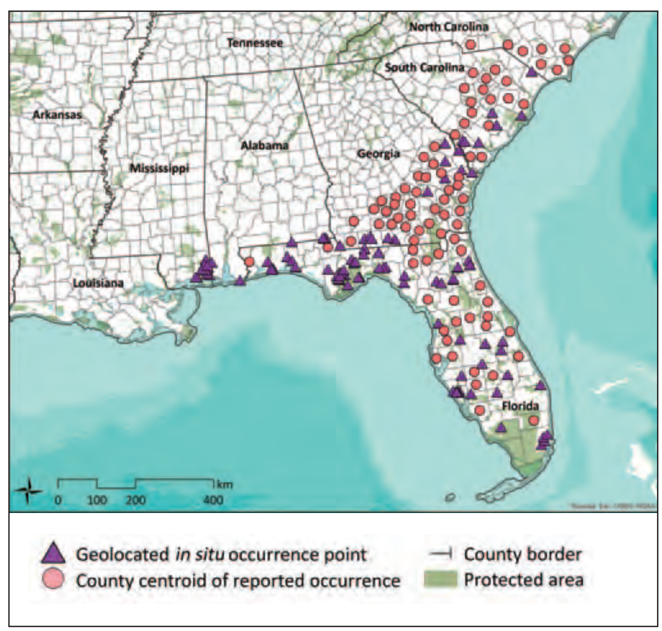


Figure 2. Documented *in situ* occurrence points for *Quercus pumila*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[7]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus pumila*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	Score
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km^2 or AOO < 10 km^2 or 2-4 locations	EOO < 5,000 km^2 or AOO < 500 km^2 or 5-9 locations	EOO < 20,000 km^2 or AOO < 2,000 km^2 or 10+ locations	EOO > 20,000 km^2 or AOO > 2,000 km^2	Unknown	0
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	10
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	-
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	5
						Average vulnerability score	4.0
						Rank relative to all U.S. oak species of concern (out of 19)	17

TTHREATS TO WILD POPULATIONS

High Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: The pine-oak scrub communities that *Q. pumila* occupies are threatened by fire suppression, which allows taller species to encroach and shade out scrub oaks, including Runner oak.[8]

Moderate Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: Tall Timbers Research Station and Land Conservancy found that Runner oak was among a group of species especially sensitive to disturbance.[9] Development persists in many areas occupied by *Q. pumila* and may be disproportionately affecting the species. Because *Q. pumila* tends to reproduce sexually only in aboriginal soil conditions, it is unlikely to volunteer in "new ground." Therefore, its sustained inhabitancy is assured to the extent that its aboriginal habitat is protected from severe soil disturbance (G. Wilhelm pers. comm., 2018).

Low Impact Threats

Human use of landscape — tourism and/or recreation: Scrub habitat is readily damaged by off-road vehicle traffic or even foot traffic, which destroys the delicate ground cover and allows the loose sand to erode.[10]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Scrub communities are known to be sensitive to disturbance regime changes, which are altered by a changing climate. Further research is necessary regarding the the effects of climate change on the fluctuation of fire regimes.[11] No climate change projections are known for *Q. pumila* specifically.

Genetic material loss — inbreeding and/or introgression: Negative effects have not yet been seen, but hybridization with *Quercus hemisphaerica*, *Q. incana, Q. myrtifolia*, and *Q. phellos* has been noted.[1]

Pests and/or pathogens: Because *Q. pumila* is a member of the red oak clade (Sect. Lobatae), it has the potential to be affected by oak wilt, Sudden oak death (SOD), and Goldspotted oak borer.[12,13,14] No serious damage has been reported to-date, though continued monitoring is necessary. Based on SOD's current distribution in California and the environmental conditions at these locations, models "indicated highest potential for establishment [of SOD] in the southeastern USA;" therefore, Runner oak is at particular risk should the pathogen spread throughout the Southeast.[13]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	9
Number of plants in *ex situ* collections:	20
Average number of plants per institution:	2
Percent of *ex situ* plants of wild origin:	45%
Percent of wild origin plants with known locality:	89%

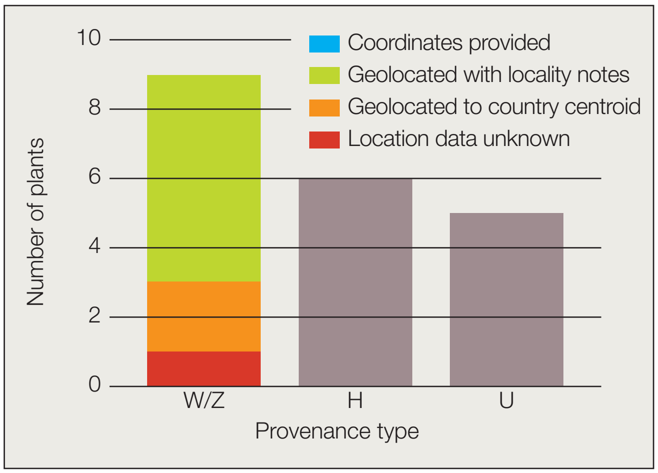


Figure 3. Number and origin of *Quercus pumila* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

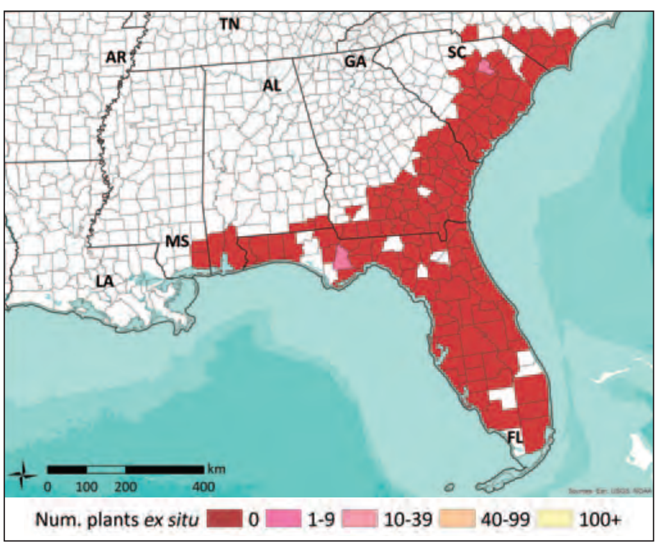


Figure 4. *Quercus pumila* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	5%
Ecological coverage:	41%

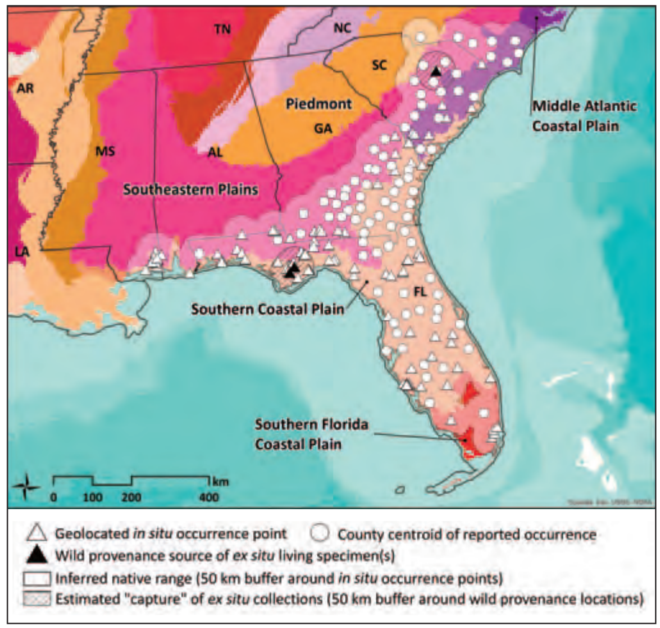


Figure 5. *Quercus pumila in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[15] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

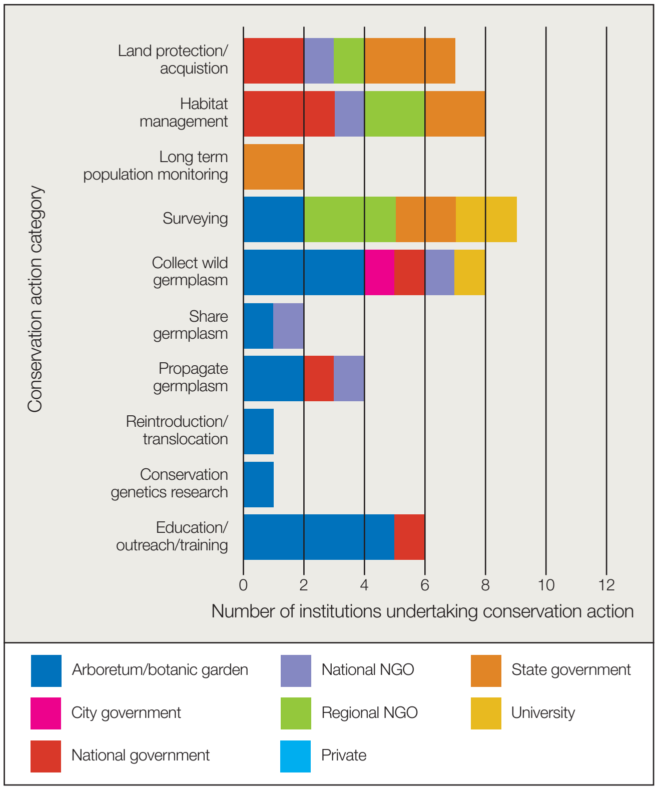


Figure 6. Number of institutions reporting conservation activities for *Quercus pumila* grouped by organization type. Twenty-one of 252 institutions reported activities focused on *Q. pumila* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. pumila*, 19% of the land is covered by protected areas (Figure 7). However, compared to other regions in the southwestern U.S., Florida has a large proportion of protected area, indicating this estimate may be low. Runner oak is also known to have many robust populations within protected areas, and the more concerning issue is fragmentation of preserves rather than the lack of land protection.

Quercus pumila is often associated with Longleaf pine, whose habitat is actively protected and managed across the southeastern U.S. Detailed maps are available and include locations of significant landscapes, protected areas, federally managed lands, and conservation organizations and projects associated with each area.[16] The species is also specifically documented on Persimmon Ridge Preserve in Lee County, Florida, which connects to a series of other preserves.[17]

Sustainable management of land: As a keystone species, Longleaf pine decline in the southeastern U.S. affects the entire fire-adapted associated ecosystem. Litter buildup of longleaf promotes the spread of low temperature fires, and the coexisting species within these ecosystems have developed a reliance on this fire frequency and intensity. *Quercus pumila, Q. minima, Q. laevis, Q. incana*, and *Q. margaretta* all produce acorns on two-year old shoots after fire.[18] Therefore, restoration and management of Longleaf pine habitat (for which there are many initiatives), is likely to increase the survival and successful regeneration of *Q. pumila* and related scrub oaks in the ecosystem. Runner oak is also within a Gopher tortoise habitat management area, where active management takes place to increase tortoise populations. Short-term management aims to create “appropriate canopy coverage (canopy thinning and other treatments to achieve immediate site enhancement)” and long-term plans are focused on “establishing [a] thriving understory to support gopher tortoises (prescribed fires, roller chopping) in perpetuity.”[19] It is unclear if these management actions will negatively affect *Q. pumila*, due to its sensitivity to disturbance.

Population monitoring and/or occurrence surveys: Nine institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Wild collecting and/or *ex situ* curation: Seven institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Propagation and/or breeding programs: The non-profit organization Trees Atlanta propagated and sold *Q. pumila* in their fall 2011 tree sale.[20]

Reintroduction, reinforcement, and/or translocation: One institution reported this activity in the conservation action questionnaire, but no other details are currently known.

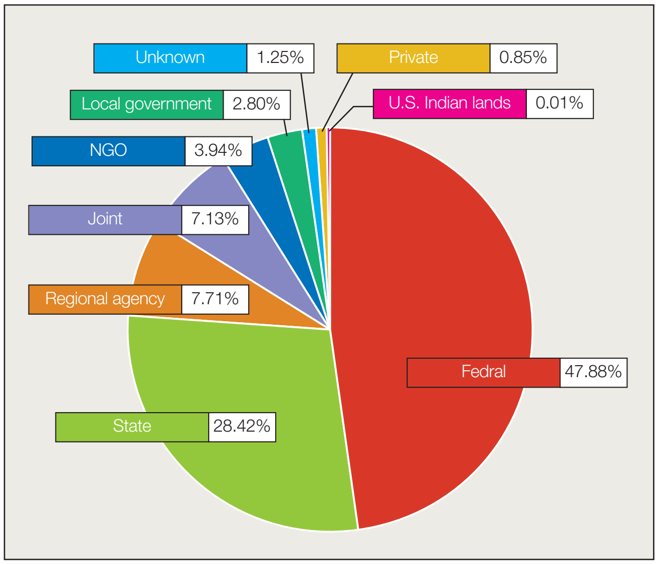


Figure 6. Management type of protected areas within the inferred native range of *Quercus pumila*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[7]

Research: In winter 2012 and 2013, Tall Timbers Research Station and Land Conservancy took advantage of firebreaks created with a tractor and disk in two different longleaf pine-wiregrass areas to study the subsequent impact on the native plants. Of the species monitored, 12 were significantly reduced by the single disking three to four years after the disturbance. Oak species found to be sensitive to soil disturbance include Running oak, Sand post oak (*Q. margarettae*), and Bluejack oak (*Q. incana*). The study concludes "that while most plant species in longleaf native groundcover can survive or become re-established following a small-scale soil disturbances, there is a certain suite of species that are negatively impacted and slow to recover, and which otherwise make up a significant proportion of the vegetation cover in undisturbed areas."[9]

Education, outreach, and/or training: The Natives For Your Neighborhood program in southern Florida lists *Q. pumila* as a landscaping possibility, though only "grown by enthusiasts and occasionally by native plant nurseries."[21]

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

Conservation of Runner oak should include a study of wild populations to determine the amount of genetic diversity within the species; once an understanding of this diversity is known, it can inform the necessary *in situ* and *ex situ* preservation efforts. Among these efforts, it would be useful to verify the locations that are only known from county centroid occurrence data. It is clear that there are threats to *Q. pumila* from various human activities, including fire suppression, land use, and development. In order to target populations for conservation, it would be important to get a fuller understanding of those populations with high or unique levels of diversity. With this information in hand, distinct populations could be targeted for *in situ* conservation through habitat restoration and appropriate controlled burns regimes. It may be important to provide training for land managers, regarding best practices for Runner oak habitats. Given the extremely low level of the species' wild distribution represented in collections, a greater understanding of the most vulnerable and diverse populations would inform targeted collecting of populations to be held in *ex situ* collections.

Conservation recommendations for *Quercus pumila*

Highest Priority
- Research (climate change modeling; demographic studies/ecological niche modeling; land management/disturbance regime needs; population genetics)
- Sustainable management of land

Recommended
- Education, outreach, and/or training
- Population monitoring and/or occurrence surveys
- Reintroduction, reinforcement, and/or translocation
- Wild collecting and/or *ex situ* curation

REFERENCES

1. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
2. **Helardot, J. L. (2012).** Oaks of the world. Retrieved from http://oaks.of.the.world.free.fr/index.htm
3. **Wilbur, R. L., & Ho, M. (2008).** In defense of the binomial *Quercus elliottii* (Fagaceae) for the running oak of the southeastern United States. *Rhodora, 110*(944), 479-483. Retrieved from http://dx.doi.org/10.3119/08-1.1
4. **Stein, J., Binion, D., & Acciavatti, R. (2003).** *Field guide to native oak species of eastern North America*. Forest Service, U.S. Department of Agriculture.
5. **Weakley, A. S. (2015).** *Flora of the Southern and Mid-Atlantic states: Working draft of 21 May 2015*. University of North Carolina Herbarium, North Carolina Botanical Garden, University of North Carolina at Chapel Hill. Retrieved from http://www.herbarium.unc.edu/FloraArchives/WeakleyFlora_2015-05-29.pdf
6. **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
7. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
8. **Dinerstein, E., Weakley, A., Noss, R., Snodgrass, R., & Wolfe, K. (n.d.).** Florida sand pine scrub. Retrieved from https://www.worldwildlife.org/ecoregions/na0513
9. **Robertson, K. (n.d.).** Disking effects on native groundcover plant species. Tall Timbers. Retrieved from https://talltimbers.org/disking-effects-native-groundcover-plant-species/
10. **Florida Natural Areas Inventory. (2010).** *Guide to the natural communities of Florida: 2010 edition*. Tallahassee, FL. Retrieved from: https://www.fnai.org/naturalcommguide.cfm
11. **Defenders of Wildlife. (n.d.).** Climate change and Florida scrub jays. Retrieved from http://www.landscope.org/article/FL/climate_scrub_jays/1/
12. **Canadian Food Inspection Agency (2019).** *Bretziella fagacearum* (previously known as *Ceratocystis fagacearum* (Oak Wilt) - Fact Sheet. Retrieved from http://www.inspection.gc.ca/plants/plant-pests-invasive-species/diseases/oak-wilt/fact-sheet/eng/1325629194844/1325632464641
13. **Kluza, D. A., Vieglais, D. A., Andreasen, J. K., & Peterson, A. T. (2007).** Sudden oak death: geographic risk estimates and predictions of origins. Plant *Pathology, 56*(4), 580-587. doi:10.1111/j.1365-3059.2007.01602.x
14. **Colman, T. W., Jones, M. I., Smith, S. L., Venette, R. C., Flint, M. L., & Seybold, S. J. (2017).** Goldspotted Oak Borer. Forest Insect & Disease Leaflet 183. U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf
15. **U.S. EPA Office of Research & Development. (2013, April).** 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
16. **America's Longleaf. (n.d.).** The initiative. Retrieved from http://www.americaslongleaf.org/the-initiative/
17. **Lee County Southwest Florida. (2012).** Persimmon Ridge Preserve plant species list. Retrieved from http://www.leegov.com/conservation2020/documents/plants/PRP_Plants.pdf
18. **Berry College Department of Biology. (2002, July).** *The Berry College longleaf management plan: A proposal for the study and management of Mountain longleaf pine on Lavender Mountain*. Mount Berry: GA. Retrieved from https://www.berry.edu/uploadedFiles/Website/Academics/School_-_Math_and_Science/Departments/Biology/Longleaf_Pine_Project/_Assets/Documents/Management%20Plan.pdf
19. **Hofstetter, S. (2009, September).** Gopher tortoise habitat management assistance request. Alachua County, FL: Florida Fish and Wildlife Conservation Commission. Retrieved from http://meetingdocs.alachuacounty.us/documents/bocc/agendas/2010-03-23/247500a9-9232-48da-858b-c7095113c30b.pdf
20. **Trees Atlanta. (2011).** Tree sale festival: A dazzling selection. *The Atlanta Treebune*. Retrieved from https://treesatlanta.org/wp-content/files_mf/2011fall.pdf
21. **The Institute for Regional Conservation. (n.d.).** Natives for your neighborhood. Delray Beach, FL. Retrieved from https://regionalconservation.org/beta/nfyn/default.asp

Shirley Denton

Conservation Gap Analysis of Native U.S. Oaks

Species profile: *Quercus robusta*

Emily Beckman, Andrew McNeil-Marshall, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, ***Quercus robusta****, Quercus tardifolia*

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U S DEPARTMENT AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus robusta C.H.Müll.

Synonyms: N/A **Common Names:** Robust oak

Species profile co-author: Andrew McNeil-Marshall, Lady Bird Johnson Wildflower Center, The University of Texas at Austin;
Shannon M. Still, UC Davis Arboretum and Public Garden
Contributors: Adam Blackt, Peckerwood Garden

Suggested citation: Beckman, E., McNeil-Marshall, A., Still, S. M., Meyer, A., & Westwood, M. (2019). *Quercus robusta* C.H.Müll. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 184-189). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-robusta.pdf

DISTRIBUTION AND ECOLOGY

Quercus robusta, or Robust oak, is believed to be endemic to the Chisos Mountains of southwestern Texas, U.S., and is currently known from a small area in Big Bend National Park. The type locality contains the only confirmed location, but a potential second population was just discovered; more research is necessary to verify this second location (S. Still pers. comm., 2018). There is continued taxonomic debate surrounding the status of this species, with C. H. Müller describing the species in 1934, deeming it a hybrid between *Q. emoryi* and *Q. gravesii* in the mid-20th century, and finally reviewing the case again more recently and concluding Robust oak to be a true species.[1] There is some possibility that *Q. robusta* exists within northern Mexico, but no evidence has yet been found. The species is not present in Valencia and Flores-Franco's 2006 authoritative Fagaceae of Mexico.[2] Robust oak is large compared to other trees within the Chisos Mountains, and is found occupying the lowlands of moist wooded canyons where a creek sometimes flows, around 1,500 meters above sea level. These relatively moist conditions likely account for the species' unique stature. Cottonwoods are found alongside *Q. robusta* in its type locality, and are also rare within the Chisos Mountains; this speaks to the distinctive nature the of site (A. McNeil-Marshall pers. comm., 2018).

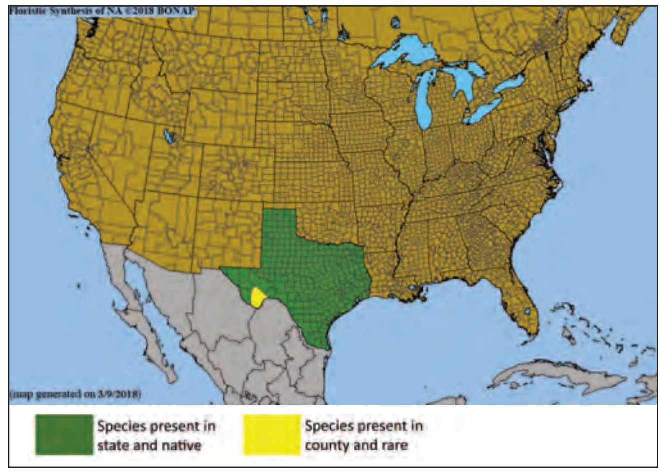


Figure 1. County-level distribution map for *Quercus robusta*. Source: Biota of North America Program (BONAP).[3]

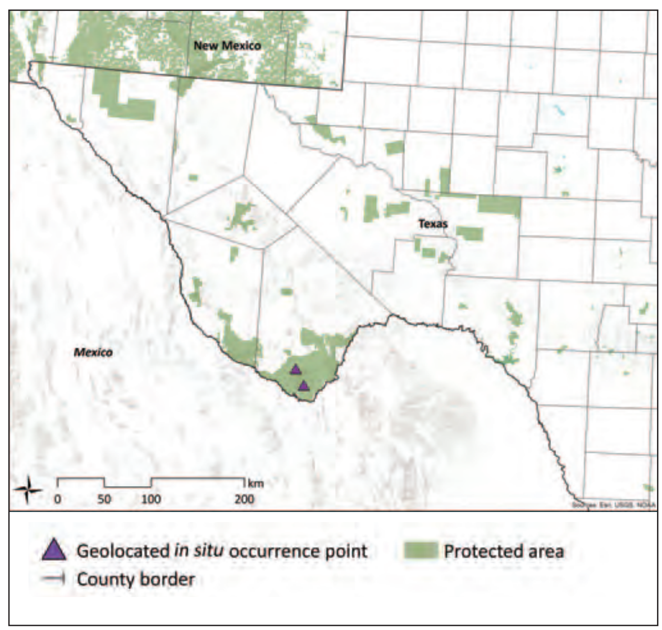


Figure 2. Documented *in situ* occurrence points for *Quercus robusta*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus robusta*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	40
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	40
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	0
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	-
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	20
Average vulnerability score							24.0
Rank relative to all U.S. oak species of concern (out of 19)							2

THREATS TO WILD POPULATIONS

High Impact Threats

Extremely small and/or restricted population: This species is currently verified in only one restricted location, though a second potential population was recently discovered; further research is required to confirm this new location (S. Still pers. comm., 2018).

Moderate Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Drought, flood, and fire all pose threats, especially since the population could be wiped out by one extreme event (A. McNeil-Marshall pers. comm., 2016).

Genetic material loss — inbreeding and/or introgression: Because this species is rare and occurs with other oak species nearby, hybridization may be a genetic threat; though there is little evidence of a problem currently (S. Still pers. comm., 2018). All known populations are extremely small, making inbreeding in the near future very likely and genetic adaptation through natural selection unlikely.

Low Impact Threats

Human use of landscape — tourism and/or recreation: Within Big Bend National Park, there is some potential threat from human impact during recreational activities (A. McNeil-Marshall pers. comm., 2016).

Human modification of natural systems — invasive species competition: In general, invasive plant species are known to pose a threat to the unique and rare species within Big Bend National Park; no specific impacts to *Q. robusta* have been reported.[5]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figure 3). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 5).

Results of 2017 *ex situ* survey	
Number of *ex situ* collections reporting this species:	2
Number of plants in *ex situ* collections:	2
Average number of plants per institution:	1
Percent of *ex situ* plants of wild origin:	50%
Percent of wild origin plants with known locality:	100%

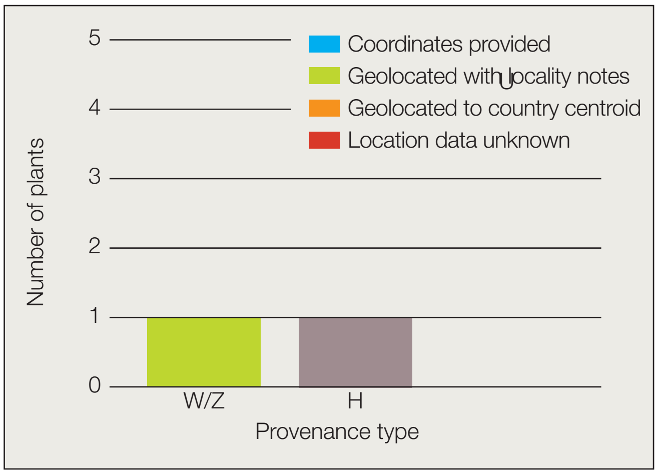


Figure 3. Number and origin of *Quercus robusta* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 4). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation	
Geographic coverage:	69%
Ecological coverage:	100%

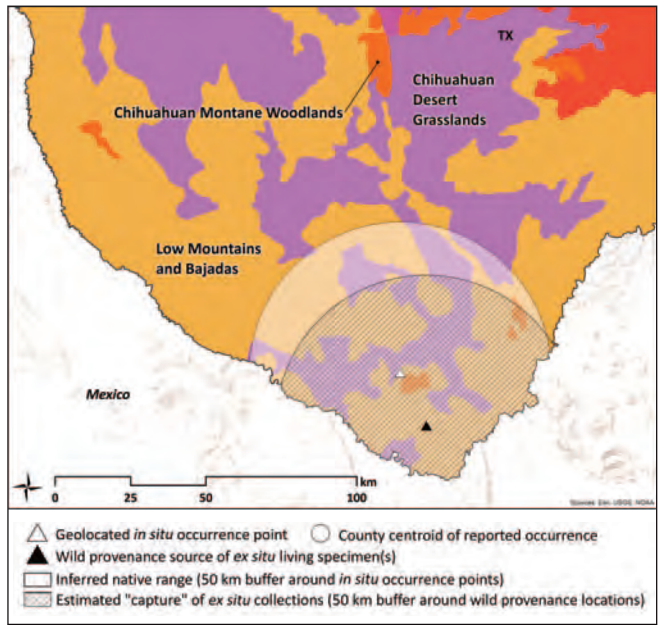


Figure 4. *Quercus robusta in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level IV Ecoregions are colored and labelled.[6] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

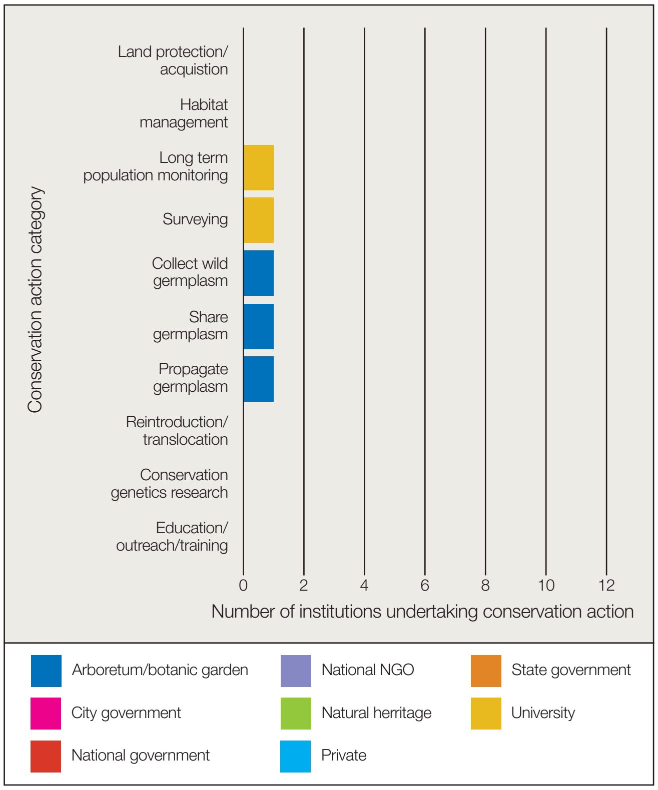


Figure 5. Number of institutions reporting conservation activities for *Quercus robusta* grouped by organization type. Two of 252 institutions reported activities focused on *Q. robusta* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. robusta*, 63% of the land is covered by protected areas (Figure 6). However, because this species' distribution is small and well-documented, we know that 100% of the species' potential occurrences within the U.S. are within protected areas.

All known populations of this species are located within Big Bend National Park, providing protection from excess human disturbance. The Park's general management plan also lists *Q. robusta* as outside the areas where current projects may disturb the landscape.[7]

Sustainable management of land: The Ecoregional Conservation Assessment of the Chihuahuan Desert ranks Big Bend Triangle as the area with the highest Irreplaceability Index and 9th highest overall conservation priority out of 39 areas of conservation concern in Texas.[8] The Texas Conservation Action Plan: Chihuahuan Desert and Arizona-New Mexico Mountains Ecoregions Handbook outlines general trends and needs in the region as a whole, including Big Bend National Park, but there is no specific mention of *Q. robusta* outside the "Species of Greatest Conservation Need" list.[9]

Population monitoring and/or occurrence surveys: Although the Texas Parks and Wildlife Department conservation action plan for the Chihuahuan Desert and Arizona-New Mexico mountain regions lists *Q. robusta* as a "Species of Greatest Conservation Need," it is unclear whether population monitoring accompanies this listing.[9] With support from APGA-USFS Tree Gene Conservation Program grants in 2016 and 2018, UC Davis Arboretum & Public Garden led expeditions to visit the species' type locality. It seemed to be in good health. A second potential population was also discovered in 2018, but needs further analysis to confirm its identification as *Q. robusta* (S. Still pers. comm., 2018).[10]

Wild collecting and/or *ex situ* curation: With support from an APGA-USFS Tree Gene Conservation Program grant, an expedition lead by UC Davis Arboretum & Public Garden located the main population of *Q. robusta* in 2016 to collect acorns, but none were present.[10] The Partnership funded a second collecting trip in 2018, which successfully obtained acorns; however, identification is uncertain and the individuals could be *Q. emoryi* x *Q. gracilliformis/gravesii* (A. Black pers. comm., 2018).

Propagation and/or breeding programs: Seeds from the collecting trip in 2018 will be distributed to grow out in cultivation and monitored for purity, and potentially confirmed through genetic characterization in the future (A. Black pers. comm., 2018).

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

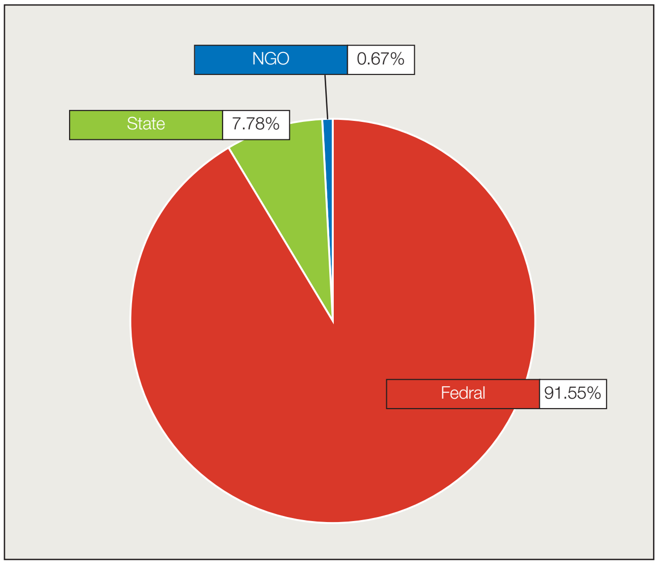


Figure 6. Management type of protected areas within the inferred native range of *Quercus robusta*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

PRIORITY CONSERVATION ACTIONS

Robust oak is a little-understood plant whose main conservation gap is the lack of an articulate, comprehensive taxonomic study. There are very little primary data available to help in determining whether this small group of plants, occurring fairly separately from other oaks in the area, should be considered a distinct species or whether it should be placed in the wider context of a *Q. emoryi*-*Q. gravesii* continuum that exists in the Chisos Mountains. Also noteworthy is the very recent discovery of a second population appearing to be *Q. robusta*. If these plants are indeed *Q. robusta*, the number of verified populations, and likely the number of individuals as well, would double. This development would certainly increase the stability of the species. Though, these plants are in close proximity to several other species that are not found in the type locality, giving rise to suspicion regarding their identity.

Physical conservation of this species seems fairly assured given that it is found only within the boundaries of Big Bend National Park. *Ex situ* conservation is the obvious next step in ensuring the longevity and further study of this plant. It will be important to cultivate the species within a wide range of growing sites to determining the extent to which the natural habitat is influencing morphology of the known plants. For instance, it could be discovered whether the distinctive stature of naturally occurring *Q. robusta* is due to increased moisture at its native site. The remoteness of the site makes collection a challenge, especially due to highly sporadic acorn production in the region, although acorns were collected from both localities in 2018. Nonetheless, efforts to collect, distribute, and propagate germplasm should be continued for the purposes of *ex situ* conservation and taxonomic study. Reinforcement and/or translocation could also be considered to further stabilize the species. Public education regarding the unique flora and fauna of the Chisos Mountains could provide further resources for the research and protection of this region; for example, interpretation could be installed at botanic gardens housing these rare species.

Research: In 2016, the Australian City of Melbourne completed The city of Melbourne's Future Urban Forest: Identifying vulnerability to future temperatures, which analyzed species currently planted within the city as well as species with possible suitability for urban planting in the future. *Quercus robusta* was analyzed as a tree not currently planted in the City of Melbourne, and was rated as moderately appropriate in low and medium intensity climate projections, and unsuitable in high intensity projections.[11]

Education, outreach, and/or training: No known initiatives at the time of publication.

Species protection policies: In 2009, a petition was submitted to the U.S. Fish and Wildlife Service, to list 475 species in the southwestern U.S. as Threatened or Endangered under the Endangered Species Act. Robust oak was determined to have an inadequate amount of threat information provided in the petition, and was subsequently rejected.[12] In addition to listing species as endangered or threatened, Texas maintains a list of more than 1,300 Species of Greatest Conservation Need (SGCN). These species are "declining or rare and in need of attention to recover or to prevent the need to list under state or federal regulation…[and are] the focus of Texas Parks and Wildlife Department's Texas Conservation Action Plan," but are not provided the same protections as endangered or threatened species. *Quercus robusta* is listed as a SGCN.[13]

Conservation recommendations for *Quercus robusta*

Highest Priority
- Population monitoring and/or occurrence surveys
- Propagation and/or breeding programs
- Research (restoration protocols/guidelines; taxonomy/phylogenetics)
- Wild collecting and/or *ex situ* curation

Recommended
- Education, outreach, and/or training
- Reintroduction, reinforcement, and/or translocation

REFERENCES

1. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
2. **Valencia, A. S., & Flores-Franco, G. (2006).** Catálogo de autoridades taxonómicas de las fagáceas (Fagaceae: Magnoliopsida) de México. Facultad de Ciencias, UNAM. Base de datos SNIB-CONABIO, proyecto CS008. México.
3. **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
4. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
5. **National Park Service. (2016).** *Foundation document, Big Bend National Park.* TX: U.S. Department of the Interior. Retrieved from http://www.npshistory.com/publications/foundation-documents/bibe-fd-2016.pdf
6. **U.S. EPA Office of Research & Development. (2013, April).** 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
7. **National Park Service. (2004).** *Final general management plan / environmental impact statement Big Bend National Park*. Brewster County, TX: United States Department of the Interior.
8. **Pronatura Noreste, The Nature Conservancy, & World Wildlife Fund. (2004).** *Ecoregional conservation assessment of the Chihuahuan Desert* (Second edition). Retrieved from https://www.conservationgateway.org/ConservationPlanning/SettingPriorities/EcoregionalReports/Documents/Chihuahuan Desert Report.pdf
9. **Texas Parks and Wildlife Department. (2012).** *Texas conservation action plan: Chihuahuan Desert and Arizona-New Mexico mountains ecoregions handbook*. Connally, W. (Ed.). Austin, TX. Retrieved from https://tpwd.texas.gov/landwater/land/tcap/documents/chih_tcap_2012.pdf
10. **Still, S., Griswold, E., & McNeil-Marshall, A. (2016).** *Scouting and collection trips for Trans-Pecos Quercus germplasm: APGA-USFS Tree Gene Conservation Partnerships*. Retrieved from https://www.publicgardens.org/file/2016-trans-pecosoaksreportpdf
11. **Kendal, D., & Baumann, J. (2016).** *The City of Melbourne's future urban forest: Identifying vulnerability to future temperatures*. Retrieved from https://minerva-access.unimelb.edu.au/handle/11343/122913
12. **U.S. Fish and Wildlife Service. (2009).** Endangered and threatened wildlife and plants; Partial 90 day finding on a petition to list 475 species in the Southwestern United States as threatened or endangered with critical habitat; proposed rule. Federal Register, 74(240), 66866-66905.
13. **Texas Parks and Wildlife Department. (2013).** Species of greatest conservation need. Retrieved from https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/tcap/sgcn.phtml

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus sadleriana***

Emily Beckman, Stuart Osbracki, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, ***Quercus sadleriana***

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus sadleriana R.Br.ter.

Synonyms: N/A **Common Names:** Sadler's Oak, Deer Oak

Species profile co-author: **Stuart Osbrackl,** Rogue River-Siskiyou National Forest, USDA Forest Service
Contributors: **Pam Allenstein,** Plant Collections Network, American Public Gardens Association; **Lisa Hoover,** Six Rivers National Forest, USDA Forest Service; **David Pivorunas,** National Forest System, USDA Forest Service

Suggested citation: Beckman, E., Osbrack, S., Meyer, A., & Westwood, M. (2019). *Quercus sadleriana* R.Br.ter. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 190-195). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-sadleriana.pdf

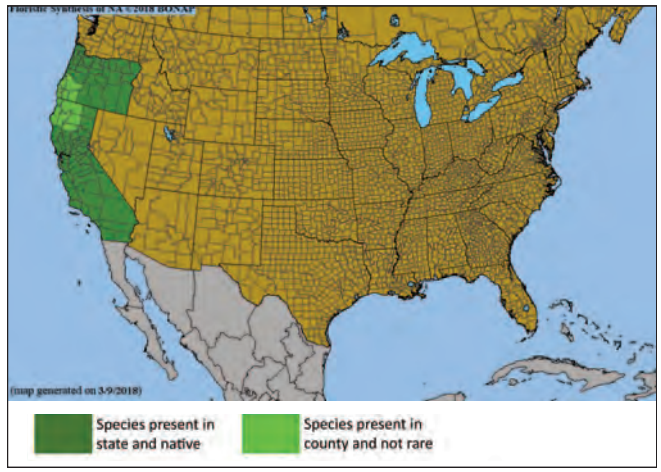


Figure 1. County-level distribution map for *Quercus sadleriana*. Source: Biota of North America Program (BONAP).[2]

DISTRIBUTION AND ECOLOGY

Quercus sadleriana, also known as Sadler's Oak, exists only in southwestern Oregon (Josephine, Curry, Douglas, and Coos Counties) and northwestern California (Humboldt, Trinity, Siskiyou, Shasta and Del Norte Counties), within the Klamath-Siskiyou mountain region of the U.S. Its current range is concentrated within the Six Rivers, Klamath, Rogue River, and Siskiyou National Forests. Sadler's Oak is one of the most distinctive western U.S. oaks due to its evident similarities to some eastern North American and Asian species of *Quercus* with "chestnut" leaves. With its restriction to the Klamath-Siskiyou region and uncertain taxonomic relationships within that area, *Q. sadleriana* is suggested to be a relictual species. This species is a montane shrub that is often a dominant member of the understory layer within middle to upper elevations, 600 to 2200 meters above sea level.[1] Sadler's oak thrives on open, rocky slopes and ridges in a variety of soil types and plant association groups including tanoak, Douglas fir, Hemlock, White fir, Red fir, and Port Orford cedar. Soils can be shallow or deep. The species percent cover varies in the different plant associations and can range up to 48% (S. Osbrack pers. comm., 2018).

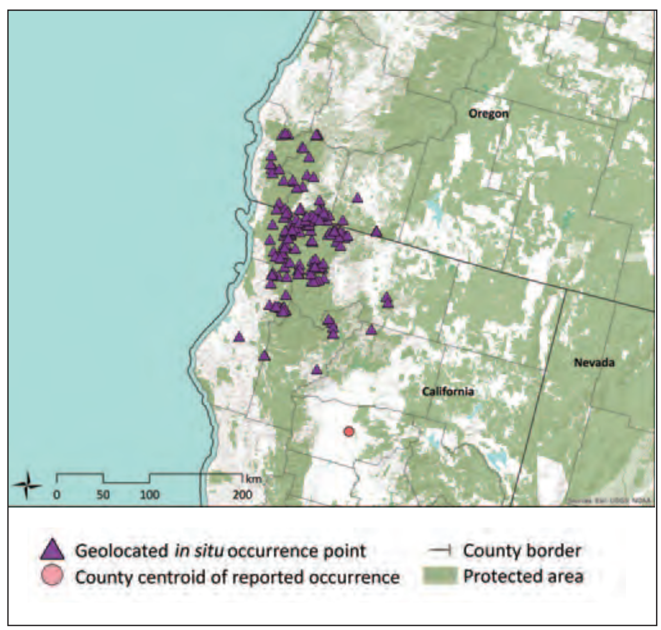


Figure 2. Documented *in situ* occurrence points for *Quercus sadleriana*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[3]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus sadleriana*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	Score
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	5
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	0
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	5
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	5
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	-
Average vulnerability score							3.0
Rank relative to all U.S. oak species of concern (out of 19)							19

THREATS TO WILD POPULATIONS

High Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Fire suppression threatens the integrity of low elevation *Q. sadleriana* habitat.[4] Frequent, low-intensity fires maintain the health of Sadler's oak habitat, and the removal of this natural disturbance regime has allowed the buildup of an extremely dense understory, diminishing overall forest health. This also leads to increased fuel loads, which can cause unusually severe wildfire.[5] Fire beyond the natural range of variability for the Klamath Siskiyous National Forest would likely burn at a higher intensity than *Q. sadleriana* can survive. (L. Hoover pers. comm., 2018).

Moderate Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Climatic shift, resulting in the migration of *Q. sadleriana* to higher elevations, could be a threat. The USDA Forest Service is currently researching the potential effects of climate change regarding a species associated with *Q. sadleriana*: *Castanopsis nootkatensis*, or Alaska yellow cedar (L. Hoover pers. comm., 2018).

Low Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: Decades of commercial logging, mineral extraction, and livestock grazing could threaten the integrity of *Q. sadleriana's* habitat, though most of the significant blocks of protected land encompass high elevation habitats where Sadler's Oak thrives.[4]

Human use of landscape — residential/commercial development, mining, and/or roads: Because the majority of *Q. sadleriana's* range is protected within national forests, there is not extreme pressure from human land use; however, threats may still occur in specific locations. Increasing population growth and development in residential communities may put pressure on Sadler's oak in the Rouge River National Forest, Oregon. This forest stretches along the California border, where the nationally-owned land is fragmented by private ownership of developed landscapes.[4] These concerns are not applicable to the Six Rivers National Forest in California (L. Hoover pers. comm., 2018).

Human modification of natural systems — invasive species competition: Noxious weeds and invasive plants are an increasing threat to lower elevations within the Klamath National Forest ecosystem. The neighboring Rogue River-Siskiyou National Forest also considers invasive plants to be an increasing problem on their land.[6] However, these invasives are unlikely to threaten *Q. sadleriana*, due to the species' typical habitation at higher elevations than areas experiencing increasing exotic plant presence (L. Hoover pers. comm., 2018).

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	13
Number of plants in *ex situ* collections:	76
Average number of plants per institution:	6
Percent of *ex situ* plants of wild origin:	80%
Percent of wild origin plants with known locality:	70%

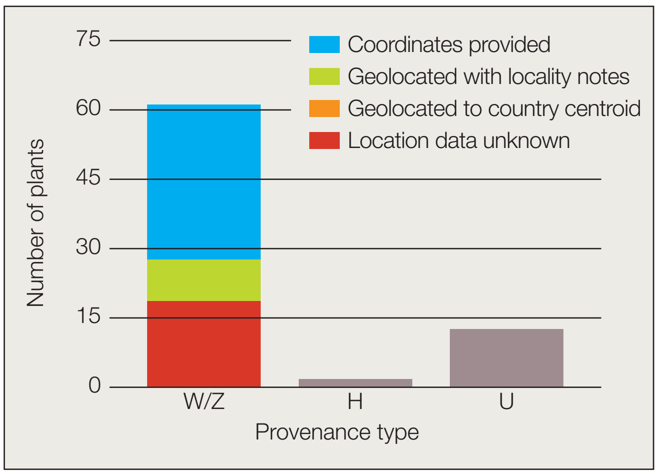


Figure 3. Number and origin of *Quercus sadleriana* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

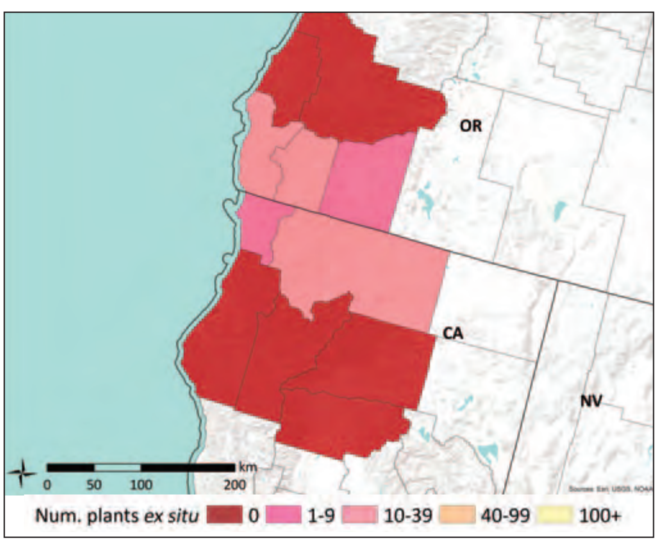


Figure 4. *Quercus sadleriana* counties of *in situ* occurrence, reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	34%
Ecological coverage:	56%

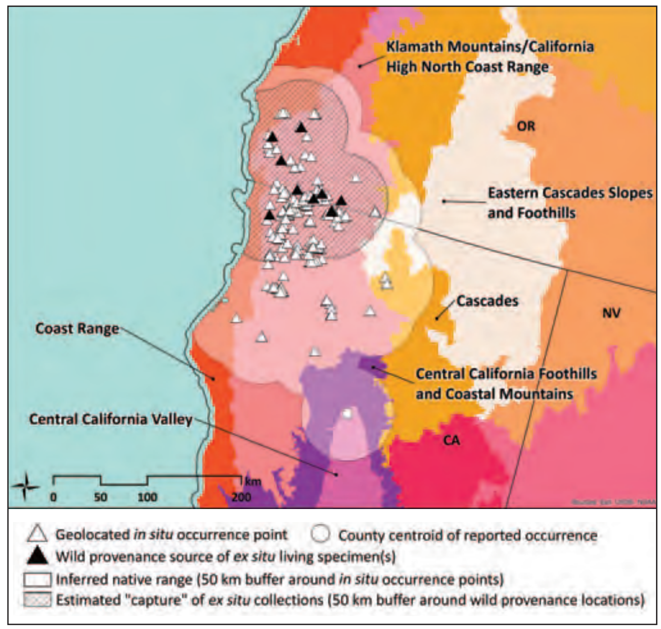


Figure 5. *Quercus sadleriana in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[7] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

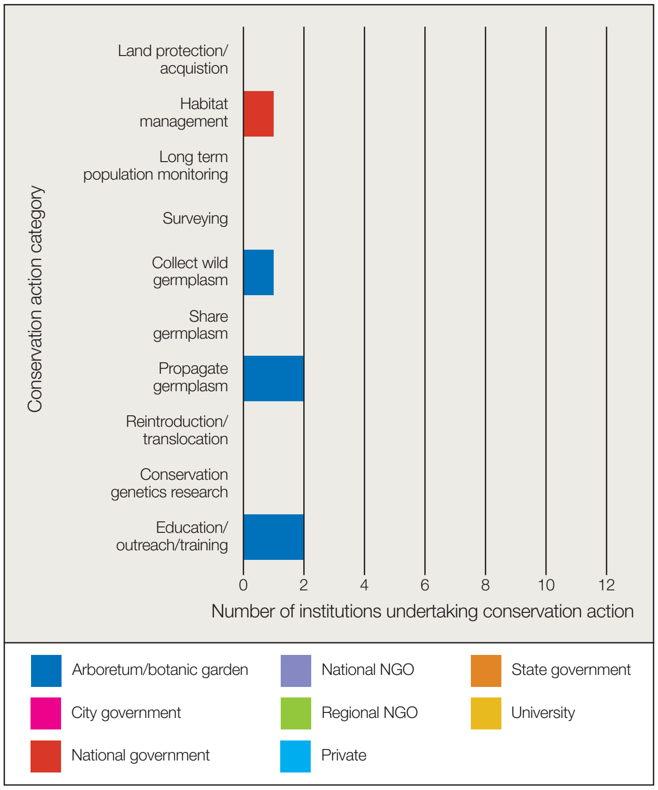


Figure 6. Number of institutions reporting conservation activities for *Quercus sadleriana* grouped by organization type. Four of 252 institutions reported activities focused on *Q. sadleriana* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. sadleriana*, 53% of the land is covered by protected areas (Figure 7). However, because Sadler's oak has a well-documented distribution, the vast majority of its population is known to be within federally protected areas.

Both Klamath National Forest and Six Rivers National Forest house exceptionally diverse flora, with many rare and endemic species. Most documented populations of *Q. sadleriana* are found within this enriched mixed conifer forest, which is already a high priority for continued protection (L. Hoover pers. comm., 2018).[6] The species can also be found within the Smith River National Recreation Area and the Bear Basin Butte Botanical Area (7,500 acres total), as well as the Broken Rib Ecological Area (1,069 acres; L. Hoover pers. comm., 2018).

Sustainable management of land: Conservation actions specific to *Q. sadleriana* are not prevalent, and therefore its conservation stems from the protection of its habitat due to the high biodiversity in that area and its prevalence on USDA Forest Service lands. It is very likely though, that the integrity of certain Klamath-Siskiyou forest communities relies on the health of Sadler's oak subpopulations, since the species is a main component within that habitat.[4] This could lead to further conservation efforts for *Q. sadleriana*, if the tree is linked to other threatened species of high priority in the region. Sadler's Oak is present within Mt. Shasta Wilderness, Red Buttes Wilderness, Siskiyou Wilderness, and Wild Rogue Wilderness, which, under the Wilderness Act (1964), are required to be "protected and managed so as to preserve [their] natural conditions."[8] In the Six Rivers National Forest, most occurrences of Sadler's Oak are found within the Smith River National Recreation Area (SRNRA), where management activities focus on fuels and biological related projects. The SRNRA houses the Siskiyou Wilderness and adjoining Bear Basin Butte Botanical Area and Broken Rib Ecological Area, which are managed for conservation purposes (L. Hoover pers. comm., 2018). The Klamath National Forest Land and Resource Management Plan is robust, though has not been updated since 2010.[9]

The North Willamette Valley Upland Oak Restoration Partnership project implements long-term land conservation strategies as well as short-term investments such as land acquisitions and conservation easements. A team of federal, state, local, and other conservation agencies work to restore oak habitat in 19 key areas throughout Yamhill and Polk counties. Partners include the Polk Soil and Water Conservation District, Natural Resources Conservation Service, U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, The Trust for Public Lands, Greater Yamhill Watershed Council, The Nature Conservancy, and Confederated Tribes of Grand Ronde.[10]

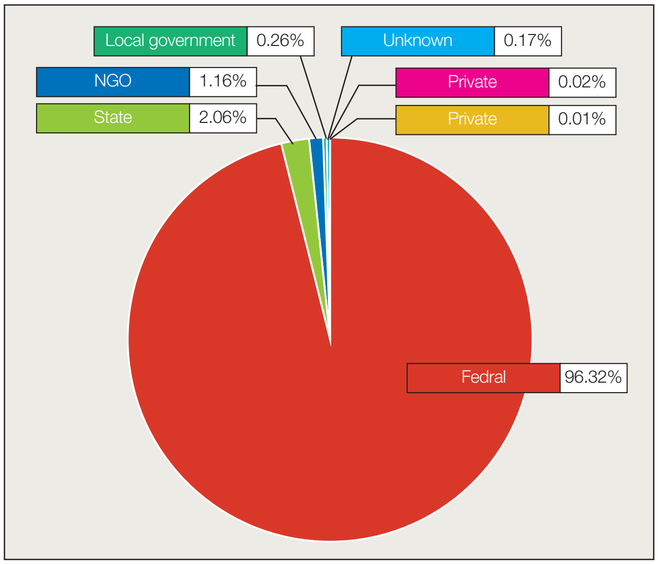


Figure 7. Management type of protected areas within the inferred native range of *Quercus sadleriana*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[3]

The North Pacific Landscape Conservation Cooperative facilitated a 2014 project that worked towards cross-boundary planning for the restoration of dry forest and savannah habitats in The Georgia Basin, which aimed to "synthesize existing data into GIS tools that prioritized land acquisition and conservation investment" for use "throughout British Columbia, Washington & Oregon to facilitate cross-boundary planning for the endangered forest and Savannah habitat."[11] Since 1995 the non-profit organization Lomakatsi Restoration Project has been a leader in collaborative, holistic approaches to oak ecosystem restoration in southern Oregon and northern California.[5]

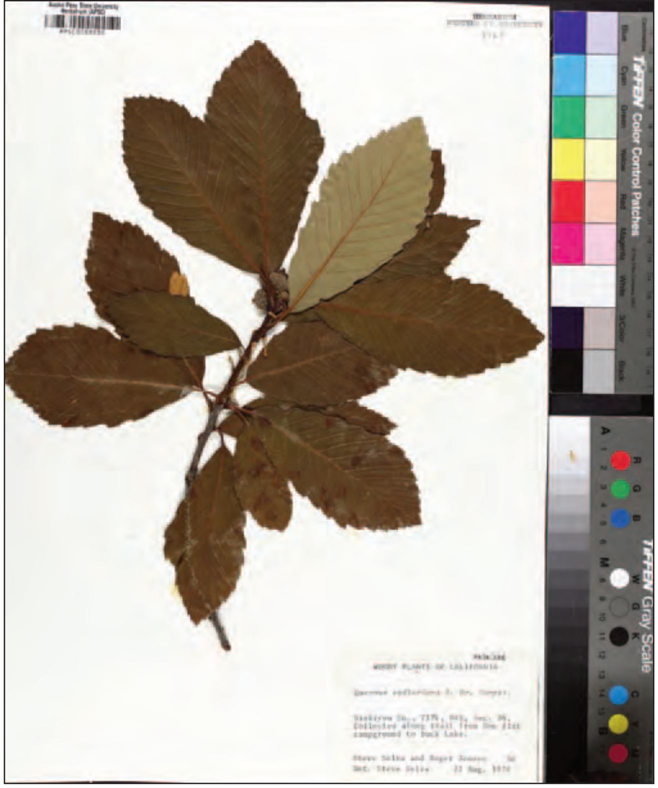
Population monitoring and/or occurrence surveys: The Happy Camp/Oak Knoll Ranger District of Klamath National Forest closely monitors Bald eagles, Peregrine falcons, Northern goshawk, and Northern spotted owls, which all rely on an ecosystem which includes *Q. sadleriana*.[6] However, land-based surveys specifically for Sadler's oak seem to be lacking (L. Hoover pers. comm., 2018).

Wild collecting and/or *ex situ* curation: The University of Washington Botanic Gardens is working to increase wild-sourced specimens within its collections, and acquired *Q. sadleriana* in a fall 2007 expedition to the Siskiyou Mountains of southern Oregon. Denver Botanic Gardens, in collaboration with Chicago Botanic Garden and Bartlett Tree Research Lab, have been awarded a 2017 APGA-USFS Tree Gene Conservation Partnership grant to scout suitable populations for collecting and hopefully gather germplasm for propagation (P. Allenstein pers. comm., 2017).[12]

Propagation and/or breeding programs: The MsK Rare and Native Plant Nursery was founded in 1970 by Kruckeberg Botanic Garden and continues to be an important source of native plants. In 2011, a variety of oaks were available, including *Q. garryana, Q. vaccinifolia, Q. sadleriana, Q. pontica, Q. gambelii, Q. kelloggii, Q. acutissima*, and *Q. macranthera*.[13]

Reintroduction, reinforcement, and/or translocation: Habitat restoration initiatives usually include reinforcement of populations for keystone species if significant declines have been detected. Though this is not currently the case for *Q. sadleriana*, there are many restoration projects (listed within the Sustainable management of land section) that would likely reinforce populations of *Q. sadleriana* should it become necessary.

Research: Specialist animals are reliant on the exact physical conditions that allow their survival. In a region with extensive diversity, such as the Klamath-Siskiyou mountains, a greater number of species become specialists. One example is Cameraria sadlerianella, a tiny leaf-mining moth found only on Sadler's oak.[14] The California Department of Fish and Wildlife is working to map and document all natural communities within the state, using the National Vegetation Classification Standard (NVCS). This initiative evaluates Natural Communities using NatureServe's Heritage Methodology, with



communities ranked as vulnerable or higher considered Sensitive Natural Communities. These sensitive communities are mandated to be addressed in the environmental review processes of the California Environmental Quality Act and its equivalents. Nine Alliances or Associations (finest two levels of the NVCS) listed within the January 2018 California Sensitive Natural Communities database include *Q. sadleriana*. These nine communities are ranked globally as vulnerable (5 communities), apparently secure (1), and secure (3).[15]

Education, outreach, and/or training: Klamath National Forest hosts a significant volunteering program, which includes trail work, campground host, bird surveys, conservation education, fire lookout, Adopt-A-Trail, information receptionist, and wilderness restoration projects. These opportunities give participants the opportunity to learn about the valuable ecosystems represented within the Forest, as well as share this knowledge with park visitors.[6] The Lomakatsi Restoration Project and North Willamette Valley Upland Oak Restoration Partnership both use education as an important conservation activity. The Willamette Valley Partnership works with landowners of oak habitats in Polk and Yamhill counties by providing information and assistance for participation in the National Resource Conservation Service (NRCS) voluntary Environmental Quality Incentives Program. Through this program, the NRCS facilitates conservation by giving financial and technical assistance to landowners implementing long-term oak habitat health and restoration projects. One example is the transition of marginal sites into more valuable habitat through measurement and control of invasive plants by landowners.[5,9]

Species protection policies: No known initiatives at the time of publication.

PRIORITY CONSERVATION ACTIONS

Sadler's oak sites are typically montane; consequentially much of its habitat exists within National Forests, which afford *Q. sadleriana* a certain amount of protection. This understory shrub also has a low susceptibility to fire and can readily sprout. Restoration needs for the species are not currently known or clearly identified. Sadler oak's small form appears to protect it from a common threat faced by oaks of a larger stature in oak savannas, oak woodlands, or other oak communities: understory species encroaching in or usurping the more open habitat necessary for oak regeneration. Additional conservation activities may not be required at this time since threats to this species persistence in the landscape are not known and may not exist. It is necessary for sustainable management of land to continue, and populations should be monitored in relation to changing climate. This could include the use of predictive modeling to identify preparatory actions to equip *Q. sadleriana* for shifting climate in the future. Although this species is already present within at least 13 *ex situ* collections and represented by more than 50 plants of known wild origin, less than half of Sadler's oak native distribution is represented *ex situ*. Collection from unrepresented locations is recommended for optimal preservation of genetic diversity.

Conservation recommendations for *Quercus sadlerianella*

Highest Priority

- Sustainable management of land

Recommended

- Population monitoring and/or occurrence surveys
- Research (climate change modeling)
- Wild collecting and/or *ex situ* curation

REFERENCES

1. **Muth, G. J. (1979).** *Quercus sadleriana* R. Br. Campst., its distribution, ecology, and relationships to other oaks. In *Proceedings of the symposium on the ecology, management, and utilization of California oaks* (Gen. Tech. Rep. PSW-44). Claremont, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.fed.us/psw/publications/documents/psw_gtr044/psw_gtr044_fm.pdf
2. **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
3. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
4. **Oregon Department of Fish and Wildlife. (2006, January).** *Oregon conservation strategy: Klamath Mountains ecoregion*. Retrieved from http://library.state.or.us/repository/2009/200907171321185/b-eco_km.pdf
5. **Lomakatsi Restoration Project. (n.d.).** Oak habitat restoration program. Retrieved from https://lomakatsi.org/oak-habitat-restoration/
6. **USDA Forest Service. (n.d.).** Klamath National Forest. Retrieved from https://www.fs.usda.gov/detail/klamath/
7. **U.S. EPA Office of Research & Development. (2013, April).** 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
8. **Wilderness Act of 1964,** Pub. L. No. 88-577.
9. **Klamath National Forest. (1995).** Revised 2010. *Land and resource management plan: Klamath National Forest*. Pacific Southwest Region, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/main/klamath/landmanagement/planning
10. **Natural Resources Conservation Service Oregon. (n.d.).** North Willamette Valley Upland Oak Restoration Partnership. United States Department of Agriculture. Retrieved from https://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/home/?cid=nrcseprd346418
11. **North Pacific Landscape Conservation Cooperative. (2016).** Cross-boundary planning for resilience and restoration of endangered oak savannah and coastal Douglas-fir forest ecosystems. Retrieved from http://www.northpacificlcc.org/cross-boundary-planning-for-resilience-and-restoration-of-endangered-oak-savaNnah-and-coastal-douglas-fir-forest-ecosystems
12. **American Public Gardens Association. (n.d.).** Tree Gene Conservation Partnership showcase.
13. **Giseburt, D. (2011).** Fagaceae at the Kruckeberg Botanic Garden. *Oak News & Notes*, *The Newsletter of the International Oak Society, 15(*1), 1-3.
14. **U.S. Fish and Wildlife Service. (1995).** *Draft environmental alternatives analysis for a 4(d) rule for the conservation of the Northern spotted owl on non-federal lands.*
15. **California Department of Fish and Wildlife. (n.d.).** Natural communities. Retrieved from https://www.wildlife.ca.gov/Data/VegCAMP/Natural-Communities

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus similis***

Emily Beckman, Tim Boland, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, ***Quercus similis***

The Morton Arboretum®

BOTANIC GARDENS CONSERVATION INTERNATIONAL

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

FAUNA & FLORA INTERNATIONAL

Quercus similis Ashe

Synonyms: *Quercus ashei* Sterrett, *Q. mississippiensis* Ashe, *Q. margarettae* var. *paludosa* (Sarg.) Ashe, *Q. stellata* var. *Attenuata* Sarg., *Q. stellata* var. *mississippiensis* (Ashe) Little, *Q. stellata* subsp. *paludosa* (Sarg.) A.E.Murray, *Q. stellata* var. *paludosa* Sarg., *Q. stellata* var. *similis* (Ashe) Sudw. **Common Names:** Swamp post oak, Delta post oak

Species profile co-author: Tim Boland, The Polly Hill Arboretum
Contributors: Patrick Thompson, Donald E. Davis Arboretum, Auburn University College of Sciences and Mathematics

Suggested citation: Beckman, E., Boland, T., Meyer, A., & Westwood, M. (2019). *Quercus similis* Ashe. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 196-201). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-similis.pdf

DISTRIBUTION AND ECOLOGY

Quercus similis, also known as Swamp post oak, occurs in the southeastern U.S. from South Carolina west to Texas. It is thought to have a very patchy distribution from South Carolina to Alabama and more significant populations in Louisiana, eastern Texas, southern Arkansas, and western Mississippi. This species' distribution is generally not well documented, and it is sometimes considered a variety of *Q. stellata*; therefore *Q. similis* could be significantly more prevalent or uncommon than currently thought. Swamp post oak thrives in the rich, moist bottom lands of eastern Texas pineywoods, as well as gulf prairies and marshes moving further east. It is a moderate to large tree that can reach a maximum height between 25 and 33 meters.[1,2] NatureServe rates the species as Apparently Secure in Texas, Critically Imperiled in Alabama, Georgia, and South Carolina, and has not yet ranked the species in Louisiana, Arkansas, or Mississippi. *Quercus similis* is also listed as a main component of eight different Ecological Associations, all of which have a confidence level of Low - Poorly Documented.[3]

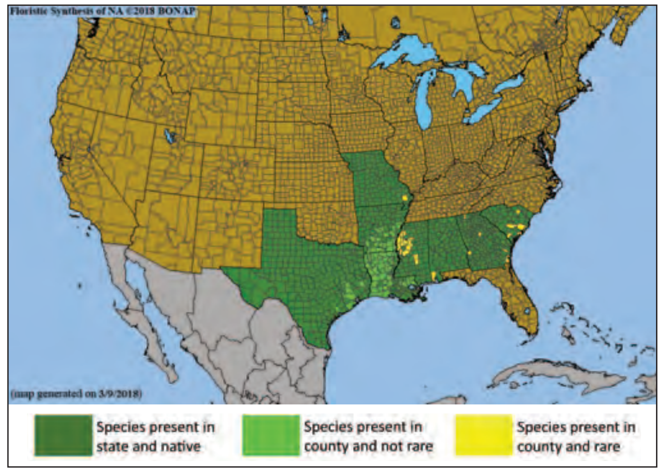


Figure 1. County-level distribution map for *Quercus similis*. Source: Biota of North America Program (BONAP).[4]

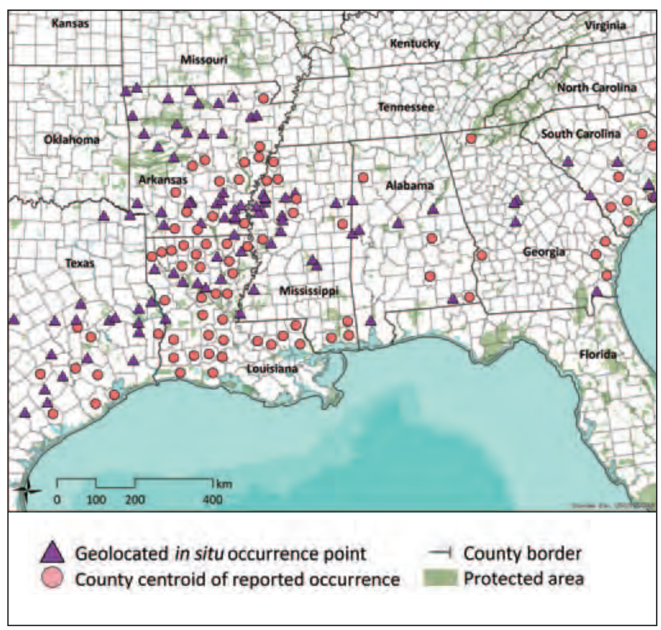


Figure 2. Documented *in situ* occurrence points for *Quercus similis*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus similis*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	Score
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	0
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	10
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	5
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	-
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	-
						Average vulnerability score	5.0
						Rank relative to all U.S. oak species of concern (out of 19)	15

THREATS TO WILD POPULATIONS

High Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: Specific threats to *Q. similis* are not well documented, but significant effects due to habitat use for agriculture, silviculture, and/or grazing are highly suspected based on reports regarding other similar oak species in the region.

Moderate Impact Threats

Human use of landscape — residential/commercial development, mining, and/or roads: This threat is also not documented specifically for *Q. similis*, but for other well-documented oaks in its region, the most common and persistent threats are related to human use of the landscape.

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: The 2016 ForeCAST Project climate change modeling predicts a 57% reduction in suitable habitat area for *Q. similis* by 2050.6 In 2013 the same authors had predicted a 92% reduction in suitable habitat area by 2015.[7] A recent analysis of U.S. tree vulnerability to climate change gave *Q. similis* a moderate vulnerability ranking based on species-specific traits, predicting high threat exposure and low-to-moderate adaptive capacity, but low threat sensitivity.[8] Extreme flooding and fire have affected the species' main distribution, and these conditions are predicted to continue and perhaps increase in intensity and frequency moving forward.

Low Impact Threats

Human use of species — wild harvesting: Swamp post oak has broad utility as timber and is known as a mast producer used for low-grade lumber, but no unsustainable harvesting is currently known.[9] Its yellow-tan cast restricts its use as veneer.[10]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	2
Number of plants in *ex situ* collections:	4
Average number of plants per institution:	2
Percent of *ex situ* plants of wild origin:	100%
Percent of wild origin plants with known locality:	100%

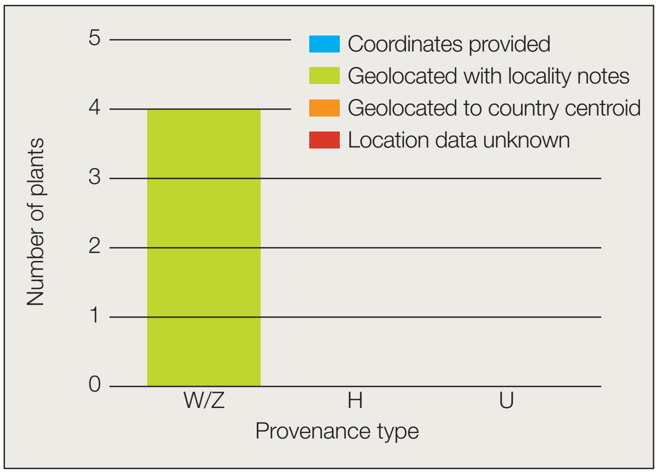


Figure 3. Number and origin of *Quercus similis* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

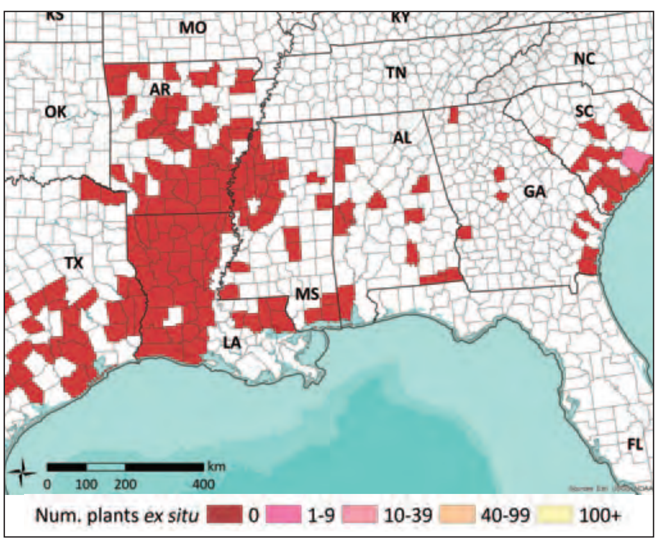


Figure 4. *Quercus similis* counties of *in situ* occurrence, reflecting the number of plants from each county *in ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	1%
Ecological coverage:	3%

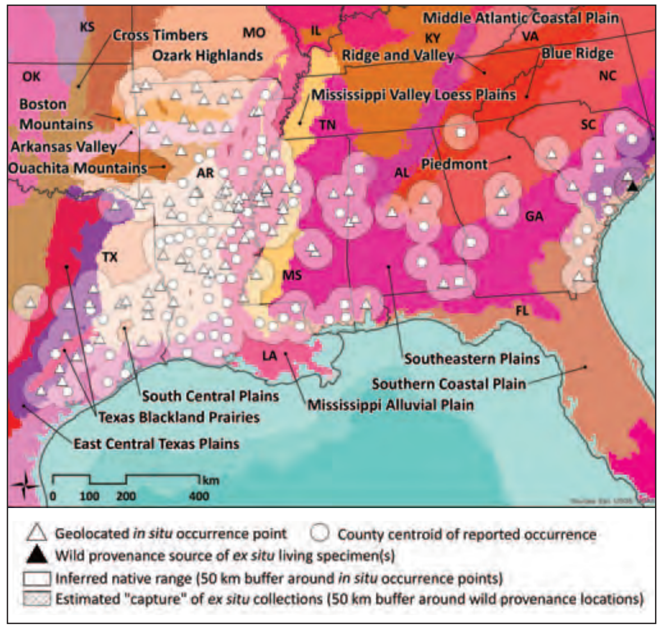


Figure 5. *Quercus similis in situ* occurrence points and *ex situ* collection source localities. U.S. EPA Level III Ecoregions are colored and labelled.[11] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

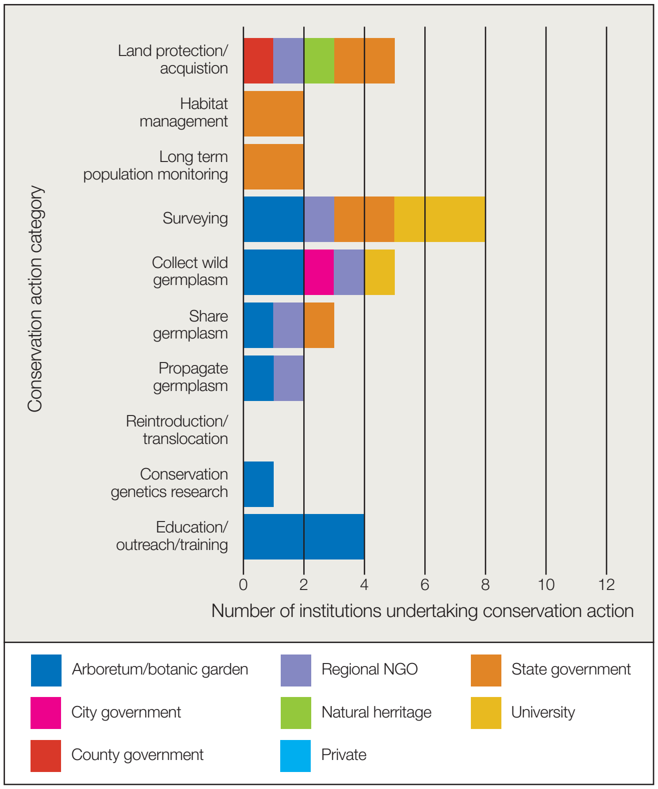


Figure 6. Number of institutions reporting conservation activities for *Quercus similis* grouped by organization type. Fifteen of 252 institutions reported activities focused on *Q. similis* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. similis*, only 10% of the land is covered by protected areas (Figure 7). There is little information available regarding the size and health of *Q. similis* populations within protected areas, or the management of such populations. It is assumed the vast majority of Swamp post oak individuals are unprotected, though the use and condition of private lands housing the species are also largely unknown.

Land where a Swamp post oak herbarium record was taken in Bibb County, Alabama, has recently been purchased by The Nature Conservancy. The Conservancy was not aware of the record, but work is being done to confirm its presence (P. Thompson pers. comm., 2017). The White River National Wildlife Refuge has been reported to contain *Q. similis*.[12] The Little Sandy National Wildlife Refuge: Draft Comprehensive Conservation Plan and Environmental Assessment also reports the species.[13]

Sustainable management of land: A project focusing on the reclamation of a remnant Post Oak Savannah within Northwest Arkansas Community College's Outdoor Living Laboratory located a previously-unknown stand of what seems to be *Q. similis*. Project participants are working to scientifically prove the trees to be *Q. similis*, which would make the stand the northernmost recorded population of the species.[14]

Population monitoring and/or occurrence surveys: A Forest Inventory and Analysis (FIA) inventory of Louisiana's forests revealed that Loblolly pine was the most common species, with over 25,000 observations, Sweetgum was the next most commonly observed, with 6,440 observations, and Swamp post oak was observed four times.[15] Auburn University's Davis Arboretum is planning to create a vetted occurrence point dataset as they find verifiable specimens of *Q. similis* in Alabama (T. Boland pers. comm., 2017).

Wild collecting and/or *ex situ* curation: The Polly Hill Arboretum will be embarking on a seed collecting trip in the fall of 2019, including sites in Georgia, South Carolina, and Alabama. The Arboretum is interested in locating *Q. similis* if possible, for collection. This trip will also be used to geolocate populations with limited location data, and to share seed with collaborating public garden institutions (T. Boland pers. comm., 2018).

Propagation and/or breeding programs: Two institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: Within the Little Sandy Wildlife Refuge, *Q. nigra, Q. similis, Q. phellos*, and *Q. lyrata* cumulatively "comprise a scant 10% of the small stems, despite canopy dominance of the latter two species." *Quercus similis* is noted as majority "very large trees (> 75 cm dbh)," rather than presence as "small stems."[13] The Coastal Georgia Land Conservation Initiative--a collaboration among the Georgia Department of Natural Resources, Georgia Conservancy, and Association County Commissioners of Georgia--confirmed *Q. similis* to be present in the state, which had previously been arguable.[16]

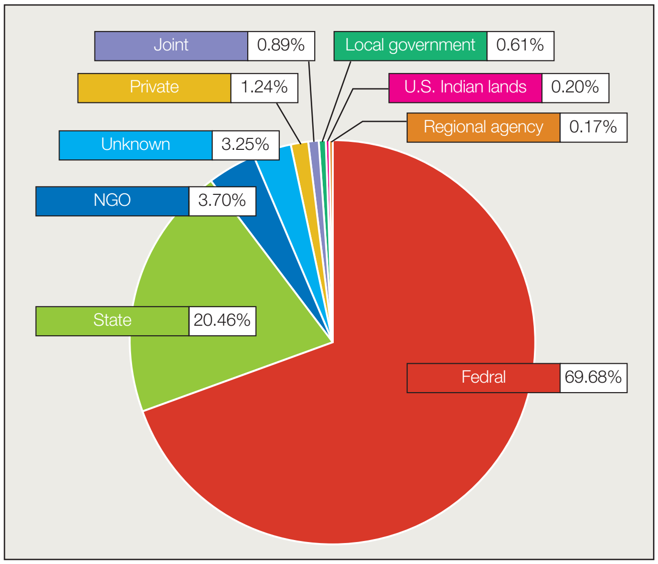


Figure 7. Management type of protected areas within the inferred native range of *Quercus similis*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[5]

Ron Lance

Education, outreach, and/or training: Four institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Species protection policies: NatureServe ranks *Q. similis* as Critically Imperiled in South Carolina, Georgia, and Alabama, but it is unknown if specific protection policies accompany these rankings.[3]

PRIORITY CONSERVATION ACTIONS

It is clear from current and past efforts that Swamp post oak offers opportunities for more detailed study in several areas. Populations in South Carolina, Georgia, and Alabama should be placed under protection where possible, and monitored for changes in population size, health, and existing threats to their livelihood. Given its current known distribution, exploration into the Florida panhandle may find additional populations based on habitat preference. More extensive distribution studies are recommended based on existing documentation.

There is also significant room for improvement of genetic diversity representation in *ex situ* collections, which will provide adequate germplasm backup if the severe impacts of climate change predicted for this species decimate valuable subpopulations. This species has poor representation in *ex situ* collections at this time, with limited population sampling from its current known distribution. Opportunities exist to determine successful protocols for propagation of Swamp post oak, and its requirements for reintroduction into the wild. In addition, taxonomic examination of this species and its relationship to its two dry land relatives, *Q. stellata* Wangenh and *Q. margarettae* (Ashe) Small, should be undertaken to determine their shared evolutionary past and current relationships.

Conservation recommendations for *Quercus similis*

Highest Priority

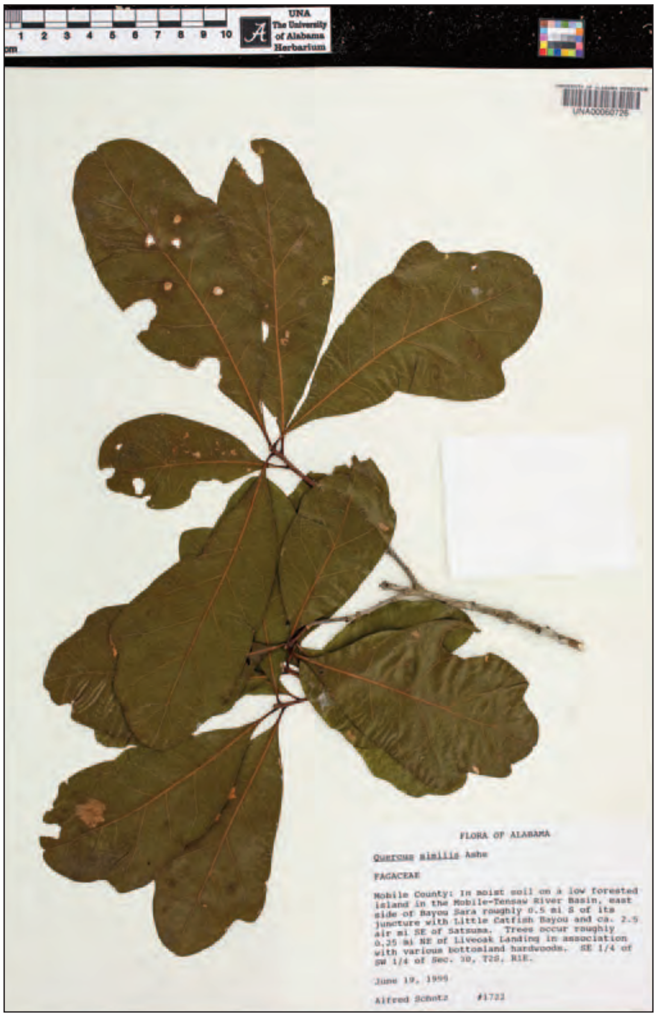
- Land protection
- Population monitoring and/or occurrence surveys
- Research (demographic studies/ecological niche modeling; restoration protocols/guidelines; taxonomy/phylogenetics)

Recommended

- Wild collecting and/or *ex situ* curation

REFERENCES

1. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
2. **Stein, J., Binion, D., & Acciavatti, R. (2003).** *Field guide to native oak species of eastern North America*. Forest Service, U.S. Department of Agriculture.
3. **NatureServe. (2017).** NatureServe Explorer: An online encyclopedia of life [online]. Version 7.1. Arlington, VA. Retrieved from http://explorer.natureserve.org.
4. **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
5. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
6. **Hargrove, W. W., & Potter, K. M. (2016).** The ForeCASTS project: Forecasts of climate-associated shifts in tree species. Version 5 Tree Atlas. Retrieved from https://www.geobabble.org/ForeCASTS/index.html
7. **Potter, K. M., & Hargrove, W. W. (2013).** Quantitative assessment of predicted climate change pressure on North American tree species. *Mathematical and Computational Forestry & Natural Resource Sciences, 5*(2), 151-169. Retrieved from https://www.fs.usda.gov/treesearch/pubs/45423
8. **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
9. **LSU AgCenter. (n.d.).** Delta post oak, *Quercus similis*. BatonRouge, LA: School of Renewable Natural Resources, Louisiana Plant Identification and Interactive Virtual Tours. Retrieved from http://www.rnr.lsu.edu/plantid/species/deltapostoak/deltapostoak.htm
10. **Carey, J. H. (1992).** *Quercus stellata*. In Fire Effects Information System [online]. CO: Fire Sciences Laboratory, Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.fed.us/database/feis/plants/tree/queste/all.html
11. **U.S. EPA Office of Research & Development. (2013, April).** 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
12. **Arkansas Agricultural Development. (n.d.).** Bottomland post oak (*Quercus similis*). Retrieved from http://www.agriculture.arkansas.gov/oak-bottomland-post-quercus-similis
13. **U.S. Fish and Wildlife Service. (2017, January).** *Little Sandy National Wildlife Refuge: Draft comprehensive conservation plan and environmental assessment*. Retrieved from https://www.fws.gov/southwest/refuges/texas/little_sandy/CCP/LittleSandyStateReveiwDraft.pdf
14. **Walker, S., Buell, M. A., & Blackford, D. (2013).** Reclamation of the Delta post oak grove and the restoration of the primary Nebkah Mound. Retrieved from http://faculty.nwacc.edu/east_original/Spring%202013/Plant%20Biology/Post%20Oak%20Savanna/Final%20Presentation.pdf
15. **Oswalt, S. N. (2013).** *Louisiana's forests* (Resource Bulletin SRS-210). LA: Southern Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.srs.fs.usda.gov/pubs/rb/rb_srs210.pdf
16. **Georgia Department of Natural Resources. (n.d.).** Coastal Georgia land conservation initiative. Retrieved from https://georgiawildlife.com/conservation/coastallandcover



Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus tardifolia***

Emily Beckman, Andrew McNeil-Marshall, Shannon M. Still, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, ***Quercus tardifolia***

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus tardifolia C.H.Müll.

Synonyms: N/A **Common Names:** Lateleaf oak

Species profile co-authors: Andrew McNeil-Marshall, Lady Bird Johnson Wildflower Center, The University of Texas at Austin; Shannon M. Still, UC Davis Arboretum and Public Garden
Contributor: Béatrice Chassé, Arboretum des Pouyouleix

Suggested citation: Beckman, E., McNeil-Marshall, A., Still, S. M., Meyer, A., & Westwood, M. (2019). *Quercus tardfiolia* C.H.Müll. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 202-207). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-tardifolia.pdf

DISTRIBUTION AND ECOLOGY

Quercus tardifolia, or Lateleaf oak, is a little-known species from the Chisos Mountains of southwestern Texas, U.S. It is only agreed to be found in Big Bend National Park, and is currently under taxonomic debate. Many believe the tree is a rare hybrid occurrence of *Q. gravesii* and either *Q. hypoxantha* or *Q. arizonica* (B. Chassé pers. comm., 2017).[1] One unverified report has been noted by A. M. Powell within the Mexican state of Coahuila, in the 1980s. The Sierra del Carmen mountain range runs through this region, extending south from Big Bend National Park, and is the only other area where further specimens could be discovered. The type specimen of *Q. tardifolia* was found in a semiarid, wooded area along steeply cut canyons at approximately 2,000 meters above sea level (A. McNeil-Marshall pers. comm., 2017).[1] During a 2018 collecting expedition, which visited the type locality, no individuals were confidently identified as *Q. tardifolia* (S. Still pers. comm., 2018).

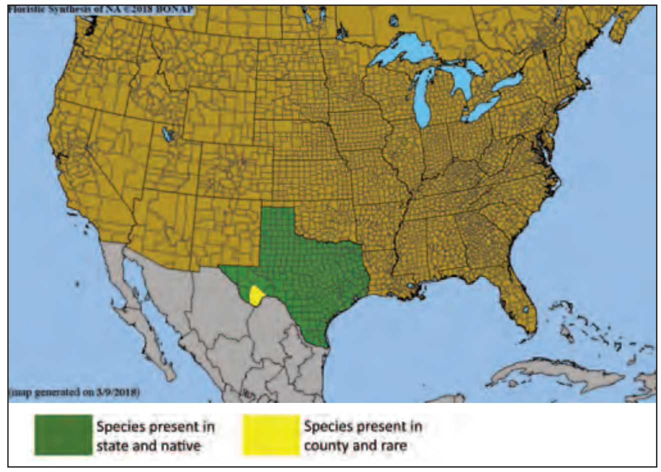


Figure 1. County-level distribution map for the U.S. distribution of *Quercus tardiofila*. Source: Biota of North America Program (BONAP).[2]

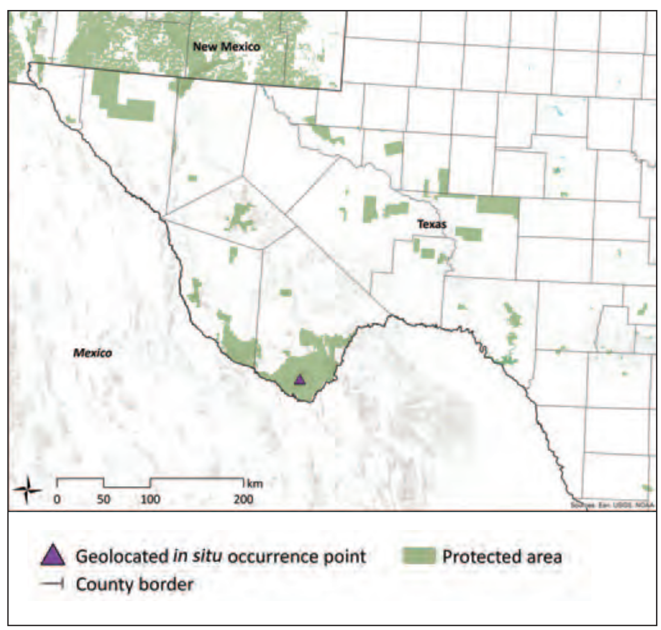


Figure 2. Documented *in situ* occurrence points for the U.S. distribution of *Quercus tardiofila*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[3]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus tardiofila*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	**Score**
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	40
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	40
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	-
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	0
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	-
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	20
Average vulnerability score							25.0
Rank relative to all U.S. oak species of concern (out of 19)							1

THREATS TO WILD POPULATIONS

High Impact Threats

Genetic material loss — inbreeding and/or introgression: Because *Q. tardifolia* is rare and occurs with other oak species nearby, hybridization may be a genetic threat. If a population exists, it is likely extremely small, making inbreeding in the near future very likely and genetic adaptation through natural selection unlikely.

Extremely small and/or restricted population: C. H. Müller defined Lateleaf oak in 1936, noting two small clumps. These trees were never successfully relocated aside from one individual at Boot Springs of Big Bend National Park, which has recently died. More exploration would be necessary to confirm the species' extirpation. Mature acorns have never been seen or recorded, so it is unknown if the species could even be propagated for reintroduction.[1] The single known location in Boot Springs was surveyed again during a recent collecting endeavor, but no trees were positively identified as *Q. tardifolia* (S. Still pers. comm., 2017).

Moderate Impact Threats

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Drought, flood, and fire all pose threats, especially since the population could be wiped out by one extreme event (A. McNeil-Marshall pers. comm., 2016).

Low Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: If the species exists within Mexico, there is no protection of the habitat, and development, ranching, or farming could impact a Lateleaf oak population.

Human use of landscape — tourism and/or recreation: There is some potential of human impact during recreational activities within Big Bend National Park (A. McNeil-Marshall pers. comm., 2016).

Human modification of natural systems — invasive species competition: Invasive plant species pose a significant threat to the unique and rare species within Big Bend National Park, but severe threat has not yet been witnessed for *Q. tardifolia*.[4]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks. *Quercus tardifolia* is the only oak species of concern which was not represented in any *ex situ* collections surveyed. Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 4).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	0
Number of plants in *ex situ* collections:	0
Average number of plants per institution:	0
Percent of *ex situ* plants of wild origin:	0%
Percent of wild origin plants with known locality:	0%

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 3). Only the native U.S. distribution of the species was considered in this analysis, due to availability of ecoregion maps. Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	0%
Ecological coverage:	0%

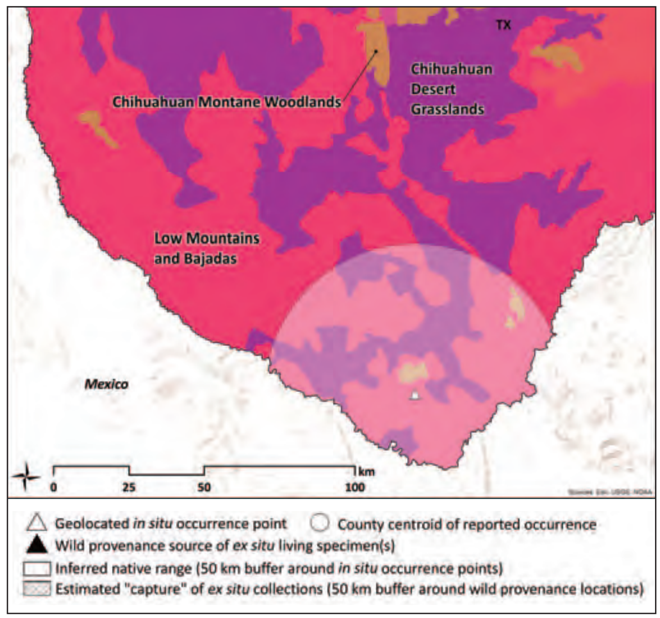


Figure 3. *Quercus tardiofila in situ* occurrence points and *ex situ* collection source localities within the United States. U.S. EPA Level IV Ecoregions are colored and labelled.[5] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

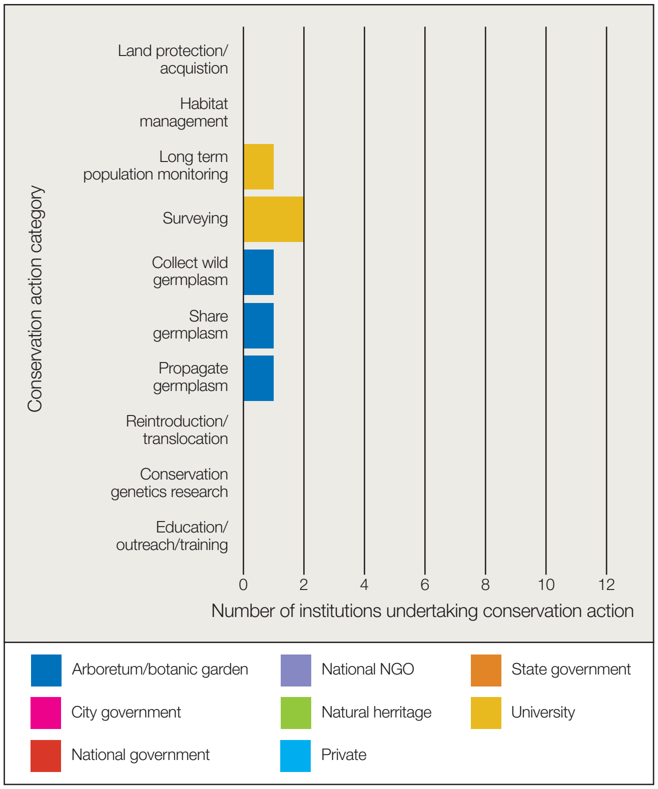


Figure 4. Number of institutions reporting conservation activities for *Quercus tardiofila* grouped by organization type. Three of 252 institutions reported activities focused on *Q. tardiofila* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. tardiofila*, 70% of the land is covered by protected areas (Figure 6). However, because this species' distribution is small and well-documented, we know that 100% of the species' potential occurrences within the U.S. are within Big Big National Park. The park has also determined that *Q. tardifolia* is outside areas where current projects may disturb the species.[6]

Sustainable management of land: The Ecoregional Conservation Assessment of the Chihuahuan Desert ranks Big Bend Triangle as the area with the highest Irreplaceability Index and 9th highest overall conservation priority out of 39 areas of conservation concern in Texas.[7] The Texas Conservation Action Plan: Chihuahuan Desert and Arizona-New Mexico Mountains Ecoregions Handbook outlines general trends and needs in the region as a whole, including Big Bend National Park. However, there is no specific mention of *Q. tardifolia* outside the "Species of Greatest Conservation Need" list.[8]

Population monitoring and/or occurrence surveys: Although the Texas Parks and Wildlife Department conservation action plan for the Chihuahuan Desert and Arizona-New Mexico mountain regions lists *Q. tardifolia* as a "Species of Greatest Conservation Need," it is unclear whether population monitoring accompanies this listing.[8] With support from a 2018 APGA-USFS Tree Gene Conservation Program grant, UC Davis Arboretum & Public Garden led expeditions to search for Lateleaf oak in late summer 2016 and 2018. No individuals were confidently identified during either trip. However, a wide range of vouchers were collected within the species' type locality in 2018, in hopes of confirming the species' status through further study. As its name suggests, visiting the Lateleaf oak site when leaves drop or as the tree leafs out in spring could aid in identifying the species (S. Still pers. comm., 2018).[9]

Wild collecting and/or *ex situ* curation: Collecting trips targeting Q. tardifolia were lead by UC Davis Arboretum & Public Garden in 2016 and 2018, with funding from the APGA-USFS Tree Gene Conservation Partnership. No individuals were confidently identified (S. Still pers. comm., 2018).[9]

Propagation and/or breeding programs: One institution reported this activity in the conservation action questionnaire; but, no other details are currently known.

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: No known initiatives at the time of publication.

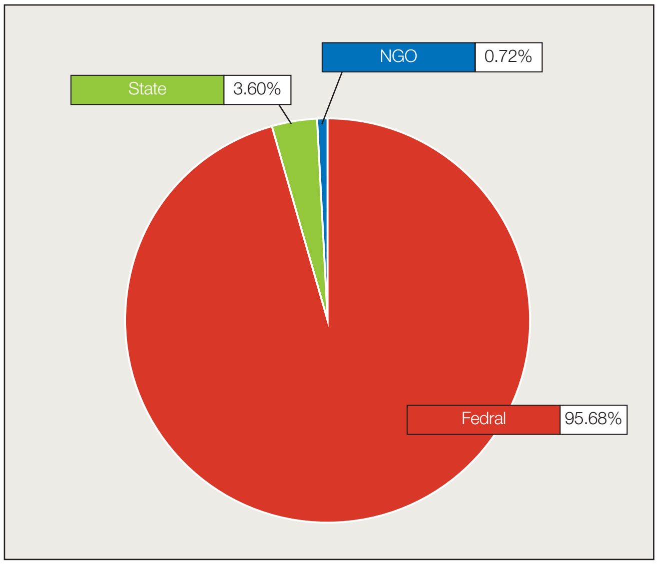


Figure 5. Management type of protected areas within the inferred native range of *Quercus tardiofila*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[3]

Education, outreach, and/or training: No known initiatives at the time of publication.

Species protection policies: In 2009, a petition was submitted to the U.S. Fish and Wildlife Service to list 475 species in the southwestern U.S. as Threatened or Endangered under the Endangered Species Act. *Quercus tardifolia* was determined to have an inadequate amount of threat information provided in the petition, and was subsequently rejected.[10] In addition to listing species as endangered or threatened, Texas maintains a list of more than 1,300 Species of Greatest Conservation Need (SGCN), including *Q. tardifolia*. These species are "declining or rare and in need of attention to recover or to prevent the need to list under state or federal regulation…[and are] the focus of Texas Parks and Wildlife Department's Texas Conservation Action Plan;" though SGCN are not provided the same protections as endangered or threatened species.[11]

PRIORITY CONSERVATION ACTIONS

Several groups have visited the Chisos Mountains in search of Lateleaf oak during the past few years. However, none of the expeditions have returned with definitive proof of the presence or absence of the species. Some individual trees have been found that may be *Q. tardifolia*, and vouchers were collected, but the identification is unclear. With so little known about this species, few conservation recommendations can be made other than further study. Sustained efforts are needed to locate *Q. tardifolia* in the Chisos Mountains. Communication with plant professionals from the area, past and present, might illuminate questions regarding when and where, and in how many locations, this plant has been observed. Until this plant is located in its single recorded site and further documentation is made, there is little else that can be said about *ex* or *in situ* conservation.

The putative loss of this plant from the wild, and the paucity of information regarding its place in a more general *Quercus* taxonomy, underscores the need for study and appreciation of the morphological diversity of oaks in the Chisos Mountains. Even if this species were to lose its species status in the future, it is still a unique botanical occurrence and there is no reason to let similar occurrences escape study in the future.

Conservation recommendations for *Quercus tardifolia*

Highest Priority

- Population monitoring and/or occurrence surveys
- Research (taxonomy/phylogenetics)

REFERENCES

1. **Flora of North America Editorial Committee (Eds.). (1997).** *Flora of North America north of Mexico* (Vol. 3). New York and Oxford.
2. **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
3. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
4. **National Park Service. (2016).** *Foundation document, Big Bend National Park.* TX: U.S. Department of the Interior. Retrieved from http://www.npshistory.com/publications/foundation-documents/bibe-fd-2016.pdf
5. **U.S. EPA Office of Research & Development. (2013, April).** 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
6. **National Park Service. (2004).** *Final general management plan / environmental impact statement Big Bend National Park*. Brewster County, TX: United States Department of the Interior.
7. **Pronatura Noreste, The Nature Conservancy, & World Wildlife Fund. (2004).** *Ecoregional conservation assessment of the Chihuahuan Desert* (Second edition). Retrieved from https://www.conservationgateway.org/ConservationPlanning/SettingPriorities/EcoregionalReports/Documents/Chihuahuan Desert Report.pdf
8. T**exas Parks and Wildlife Department. (2012).** T*exas conservation action plan: Chihuahuan Desert and Arizona-New Mexico mountains ecoregions handbook*. Connally, W. (Ed.). Austin, TX. Retrieved from https://tpwd.texas.gov/landwater/land/tcap/documents/chih_tcap_2012.pdf
9. **Still, S., Griswold, E., & McNeil-Marshall, A. (2016).** *Scouting and collection trips for Trans-Pecos* Quercus *germplasm: APGA-USFS Tree Gene Conservation Partnerships.* Retrieved from https://www.publicgardens.org/file/2016-trans-pecosoaksreportpdf
10. **U.S. Fish and Wildlife Service. (2009).** Endangered and threatened wildlife and plants; Partial 90 day finding on a petition to list 475 species in the southwestern United States as threatened or endangered with critical habitat; proposed rule. *Federal Register, 74*(240), 66866-66905.
11. T**exas Parks and Wildlife Department. (2013).** Species of greatest conservation need. Retrieved from https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/tcap/sgcn.phtml

Conservation Gap Analysis of Native

U.S. Oaks

Species profile: ***Quercus tomentella***

Emily Beckman, David Pivorunas, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, ***Quercus tomentella***

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, Quercus toumeyi

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
Botanic Gardens Conservation International
Forest Service U.S. Department of Agriculture
Fauna & Flora International

Quercus tomentella Engelm.

Synonyms: *Quercus chrysolepis* subsp. *tomentella* (Engelm.) A.E.Murray, *Q. chrysolepis* var. *tomentella* (Engelm.) A.E.Murray, *Q. tomentells* var. *conjugens* Trel.   **Common Names:** Island oak

Species profile co-author: David Pivorunas, National Forest System, USDA Forest Service
Contributors: Mary Ashley, Biological Sciences, The University of Illinois in Chicago; Jonathan Dunn, AECOM;
Kaius Helenurm, Biology, University of South Dakota; Jan Larson, U.S. Navy Region Southwest, retired

Suggested citation: Beckman, E., Pivorunas, D., Meyer, A., & Westwood, M. (2019). Quercus tomentella Engelm. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. Conservation Gap Analysis of Native U.S. Oaks (pp. 208-215). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-tomentella.pdf

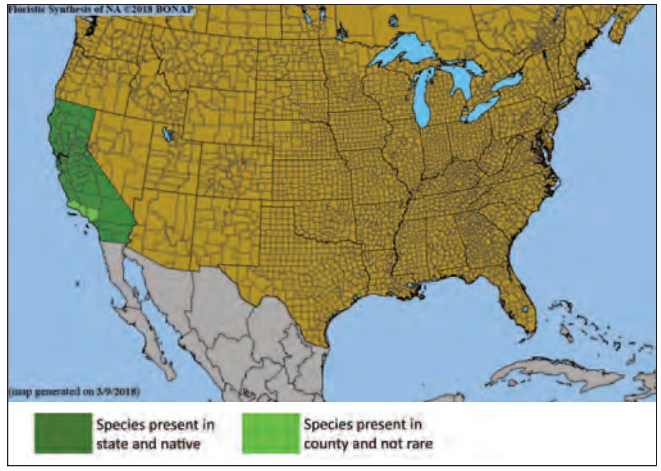


Figure 1. County-level distribution map for the U.S. distribution of *Quercus tomentella*. Source: Biota of North America Program (BONAP).[5]

DISTRIBUTION AND ECOLOGY

Quercus tomentella, also known as Island oak, is found only on the Channel Islands (Santa Rosa, Santa Cruz, Anacapa, Santa Catalina, and San Clemente) off the coast of California, U.S., and on Guadalupe Island, Mexico. The species belongs to a small, mysterious group of oaks that only exists in the western U.S. and northern Baja California, Mexico: the intermediate or golden oaks, section Protobalanus. The island habitats of *Q. tomentella* give protection from frost and drought, and sufficient moisture is provided through a combination of precipitation and fog drip. Strong winds keep the tree from thriving too close to the coast. Island oak prefers deep, moist soils within sheltered locations from 100 to 650 meters above sea level, but can survive in almost any soil type. In the best conditions, a height of seven to 12 meters can be reached, but many individuals facing the harshest winds are shrunken and bent, pruned by salt spray. Reproduction through acorns is difficult because of winds and rocky soil, so many inland groves are held constant by sprouting from adult trees.[1] On San Clemente Island, the species grows in pure stands, usually within canyons or on the high, coastal, north-eastern slopes.[2] On the northern islands it forms a woodland community with Canyon oak (*Q. chrysolepis*) and Coast live oak (*Q. agrifolia*), in contrast to the woodlands on Santa Catalina Island where Island scrub oak (Q. pacifica) dominates, while *Q. tomentella* and *Q. chrysolepis* are less frequent.[3,4]

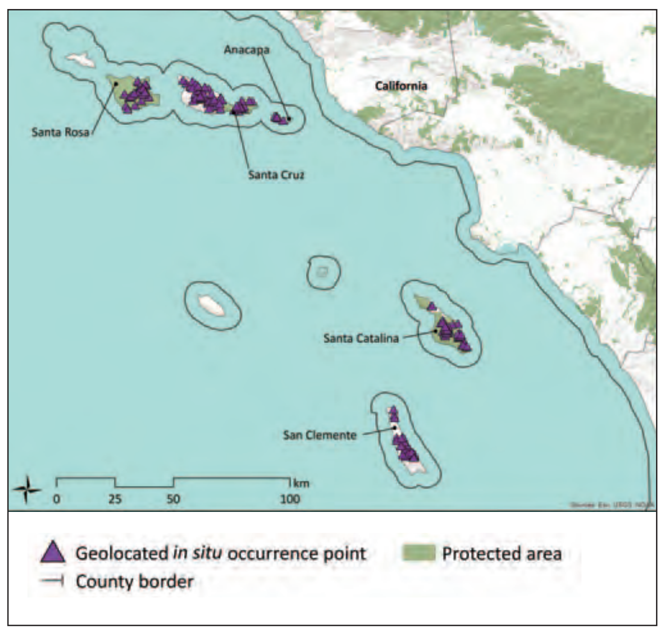


Figure 2. Documented *in situ* occurrence points for the U.S. distribution of *Quercus tomentella*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[6]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus tomentella*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						
	Emergency Score = 40	High Score = 20	Moderate Score = 10	Low Score = 5	None Score = 0	Unknown No score	Score
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	10
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	10
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	0
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	20
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	5
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	5
						Average vulnerability score	8.3
						Rank relative to all U.S. oak species of concern (out of 19)	11

THREATS TO WILD POPULATIONS

High Impact Threats

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Non-native livestock stripped much of the vegetation on Santa Catalina Island before their removal in the late 20th century. Studies of restoration potential for *Q. tomentella* on the Island point to weed saturated soils as a main challenge.[3] It is clear that overgrazing damaged the majority of native flora, resulting in increased competition from invasive plants (M. Ashley pers. comm., 2015).

Moderate Impact Threats

Extremely small and/or restricted population: Only four individuals remain on the small island of Anacapa, though populations are much larger on the other islands, excluding Guadalupe.[1]

Low Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: Intense past overgrazing from introduced herbivores degraded much of *Q. tomentella's* habitat, causing population declines.[7] Almost all of the introduced grazing animals have now been removed from the species' range and the ecosystem is recovering slowly. Guadalupe Island was the last to eradicate all introduced herbivores, which took place between 2003 and 2006. By 2011 the Island's habitats were already showing improvement, but *Q. tomentella* has not yet shown signs of regeneration.[8] Some mature specimens on Guadalupe Island have died due to soil erosion and the population is less than 50 individuals.[9]

Human Use of Landscape - e.g. residential, commercial, mining, roads: Past mining and harvesting of oaks for construction, heating, etc. could have contributed to dieback of native oaks on Santa Catalina Island; current roads could also be having a negative effect. There is little evidence for ongoing adverse human impacts on Santa Rosa and Santa Cruz Islands, as both have small settlements and infrequent road use.[10]

Human Use of Landscape - e.g. tourism and recreation: Recreation is another possible threat contributing to dieback on Santa Catalina Island, which is the only Channel Island with an incorporated city and about one million visitors annually.[11] The northern islands receive much less visitation because the Channel Islands National Park is explicitly managed as a low-visitation park.[12]

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Predicted lengthening of dry seasons may present a challenge for natural regeneration of *Q. tomentella*. Though, climate change may not have a significant impact on the Channel Islands since the climate is already extremely dry and fog drip will not likely be significantly altered.[13]

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figure 3). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 5).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	18
Number of plants in *ex situ* collections:	67
Average number of plants per institution:	4
Percent of *ex situ* plants of wild origin:	34%
Percent of wild origin plants with known locality:	96%

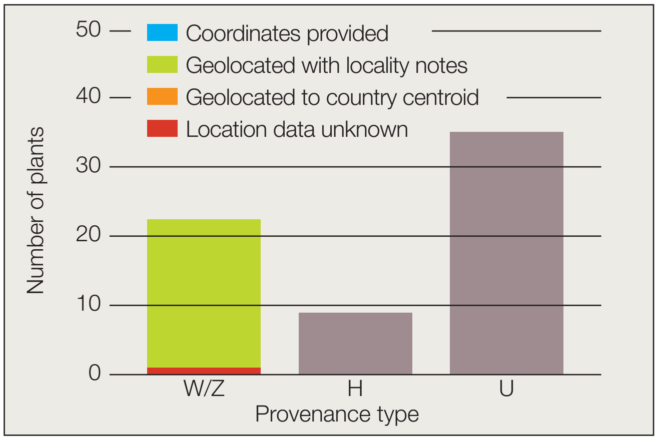


Figure 3. Number and origin of *Quercus tomentella* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 4). Only the native U.S. distribution of the species was considered in this analysis, due to availability of ecoregion maps. Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	57%
Ecological coverage:	100%

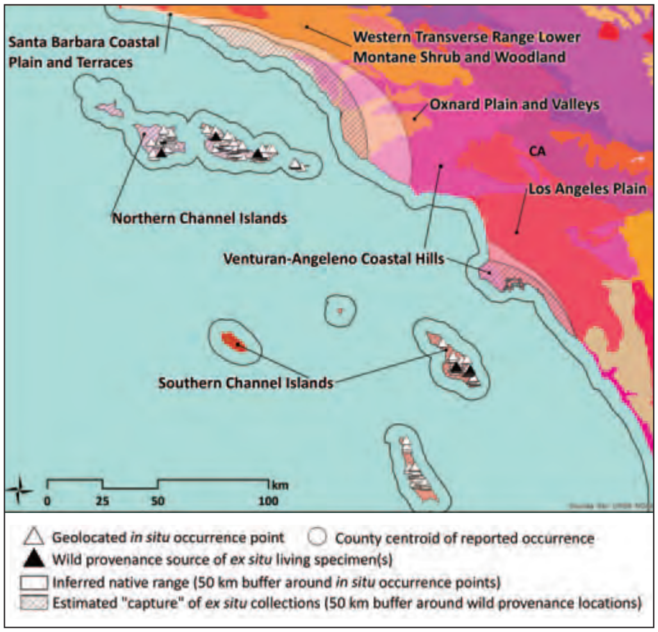


Figure 4. *Quercus tomentella in situ* occurrence points and *ex situ* collection source localities within the United States. U.S. EPA Level IV Ecoregions are colored and labelled.[16] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

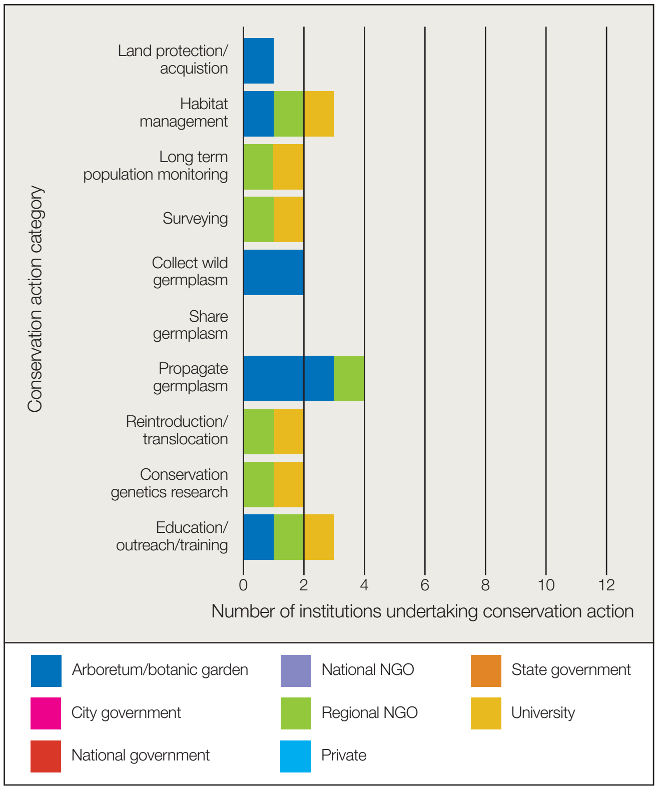


Figure 5. Number of institutions reporting conservation activities for *Quercus tomentella* grouped by organization type. Seven of 252 institutions reported activities focused on *Q. tomentella* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. tomentella* in the U.S., 44% of the land is covered by protected areas (Figure 6). However, because this species' distribution is small and well-documented, we know that close to 100% of the species' habitat is within protected areas.

The entirety of Anacapa Island, Santa Rosa Island, and Santa Cruz Island are part of Channel Islands National Park, while the oak habitat on Santa Catalina Island is managed by the Catalina Island Conservancy. San Clemente Island is federally owned and managed by the Navy, which has a long established Natural Resource program and an Integrated Natural Resource Management Plan.[17] The non-profit organization Conservation de Islas was initiated in 2004 to restore Guadalupe Island and continues to manage the land.[18] The Island was officially declared a Biosphere Reserve in 2005 by the Mexican government.[19]

Sustainable management of land: In 1997 the Catalina Island Conservancy began a restoration program after 50 years of ranching and farming, which included the removal of feral goats and pigs island-wide as well as the conversion of 80 acres of previous hayfields to native plant communities. Invasive plants are still an issue and the Conservancy has identified 76 invasive plant species as potential weeds in need of control and/or eradication. In response to this threat, the entire island has been mapped and the Catalina Habitat Improvement and Restoration Program (CHIRP) is actively managing 43 invasive plants to stop further invasion.[20]

Channel Island National Park began eradicating introduced livestock on their land in the 1990s and no individuals remain today. The Navy began a goat removal program on San Clemente Island in the 1970s as the Natural Resource Program was developed; removal continued until the all goats, as well as non-native pigs and deer, were eradicated in the early 1990s. The Navy also contracts with specialists to remove targeted weeds and invasive plant species, which may be spreading on the Island; they also developed an Integrated National Resource Management Plan and Fire Management Plan for the Island.[21,22] The Group for Ecology and Island Conservation (GECI) has been working to restore Mexican island ecosystems since 1995, and began non-native animal removal on Guadalupe in 2002. By 2007 all goats had been removed, but invasive plants from the Mediterranean Basin and Europe dominate open areas and there is extensive soil erosion.[9]

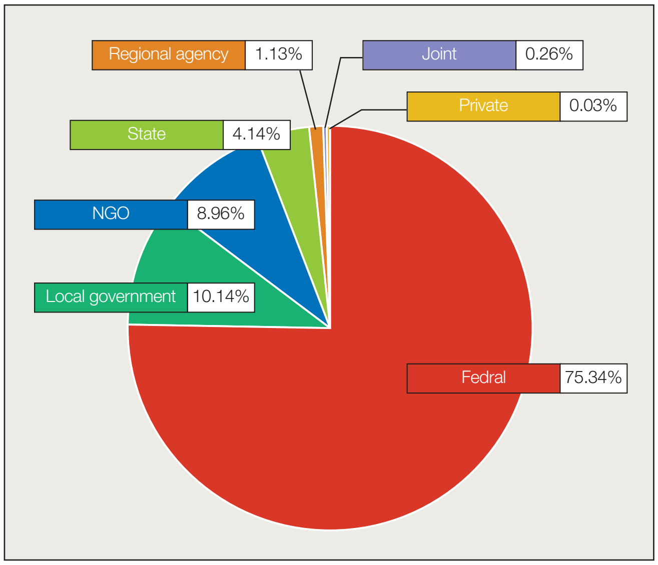


Figure 6. Management type of protected areas within the inferred native range of *Quercus tomentella*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[6]


Kim O'Connor

Population monitoring and/or occurrence surveys: A flora of San Clemente Island was first published in 1963 by Peter Raven.[23] Once the Island's Natural Resource program began in the 1970s, more surveys and inventories were conducted.[24,25] The Navy contracted Santa Barbara Botanic Garden to conduct comprehensive surveys of the Island's rare species in 1996 and 1997, which included an inventory of *Q. tomentella*.[2] Other rare species surveys included those conducted by Steve Junak in 2003 and 2004, as well as Kellogg and Kellogg's repeated surveys of over 100 vegetative transects around the Island.[26] These transects were first set up in the 1990s and inventoried on a regular basis to measure recovery of the island species after goat removal. Oak populations on San Clemente Island are healthy and have responded well to the removal of the goats, with some natural regeneration in at least one location observed in 2003 (D. Pivorunas pers. comm., 2018).

The Catalina Island Conservancy monitors oak dieback through an annual survey in July. In the most recent survey, they found that "large stands of dead oaks are forming around Catalina, mostly on the channel side of the Island. This could be due to any of a number of interacting factors, including old age (and lack of regeneration due to feral animals), oak root rot fungus, air pollution, and water cycles… [but] progress of the dieback is slow, suggesting that it is not a pathogen that is causing the deaths."[27]

Wild collecting and/or *ex situ* curation: Two institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Propagation and/or breeding programs: The Tree of Life Nursery has been producing native California plants for more than two decades and is one of the largest suppliers of native plants in the state. Their grounds include 30 acres of growing area in addition to laboratory facilities for the propagation and testing of mycorrhizal plants and inoculum. They grow a wide variety of native oak species, including *Q. tomentella*.[28] The Tree Plantation also reports propagating and selling *Q. tomentella*.[29]

Reintroduction, reinforcement, and/or translocation: In 2000, the Navy began revegetation efforts on San Clemente Island. This initiative included propagating native shrubs and trees from wild-collected San Clemente Island sources, then outplanting in 2001. Several hundred oaks seedlings were planted in multiple locations in the first two years, with about 80% survival one year after planting and 50% of the plants remaining after two years. Individuals seem to survive through fog drip moisture as adults, if some water is provided the first several years. The most favorable sites now host mature trees, which produced a good crop of acorns in 2013. Storage of seeds was successful for at least two to three years with refrigeration at ~32°F and a dusting of cinnamon powder (J. Dunn pers. comm., 2003, 2018).


Steve Matson

Research: Regeneration trials were conducted during the Catalina Island Conservancy restoration program. This study found that recruitment is feasible without providing additional water to the acorn or sapling.[3] The population genetics of Island oak on Santa Catalina Island has been characterized by sampling trees from many of the *Q. tomentella* stands and analyzing these individuals using microsatellites. Allelic and gene diversity were found to be "high and similar to microsatellite studies of mainland species of oaks," but also exhibited a striking level of between-stand differentiation. High clonality was found on Santa Catalina and Santa Rosa Islands, but overall genetic diversity was high at all sites, including the tiny population on Guadalupe Island.[14,30] The Navy also conducts genetics studies on *Q. tomentella* through a contract with Dr. Kaius Helenurm, which included collecting and analyzing genetics tissue from ten different island locations (K. Helenurm pers. comm., 2002, 2018).

In 2006, University of California, Davis created a potential habitat model for Island oak, to estimate where the species could thrive on the Channel Islands; these data can direct habitat restoration and species reintroduction initiatives. Their model revealed that the species currently occupies less than 1% of modelled core habitat.[2]

Quercus tomentella restoration is also informed through the conservation management of rare animal species reliant on Island oak habitat.[31,32]

Education, outreach, and/or training: The East Palo Alto Tree Initiative, a "multi-year collaboration to enhance the urban forest in East Palo Alto and plant more than 1,200 trees," included *Q. tomentella* in their urban plantings, in which hundreds of volunteers participated.[33] The Chino Basin Water Conservation District provides a description of *Q. tomentella's* environmental needs within a landscape planting, including very specific water recommendations.[34]

Species protection policies: No known initiatives at the time of publication.


Keir Morse

PRIORITY CONSERVATION ACTIONS

Although introduced grazers, once a primary threat to Island oak, have been removed from the majority of the species' distribution, natural recovery will be slow. Acorns are produced sporadically in mast years and the conditions for good germination and survival will not necessarily coincide. Where populations are quite small, additional reintroduction and reinforcement efforts are vital, though all islands within the species' native range would benefit from continued reinforcement. These outplanting initiatives should use only wild collected genetic material that is sourced and produced locally on the island of reinforcement and/or reintroduction, to avoid introducing pests or diseases.

Restoration is especially important on Guadalupe Island, where genetic variability is relatively high but population numbers are low and some older trees have recently been lost to erosion. It is important that the existing trees are monitored, natural regeneration is encouraged, and reinforcement of populations is conducted. Because the population on Anacapa Island is even smaller (four individuals), it is vital to collect genetic material to avoid losing the population entirely. This material should be propagated and used for reinforcement to ensure survival of the species at this location.

Encouragement of natural regeneration on San Clemente Island should also continue, as well as plantings near existing groves and establishment of new groves in favorable habitat. The continuation of outplanting is also important because more knowledge is needed regarding the natural regeneration processes of this species. The activities of the past 15 years have provided a strong conservation base and should be continued. Natural regeneration of *Q. tomentella* is also a problem at sites within the Channel Island National Park, which includes Santa Cruz and Santa Rosa Islands.[4] These areas, in addition to Santa Catalina Island, need continued monitoring, research, and restoration of oak habitat, including the control of invasive plant species.

Conservation recommendations for *Quercus tomentella*

Highest Priority
- Population monitoring and/or occurrence surveys
- Propagation and/or breeding programs
- Reintroduction, reinforcement, and/or translocation
- Wild collecting and/or *ex situ* curation

Recommended
- Research (reproductive biology/regeneration; restoration protocols/guidelines)
- Sustainable management of land

REFERENCES

1. **Ortego, J., Gugger, P. F., & Sork, V. L. (2017).** Genomic data reveal cryptic lineage diversification and introgression in Californian golden cup oaks (section Protobalanus). *New Phytologist, 218*(2), 804-818. doi:10.1111/nph.14951
2. **Junak, S. A., & Wilken, D. H. (1998).** *Sensitive plant status survey, naval auxiliary landing field San Clemente Island, California, final report*. Santa Barbara Botanic Garden Technical Report No. 1 prepared for Department of the Navy, Southwest Division. San Diego, CA.
3. **Stratton, L. (2002).** Oak restoration trials: Santa Catalina Island. In Standiford, R. B. (Ed.), *Proceedings of the fifth symposium on oak woodlands: Oaks in California's challenging landscape* (Gen. Tech. Rep. PSW-GTR-184). Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Retrieved from https://www.fs.usda.gov/treesearch/pubs/26185
4. **Kindsvater, L. C. (2010).** Plant communities associated with the rare, paleoendemic oak, *Quercus tomentella* on Santa Cruz and Santa Rosa Islands, California. In Knapp, D. A. (Ed.) (2010), *Oak ecosystem restoration on Santa Catalina Island, California: Proceedings of an on-island workshop, February 2-4, 2007*. Avalon, CA: Catalina Island Conservancy.
5. **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
6. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
7. **Pavlik, B. M., Muick, P. C., Johnson, S. G., & Popper, M. (1991).** *Oaks of California*. Los Olivos, CA: Cachuma Press, Inc.
8. **Aguirre-Muñoz, A., Samaniego-Herrera, A., Luna-Mendoza, L., Ortiz-Alcaraz, A., Rodríguez-Malagón, M., Méndez-Sánchez, F., Félix-Lizárraga, M., Hernández-Montoya, J. C., González-Gómez, R., Torres-García, F., Barredo-Barberena, J. M., & Latofski-Robles, M. (2011).** Island restoration in Mexico: Ecological outcomes after systematic eradications of invasive mammals. In Veitch, C. R., Clout, M. N. & Towns, D. R. (Eds.), *Island invasives: eradication and management* (pp. 250-258). Gland, Switzerland: IUCN. Retrieved from http://issg.org/pdf/publications/Island_Invasives/pdfHQprint/3Aguirre-Munozl.pdf
9. **Aronson, J., Aronson, T., & Le Floc'h, E. (2015, March 11).** Guadalupe Island, Baja California: Invasive mammal eradication and perspectives for ecological restoration. MO: Natural History of Ecological Restoration, Missouri Botanical Garden. Retrieved from https://mbgecologicalrestoration.wordpress.com/2015/03/11/guadalupe-island-baja-california-invasive-mammal-eradication-and-perspectives-for-ecological-restoration/
10. **Knapp, D. A. (2005).** Rare plants in the Goat Harbor burn area, Santa Catalina Island, California. pp. 205–211 in *Proceedings of the 5th California Islands Symp.*, C.A. Schwemm (ed.). National Park Service Technical Publications CHIS-05- 01, Institute for Wildlife Studies, Arcata, CA.
11. **Knapp, D. A. (2002).** The status of Island scrub oak (*Quercus pacifica*) on Catalina Island, California. General Technical Report (PSW-GTR-184). USDA Forest Service.
12. **National Park Service. (2015).** Channel Islands National Park, Final general management plan, Wilderness study, Environmental impact statement.
13. **Fischer, D. T., Still, C. J., Ebert, C. M., Baguskas, S. A., & Williams, A. P. (2016).** Fog drip maintains dry season ecological function in a California coastal pine forest. Ecosphere, 7(6). doi:10.1002/ecs2.1364
14. **Ashley, M. V., Abraham, S., Kindsvater, L.C., Knapp, D. A., & Craft, K. (2007).** Population structure and genetic variation of Island oak, *Quercus tomentella* Engelmann on Santa Catalina Island. In Knapp, D. A. (Ed.) (2010), *Oak ecosystem restoration on Santa Catalina Island, California: Proceedings of an on-island workshop, February 2-4, 2007*. Avalon, CA: Catalina Island Conservancy.
15. **Colman, T. W., Jones, M. I., Smith, S. L., Venette, R. C., Flint, M. L., & Seybold, S. J. (2017).** Goldspotted Oak Borer. Forest Insect & Disease Leaflet 183. U.S. Department of Agriculture, Forest Service. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf
16. **U.S. EPA Office of Research & Development. (2013, April).** 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
17. **U.S. Department of the Navy. (2002).** *San Clemente Island integrated natural resources management plan draft final.* San Diego, California. Prepared by Tierra Data Systems, Escondido, California. Retrieved from http://tierradata.com/sci/wp-content/uploads/2012/10/2002-INRMP.pdf
18. **Garcillán, P. P., Ezcurra, E., & Vega, E. (2008).** Guadalupe Island: Lost paradise recovered? Overgrazing impact on extinction in a remote oceanic island as estimated through accumulation functions. *Biodiversity and Conservation, 17*(7), 1613-1625. doi:10.1007/s10531-008-9370-z
19. **Keitt, B., Junak, S., Luna-Mendoza, L., & Aguirre-Muñoz, A. (2005).** The restoration of Guadalupe Island. Fremontia, 33, 20-25.
20. **Knapp, J. (2010).** Catalina Island's invasive plant management program, with an emphasis on invasion and protection of oak ecosystems. In Knapp, D. A. (Ed.) (2010), *Oak ecosystem restoration on Santa Catalina Island, California: Proceedings of an on-island workshop, February 2-4, 2007*. Avalon, CA: Catalina Island Conservancy.
21. **U.S. Department of the Navy. (2009).** *San Clemente Island wildland fire management plan.* San Diego, CA: Commander Navy Region Southwest Natural Resource Office. Prepared by Tierra Data Systems, Escondido, California. Retrieved from http://tierradata.com/sci/wp-content/uploads/2012/10/2009-Wildland-Fire-Management-Plan2.pdf
22. **Raven, P. (1963).** A flora of San Clemente Island, California. *Aliso: A Journal of Systematic and Evolutionary Botany, 5*(3), 289-347. doi:10.5642/aliso.19630503.08
23. **Beauchamp, R. M. (1987).** San Clemente Island: remodeling the museum. In T. S. Elias (Ed.), *Conservation and management of rare and endangered plants* (pp. 575-578). Sacramento, CA: California Native Plant Society.
24. **Ross, T., Boyd, S., & Junak, S. (1996).** Additions to the vascular flora of San Clemente Island, Los Angeles County, California, with notes on clarifications and deletions. *Aliso: A Journal of Systematic and Evolutionary Botany, 15*(1), 27-40. Retrieved from http://scholarship.claremont.edu/aliso/vol15/iss1/4
25. **Junak, S. A. (2006).** Sensitive plant survey data for San Clemente Island, California. Collected for Department of the Navy, Southwest Region under cooperative agreement with Naval Facilities Engineering Command Southwest Division.
26. **Catalina Island Conservancy. (n.d.).** Oak dieback vegetation monitoring. Retrieved from https://www.catalinaconservancy.org/index.php?s=wildlife&p=oak_dieback_vegetation_monitoring
27. **McCreary, D. D. (2001).** *Regenerating rangeland oaks in California*. Oakland, CA: University of California, Agriculture and Natural Resources. Retrieved from https://anrcatalog.ucanr.edu/pdf/21601e.pdf
28. **The Tree Plantation. (n.d.).** Genus and species: *Quercus tomentella*. Retrieved from http://www.thetreeplantation.com/01-island_oak.php
29. **Ashley, M. V., Backs, J. R., Kindsvater, L., & Abraham, S. T. (2018).** Genetic variation and structure in an endemic Island oak, *Quercus tomentella*, and mainland Canyon oak, *Quercus chrysolepis*. *International Journal of Plant Sciences, 179(*2), 151-161. doi:10.1086/696023
30. **Kindsvater, L. C. (2006).** *Conservation and restoration of the endemic Island oak,* Quercus tomentella *in Channel Islands National Park using a habitat approach.* Davis, CA: University of California.
31. **Morrison, S. A., Sillett, T. S., Ghalambor, C. K., Fitzpatrick, J. W., Graber, D. M., Bakker, V. J., Bowman, R., Collins, C. T., Collins, P. W., Delaney, K. S., Doak, D. F., Koenig, W. D., Laughrin, L., Lieberman, A. A., Marzluff, J. M., Reynolds, M. D., Scott, J. M., Stallcup, J. A., Vickers, W., & Boyce, W. M. (2011).** Proactive conservation management of an island-endemic bird species in the face of global change. *BioScience, 61*(12), 1013-1021. doi:10.1525/bio.2011.61.12.11
32. **Canopy. (n.d.).** East Palo Alto tree initiative. Retrieved from http://canopy.org/our-work/tree-planting/east-palo-alto-tree-initiative/
33. **Chino Basin Water Conservation District. (n.d.).** Inland Valley Garden Planner: Plant profile *Quercus tomentella* Island oak. Retrieved from https://inlandvalleygardenplanner.org/plants/quercus-tomentella/

Conservation Gap Analysis of Native U.S. Oaks

Species profile: ***Quercus toumeyi***

Emily Beckman, Tim Thibault, Abby Meyer, Murphy Westwood

SPECIES OF CONSERVATION CONCERN

CALIFORNIA

Channel Island endemics:
Quercus pacifica, Quercus tomentella

Southern region:
Quercus cedrosensis, Quercus dumosa, Quercus engelmannii

Northern region and / or broad distribution:
Quercus lobata, Quercus parvula, Quercus sadleriana

SOUTHWESTERN U.S.

Texas limited-range endemics
Quercus carmenensis, Quercus graciliformis, Quercus hinckleyi, Quercus robusta, Quercus tardifolia

Concentrated in Arizona:
Quercus ajoensis, Quercus palmeri, ***Quercus toumeyi***

Broad distribution:
Quercus havardii, Quercus laceyi

SOUTHEASTERN U.S.

State endemics:
Quercus acerifolia, Quercus boyntonii

Concentrated in Florida:
Quercus chapmanii, Quercus inopina, Quercus pumila

Broad distribution:
Quercus arkansana, Quercus austrina, Quercus georgiana, Quercus oglethorpensis, Quercus similis

The Morton Arboretum
BOTANIC GARDENS CONSERVATION INTERNATIONAL
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
FAUNA & FLORA INTERNATIONAL

Quercus toumeyi Sarg.

Synonyms: *Quercus chuhuichupensis* C.H.Müll., *Q. hartmanii* Trel.   **Common Names:** Toumey oak

Species profile co-author: Tim Thibault, The Huntington
Contributors: John Wiens, Department of Ecology and Evolutionary Biology, The University of Arizona

Suggested citation: Beckman, E., Thibault, T., Meyer, A., & Westwood, M. (2019). *Quercus toumeyi* Sarg. In Beckman, E., Meyer, A., Man, G., Pivorunas, D., Denvir, A., Gill, D., Shaw, K., & Westwood, M. *Conservation Gap Analysis of Native U.S. Oaks* (pp. 216-221). Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/species-profile-quercus-toumeyi.pdf

DISTRIBUTION AND ECOLOGY

Since the discovery of *Quercus barrancana*, and its taxonomic acceptance in 2014, the range of *Quercus toumeyi*, or Toumey oak, has somewhat greater uncertainty. In his definition of *Q. barrancana*, Spellenberg asserts that what was originally called the southern variety of *Q. toumeyi*, located in north-central Mexico, should now accurately be labeled *Q. barrancana*. He also states that subpopulations of Toumey oak recorded in western Texas may really represent forms of *Q. turbinella*; he was only able to find introgressed *Q. toumeyi* in that region.[1] Therefore the species presence is unconfirmed in Texas. The range of *Quercus toumeyi* is now thought to stretch from southeastern Arizona (Pima, Santa Cruz, and Cochise Counties) and the southwestern corner New Mexico (Hidalgo County) in the U.S., and south to Yécora and Madera in the Mexican states of Sonora and Chihuahua, respectively. Toumey oak exists as a shrub or small tree within oak woodlands, pine-oak forests, and chaparral. It is a dominant species within evergreen broad-leaved shrublands, especially on rocky, dry slopes, and is a characteristic species of Madrean Encinal shrubland of the Sierra Madre as well as Mongollon and Coahuilan Chaparral. The species occurs from 1,200 to 2,400 meters above sea level.[6]

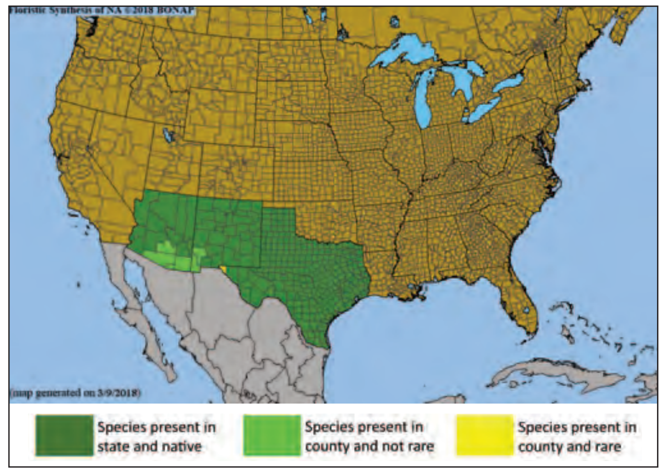


Figure 1. County-level distribution map for the U.S. distribution of *Quercus toumeyi*. Source: Biota of North America Program (BONAP).[3]

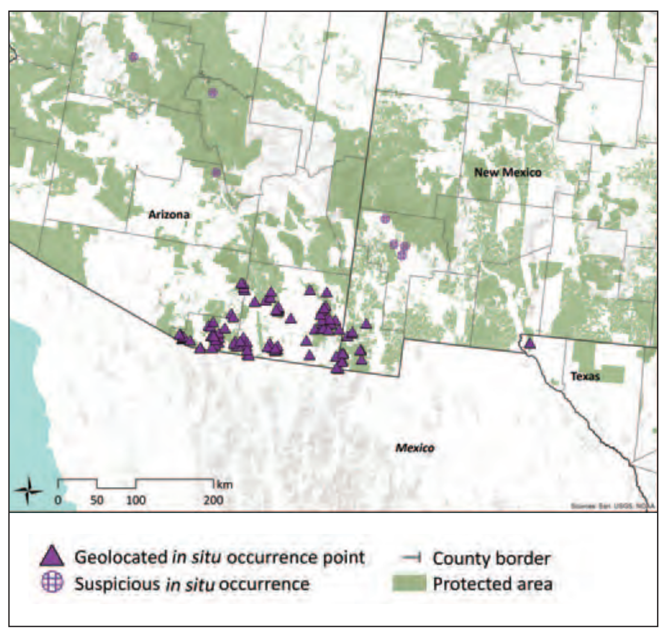


Figure 2. Documented *in situ* occurrence points for the U.S. distribution of *Quercus toumeyi*. Protected areas layer from U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

VULNERABILITY OF WILD POPULATIONS

Table 1. Scoring matrix identifying the most severe demographic issues affecting *Quercus toumeyi*. Cells are highlighted when the species meets the respective vulnerability threshold for each demographic indicator. Average vulnerability score is calculated using only those demographic indicators with sufficient data (i.e., excluding unknown indicators).

Demographic indicators	Level of vulnerability						Score
	Emergency Score = 40	**High** Score = 20	**Moderate** Score = 10	**Low** Score = 5	**None** Score = 0	**Unknown** No score	
Population size	< 50	< 250	< 2,500	< 10,000	> 10,000	Unknown	0
Range/endemism	Extremely small range or 1 location	EOO < 100 km² or AOO < 10 km² or 2-4 locations	EOO < 5,000 km² or AOO < 500 km² or 5-9 locations	EOO < 20,000 km² or AOO < 2,000 km² or 10+ locations	EOO > 20,000 km² or AOO > 2,000 km²	Unknown	0
Population decline	Extreme	>= 80% decline	>= 50% decline	>= 30% decline	None	Unknown	5
Fragmentation	Severe fragmentation	Isolated populations	Somewhat isolated populations	Relatively connected populations	Connected populations	Unknown	5
Regeneration/ recruitment	No regeneration or recruitment	Decline of >50% predicted in next generation	Insufficient to maintain current population size	Sufficient to maintain current population size	Sufficient to increase population size	Unknown	5
Genetic variation/ integrity	Extremely low	Low	Medium	High	Very high	Unknown	10
						Average vulnerability score	4.2
						Rank relative to all U.S. oak species of concern (out of 19)	16

THREATS TO WILD POPULATIONS

High Impact Threats

Genetic material loss — inbreeding and/or introgression: Introgression has likely eliminated the subpopulation that may have once occupied western Texas.[5] Hybridization or introgression with *Q. arizonica* and *Q. oblongifolia* has also been noted within the species' main U.S. distribution (T. Thibault pers. comm., 2018).

Moderate Impact Threats

Human use of landscape — agriculture, silviculture, ranching, and/or grazing: NatureServe lists *Q. toumeyi* as a major component of three plant associations: *Quercus toumeyi* / *Bouteloua curtipendula* Scrub, *Quercus toumeyi* / *Muhlenbergia emersleyi* Scrub, and *Pinus discolor* / *Quercus toumeyi* Woodland; all three are all ranked as G1 or G2 (Critically Imperiled or Imperiled) and reported to have continued impact from grazing.[2]

Human modification of natural systems — disturbance regime modification, pollution, and/or eradication: Altered fire regime has created a downward spiral in ecosystem health, especially regarding the buildup of exotic grasses at lower elevations.[6] Severe fires could spread upward to higher elevations and threaten populations of *Q. toumeyi* (T. Thibault pers. comm., 2018).

Climate change — habitat shifting, drought, temperature extremes, and/or flooding: Extended drought is one of the region's most urgent environmental issues, which is believed to be an effect of the changing climate.[6]

Low Impact Threats

Human use of species — wild harvesting: The *Quercus toumeyi* / Bouteloua curtipendula Scrub Association is reported to face some impact from firewood harvest.[2]

Human modification of natural systems — invasive species competition: Rapid spread of the invasive plant buffelgrass (*Pennisetum ciliare*) threatens the vitality of native plants in low elevations of the Sonoran Desert; its spread is facilitated by an increasing prevalence of severe fires that kill native plants and create room for exotic grasses.[6] *Quercus toumeyi* is mostly associated with higher elevations not impacted by buffelgrass, but the exotic could be evolving and may become a problem on the edge of oak habitat. Currently, exotic *Eragrostis* species are the main displacers of native grasses at oak elevations, but it is unclear whether these invasive grasses have a negative impact on oak species (J. Wiens pers. comm., 2018).

Pests and/or pathogens: One or two different species of galls have been observed on Toumey oak, parasitized by Phoradendron. Some Toumey oak seeds are the target of the paratization, and because of the species' small acorn, these seeds are even less likely to germinate or survive embryo rescue (T. Thibault pers. comm., 2018).

CONSERVATION ACTIVITIES

In 2017 *Quercus* accessions data were requested from *ex situ* collections. A total of 162 institutions from 26 countries submitted data for native U.S. oaks (Figures 3 and 4). Past, present, and planned conservation activities for U.S. oak species of concern were also examined through literature review, expert consultation, and conduction of a questionnaire. Questionnaire respondents totaled 328 individuals from 252 organizations, including 78 institutions reporting on species of concern (Figure 6).

Results of 2017 *ex situ* survey

Number of *ex situ* collections reporting this species:	3
Number of plants in *ex situ* collections:	10
Average number of plants per institution:	3
Percent of *ex situ* plants of wild origin:	80%
Percent of wild origin plants with known locality:	100%

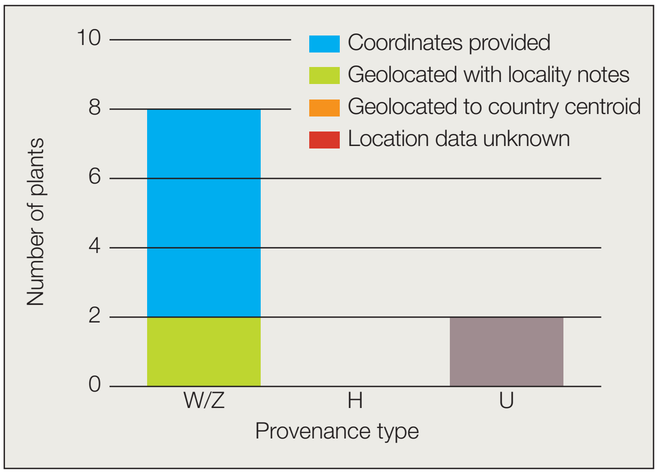


Figure 3. Number and origin of *Quercus toumeyi* plants in *ex situ* collections. Provenance types: W = wild; Z = indirect wild; H = horticultural; U = unknown.

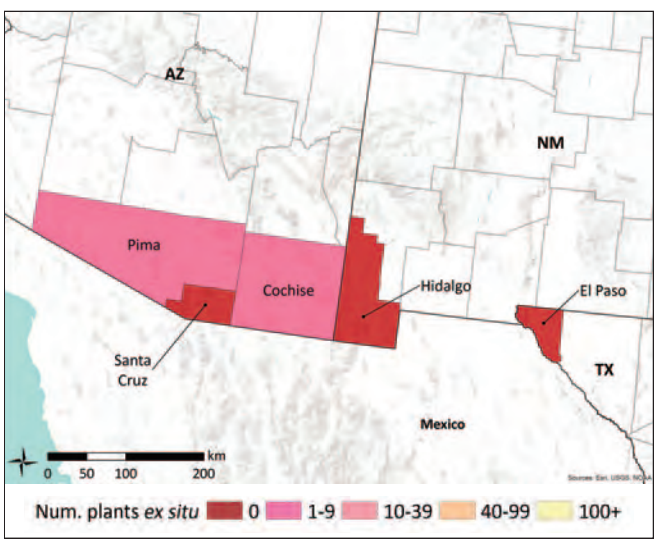


Figure 4. *Quercus toumeyi* counties of *in situ occurrence,* reflecting the number of plants from each county in *ex situ* collections.

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* collections (Figure 5). Only the native U.S. distribution of the species was considered in this analysis, due to availability of ecoregion maps. Fifty-kilometer buffers were placed around each *in situ* occurrence point and the source locality of each plant living in *ex situ* collections. Collectively, the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI50). The *ex situ* buffer area represents the native range "captured" in *ex situ* collections, or "combined area *ex situ*" (CAE50). Geographic coverage of *ex situ* collections was estimated by dividing CAI50 by CAE50. Ecological coverage was estimated by dividing the number of EPA Level IV Ecoregions present in CAE50 by the number of ecoregions in CAI50.

Estimated *ex situ* representation

Geographic coverage:	36%
Ecological coverage:	69%

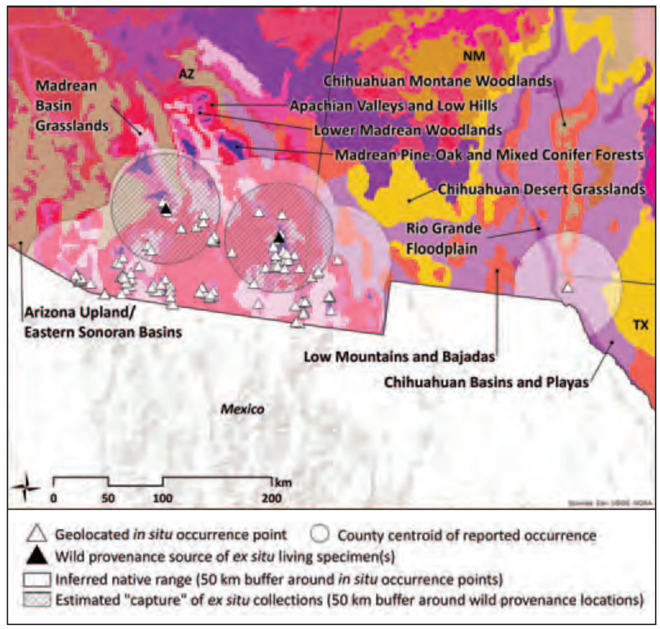


Figure 5. *Quercus toumeyi in situ* occurrence points and *ex situ* collection source localities within the United States. U.S. EPA Level IV Ecoregions are colored and labelled.[7] County centroid is shown if no precise locality data exist for that county of occurrence. Email treeconservation@mortonarb.org for information regarding specific coordinates.

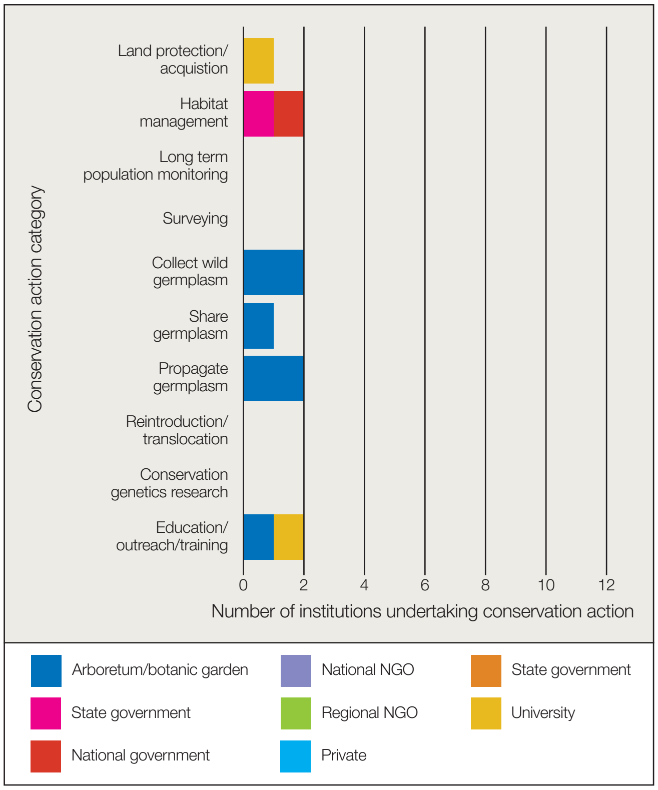


Figure 6. Number of institutions reporting conservation activities for *Quercus toumeyi* grouped by organization type. Five of 252 institutions reported activities focused on *Q. toumeyi* (see Appendix D for a list of all responding institutions).

Land protection: Within the inferred native range of *Q. toumeyi* in the U.S., 68% of the land is covered by protected areas (Figure 7). This is a very significant proportion. Energy should be focused on appropriate land management, to ensure a healthy native plant community.

Within the last ten years, The Nature Conservancy compiled an ecological and biological assessment of major landowners in Arizona and New Mexico. This publication provides a map of conservation areas, showing overlap with *Q. toumeyi's* range. They estimate that almost 57 million acres (37.6%) of the land in Arizona and New Mexico is part of a network of priority conservation areas.8 Toumey oak is also observed within Las Cienegas National Conservation Area and Rancho El Aribabi.[9,10]

Sustainable management of land: The R3 Species Database, which was developed by the USDA Forest Service in collaboration with The Nature Conservancy, has been used by The Nature Conservancy to identify priority species within National Forests; these findings could be used to update forest management plans.[8] However, the priority species are all Endangered Species Act (ESA) listed plants, which does not include *Q. toumeyi*. By associating *Q. toumeyi* with ESA Threatened or Endangered species, some idea of land management status could be gained from The Nature Conservancy's review of Region 3.

Population monitoring and/or occurrence surveys: No known initiatives at the time of publication.

Wild collecting and/or *ex situ* curation: With funding from a 2018 APGA-USFS Tree Gene Conservation Program grant, The Huntington and Arizona-Sonora Desert Museum collected *Q. toumeyi* germplasm at 12 different mountain ranges in Arizona (Cochise, Pima, and Santa Cruz counties) and New Mexico (Hidalgo County). Germination to date ranges from 0-100% at The Huntington, averaging 55% (T. Thibault pers. comm., 2018).

Propagation and/or breeding programs: The APGA-USFS Tree Gene Conservation Program is also funding the propagation of germplasm from wild collections made in 2018. The Huntington, Arizona-Sonora Desert Museum, Boyce Thompson Arboretum, and Starhill Forest Arboretum are hosting the propagules, totaling about 60 seedlings. Most of the surviving plants were collected in Rucker Canyon (Cochise County, AZ) and along Geronimo Trail (Hidalgo County, NM; T. Thibault pers. comm., 2018).[11]

Reintroduction, reinforcement, and/or translocation: No known initiatives at the time of publication.

Research: No known initiatives at the time of publication.

Education, outreach, and/or training: Two institutions reported this activity in the conservation action questionnaire, but no other details are currently known.

Species protection policies: No known initiatives at the time of publication.

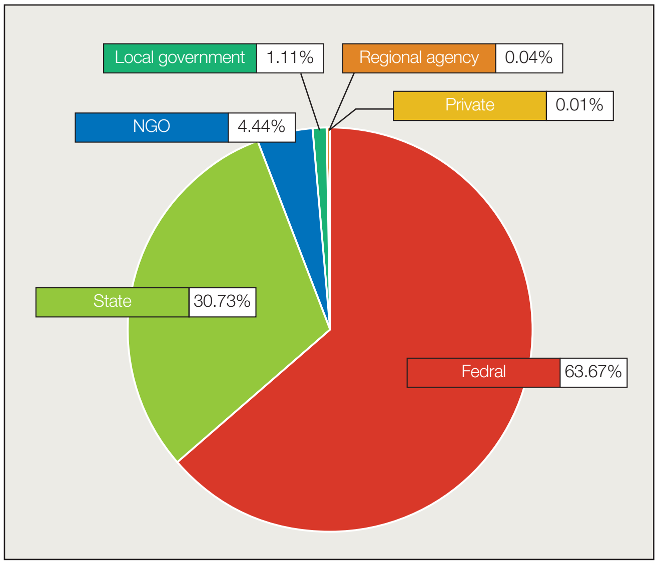


Figure 7. Management type of protected areas within the inferred native range of *Quercus toumeyi*. Protected areas data from the U.S. Geological Survey Gap Analysis Program (GAP) 2016 Protected Areas Database of the U.S. (PAD-US).[4]

Tim Thibault

PRIORITY CONSERVATION ACTIONS

The recent Red List of US Oaks listed Toumey oak as Data Deficient.[12] While the recognition of *Quercus barrancana* creates uncertainty about the southern extent of the range of *Q. toumeyi*, the species proper is known to occur in at least ten mountain ranges throughout Arizona and New Mexico. Nine of those ranges have populations on public or protected land (USFS, BLM, or The Nature Conservancy). When *Q. toumeyi* occurs, it is frequently locally common. The species crosses with *Q. arizonica* and *Q. oblongifolia* when co-occurring, opening the possibility of genetic loss through hybridization. Invasive grasses can increase fire danger, although a recent survey observed a population in the Chiricahua Mountains to have survived fire. However, sustainable management of land should remain a priority in the region. Climate change will likely change the spatial distribution of *Q. toumeyi*, potentially leading to greater fragmentation and separation of populations. While parasitic plants, gall-forming and seed parasitizing insects were observed on *Q. toumeyi*, none appears to be a threat to current populations. There is current need for monitoring to verify that populations are stable, and research to better understand the threat posed by hybridization. Additional field work is also required, primarily in Mexico, to define the southern geographic range. Adding additional populations to *ex situ* collections will help safeguard the species.

Conservation recommendations for *Quercus toumeyi*

Highest Priority

- Population monitoring and/or occurrence surveys

Recommended

- Research (climate change modeling; pests/pathogens; population genetics)
- Sustainable management of land
- Wild collecting and/or *ex situ* curation


Tim Thibault

REFERENCES

1. **Spellenberg, R. (2014).** *Quercus barrancana* (sect. *Quercus*, white oaks), a new species from northwestern Mexico. *Phytoneuron, 105*, 1-12. Retrieved from http://phytoneuron.net/2014Phytoneuron/105PhytoN-Quercusbarrancana.pdf
2. **NatureServe. (2017).** NatureServe Explorer: An online encyclopedia of life [online]. Version 7.1. Arlington, VA. Retrieved from http://explorer.natureserve.org
3. **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
4. **U.S. Geological Survey, Gap Analysis Program (GAP). (2016, May).** Protected Areas Database of the United States (PAD-US). Version 1.4 Combined Feature Class. Retrieved from https://gapanalysis.usgs.gov/padus/data/download/
5. **Romero Rangel, S., Rojas Zenteno, E. C., & Rubio Licona, L.E. (2015).** *Encinos de Mexico*. Universidad Nacional Autónoma de México.
6. **Arizona-Sonora Desert Museum. (n.d.).** Current projects - research and conservation. Retrieved from https://www.desertmuseum.org/center/current_projects.php
7. **U.S. EPA Office of Research & Development. (2013, April).** 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
8. **Lee, B. V., Smith, R., & Bate, J. (2008).** Ecological and biological assessments across major landowners in Arizona and New Mexico. In B. V. Lee & R. Smith, *Ecological and biological diversity of National Forests in Region 3*. Arlington, VA: Nature Conservancy. Retrieved from https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_021199.pdf
9. **Cooper, K. (2013).** Plants list: Observed at Rancho El Aribabi by Jesus Sanchez Escalante, Universidad de Sonora APNSAC. Retrieved from http://elaribabi.com/plants-list/
10. **Desert Research Learning Center. (n.d.).** Las Cienegas National Conservation Area. BLM-Safford. Retrieved from http://swbiodiversity.org/seinet/checklists/checklist.php?cl=3121
11. **American Public Gardens Association. (n.d.).** Tree Gene Conservation Partnership Showcase. R
12. **Jerome, D., Beckman, E., Kenny, L., Wenzell, K., Kua, C., & Westwood, M. (2017).** *Red List of US oaks*. Lisle, IL: The Morton Arboretum. Retrieved from https://www.mortonarb.org/files/Westwood_2017_Red%20List%20of%20Oaks.pdf

Conservation Gap Analysis of Native

U.S. Oaks

For further information please contact:

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

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