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Hybrid Oaks (*Quercus* spp.) of Georgia

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The native oaks of Georgia are many and varied. Each has the capacity to interbreed or hybridize with surrounding oak species which are close relatives. Georgia's hybrid oaks can be difficult to identify due to much gene sharing, cross-breeding, and associated variable leaf and acorn appearance. This publication helps professionals appreciate and understand oak hybrids in Georgia.

Oak Hybrids -- A Success Strategy

One means of oak genetic variation is generated by hybridization, leading to population divergence and specialization. Hybridization occurs naturally and can evolve into stable, genetically distinct populations and even species. Hybridization can generate new combinations of adaptations, by transferring or combining phenotypic features. (Niklas 2016) Hybridization of oaks played a significant role in their evolution. (Petit et.al. 2003) In addition to oak appearance and form, hybridization has also provided resistance-sharing among oak species to combat pathogens. (Hauser et.al. 2017)

Oaks have been long known to exchange gene sets across species boundaries through hybridization and backcrossing. (Crowl et.al. 2019) Introgression is backcrossing with the parent species, and can generate some level of fixation of gene sets and physical features. (Niklas 2016) Hybridization and introgression events in oaks have occurred often, and has helped to solidify traits and adaptations. (Crowl et.al. 2019) Closely related oaks with similar reproductive strategies and overlapping geographical ranges often hybridize naturally. (Fitzek et.al. 2018) Hybridization in oak depends upon close spacial distributions of parent trees, similar pollen dispersal timing, and internal sexual barriers to selfing and pollen effectiveness. (Fitzek et.al. 2018)

Oak Relatives

Oaks are well-suited and usually positioned to have a high rate of hybridization due to their large effective population size, high rate of infertility between distantly related species, and co-occurrence of numerous closely related species. (Crowl et.al. 2019) Little contact and only a few hybrids between distant relatives allow for diversifying, while some hybridization among closely related oaks (intrageneric hybrids), allow rapid adaptation. (Cavender-Bares et.al. 2018) Oak species interrelationships are better modeled as a network or web with interconnected branches, rather than a simple dichotomous branching or a close relative tree. (Crowl et.al. 2019)

Oak diversity is generated by a high rate of evolution along moisture gradients, and between evergreen / deciduous lifestyles. (Hipp et.al. 2018) Additionally, hybridization provides a source of

genetic variation influencing tree response to environmental change. Climate variability changes increase both the prevalence and ecological value of oak hybridization. (Moran et.al. 2012) Naturally occurring intrageneric hybrids of oaks occur where species are geographically isolated and under environmnetal change. (Niklas 2016) Oak hybridization is expected to increase with climate changes, environmental homogeny, and forced species range changes. (Fitzek et.al. 2018)

Changing & Staying The Same

Quercus commonly interbreeds within closely related species groups (genus sections / subsections), yet species retain their morphological, genetic and ecological distinctiveness. (Sullivan et.al. 2016) Hybridization can be detected in all oak species, but recurrent hybridization among species has not lead to a loss of genetic or adaptive distinctiveness. (Sullivan et.al. 2016) In red oaks, hybridization is considered common, but there is moderate selection pressure against intermediate phenotypes. (Moran et.al. 2001) Parentage suggests greater than 20% of oak seedlings have parents belonging to two distinct species. In local test areas with closely associated red oak species, approximately 35% of trees were hybrids. (Moran et.al. 2012) Internal selection, gene activation, and conservation of gene sets among female tissues help maintain suites of morphological traits characterizing unique oak species. (Moran et.al. 2012) Figure 1.

Hybridization has the capacity to generate new species and erode the boundaries of other species. But despite high levels of hybridization and introgression, many oaks still comprise distinct, stable species. (Sullivan et.al. 2016) Each sub-genus / major sub-group of *Quercus* is reproductively isolated and does not hybridize, except for single *Ilex/Cerris, Quercus/Ilex*, and *Quercus/Cerris* oak group hybrids. (Hubert et.al. 2014) Hybridization remains rare between major oak groups and frequent within closely related oak sections / subsections / sub-subsections. (Hubert et.al. 2014)

Species or Named Hybrids

Intrageneric species are groups of closely related species within the genus *Quercus* which are termed a section or subsection of the genus. Intrageneric species are much more likely to hybridize within its group than with an outside group within the same genus. (Niklas 2016) Some hybrids from intrageneric species have become unique within an area, having developed fixed, reproducible traits. These can become named hybrids, or listed as a subspecies. Hybrid populations are not given species status unless they maintain their unique biological identity in successive generations. (Niklas 2016) Subspecies are named if they inhabit different geographical areas or habitats within a species range. (Niklas 2016)

Changing Climate Impacts

Environmental changes accelerate oak hybridization rates through disrupting spacial organization of oak communities, and decreasing pollen availability of the same species. Rates of oak hybridization are increasing worldwide as biological invasions, range fragmentation, homogenization of natural environments, and climate-triggered tree flowering timing change. Climatic changes are, and have through time, disrupted biological sequencing of oak flowering and availability of pollens from different oak species. (Lagache et.al. 2012)

On an oak forest site with a mixture of many oak species, most (80%) of all available pollen will be from other oak species. Associated hybridization rates for stands with unlimited pollen is around 17%, but when pollen from the same species becomes limiting either from increasing distance away or

decreasing tree density, hybridization rates climb quickly and can theoretically reach 72%. (Lagache et.al. 2012)

The most important sexual barriers to hybrid formation are pollen competition and availability, and pollen-pistil (female selection pressure) interactions. The most important barriers to hybrid success are germination impacts and vigor of the offspring through seedling and sapling stages. (Lagache et.al. 2012) Global climate changes are disrupting oak species distributions, proportions within stands, and general abundance. The impact is an increase in oak hybridization rates. Increasing rates of site and stand disturbance are also increasing hybridization rates. (Lagache et.al. 2012)

Identifying Oak Hybrids

In the past, hybrids were considered to be morphologically intermediate with parent species. This has proven to be incorrect for the most part. (Niklas 2016) Judging hybrid relationships based only upon leaf morphology is not reliable. (Barron et.al. 2017) Morphological intermediatcy is an imperfect predictor of genetic mixtures making oak hybrids hard to identify. (Fitzek et.al. 2018) Whole tree appearance, including leaves and acorns, is not adequate for differentiating hybrids among some red oaks. Distinquishing red oak hybrids, in general, is notably poor. (Tomlinson et.al. 2000)

Similar genotypes can generate dissimilar phenotypes, while similar phenotypes can be generated by dissimilar genotypes. Very small genotypic variations can generate very different phenotypes, and very dissimilar phenotypes can be competitive equals on sites, especially when environmental disturbance is more intense. (Niklas 2016) Figure 2.

NOT Intermediate In Appearance

Off-spring of hybrid oaks can have quite variable and mixed gene sets, and associated morphological characteristics, compared with parents. These “hybrids of hybrids” may show a variety of reproductive attributes. For example, a hybrid tree may preferentially accept one parent species’ pollen over the other. A *Quercus stellata X Quercus alba* (post oak X white oak) hybrid was found to accept only *Quercus alba* pollen for reproduction of the next generation. (Fitzek et.al. 2018)

Hybrids are usually not morphologically halfway between parents, or in other words, may not appear intermediate in most traits. Since each parent may be of hybrid origin, hybrids will be a genetic and morphological mixture. A photographic example published of an oak hybrid with non-intermediate leaf morphological features was between bear oak (*Quercus ilicifolia*) and black oak (*Quercus velutina*). The hybrid leaves resembled, and could be mistaken for, blackjack oak (*Quercus marilandica*), not a strong morphological intermediate between the parents. (Niklas 2016)

Georgia’s Oak Hybrids

Quercus species in the Georgia area hybridize among closely related species and rarely with much more distantly related species. Figure 3 presents the cross-breeding groups of native Georgia red oaks. In this figure, each closely related species group is separated and color coded. The farther apart each species is listed, the less likely hybridization will occur. Figure 4 presents native white oak relatives and their closeness for hybridization.

Figure 5 is a checklist of Georgia native red oak species with their named, historic, or cited hybrids. The native red oak species of Georgia are listed in bold. Hybrids are listed which have been cited in the literature. Each hybrid is listed with its scientific name and parent species. Hybrid names have a “x” between or in front of the species name to denote this tree is a hybrid.

Figure 6 is a checklist of Georgia native white oak species with their named, historic, or cited hybrids. The native white oak species of Georgia are listed in bold. Hybrids are listed which have been cited in the literature. Each hybrid is listed with its scientific name and parent species.

Hybrid Networks

Figure 7 lists the cited hybrids (hybrid network) for each native red oak species and can suggest how closely related are each potential parent species. Numeric values listed represent one form of genetic distance apart: for these Georgia native hybrid trees, suggesting the most likely hybrid combinations present. Figure 8 provides the geographical center of each of the red oak group's native species range within Georgia, suggesting physically overlapping ranges and accessibility to pollen sources from neighboring red oak species which could lead to hybridization events. Note four native red oak group species are found nearly everywhere in Georgia and can be major hybridization parent sources.

Figure 9 lists the cited hybrids (hybrid networks) for each native white oak species and can suggest how closely related are each potential parent species. Numeric values listed represent one form of genetic distance apart: for these Georgia native hybrid trees, suggesting the most likely hybrid combinations present. Figure 10 provides the geographical center of each of the white oak group's native species range within Georgia, suggesting physically overlapping ranges and accessibility to pollen sources from neighboring white oak species which could lead to hybridization events. Note two native white oak group species are found everywhere in Georgia and can be major hybridization parent sources.

Counting Hybrids

Figure 11 provides the number of reported hybrids for each native oak species in Georgia. The red oak group species water oak (Q. nigra), willow oak (Q. phellos), blackjack oak (Q. marilandica), turkey oak (Q. laevis), and black oak (Q. velutina) lead the group in parenting more than 11 cited hybrids in Georgia. In the white oak group, white oak (Q. alba), live oak (Q. virginiana), overcup oak (Q. lyrata), and post oak (Q. stellata) lead the group parenting more than 5 cited hybrids in Georgia.

Figure 12 provides an example hybrid web for just three native red oaks of Georgia. This figure shows the numerous hybrids among blackjack oak (*Quercus marilandica*), water oak (*Quercus nigra*), and willow oak (*Quercus phellos*). Note only the species names are listed. Imagine the hybrid web complexity if all 19 native red oak and 16 native white oak species were incorporated into a hybrid web.

Conclusions

Hybrid oaks can be curiosities, confusing to identify, and ecologically valuable in a changing world. Understanding Georgia's native oak hybrids is an important component in both natural and built landscapes. These hybrids also provide a caution when identifying oaks in the field.

Citation:

Coder, Kim D. 2020. Hybrid Oaks (*Quercus* spp.) of Georgia. University of Georgia, Warnell School of Forestry & Natural Resources Outreach Publication WSFNR20-26A. Pp.28..

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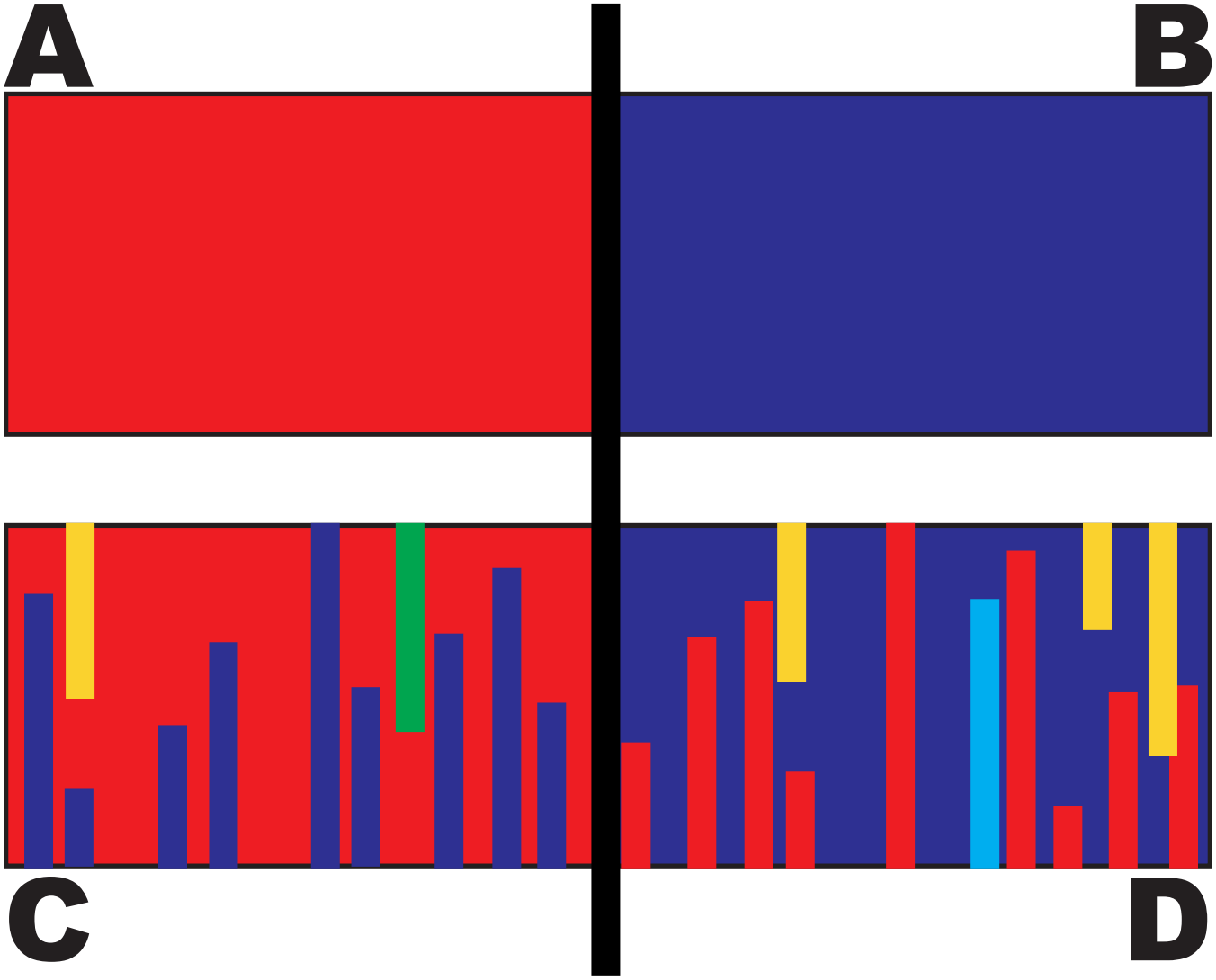

Figure 1: Classical view of a hybrid (A-B) from a pure red (A) and blue (B) parent, with A-B sharing half of each parent's gene set. Normal view of hybrid (C-D) containing highly mixed gene sets of various proportions from parents with mixed gene sets.

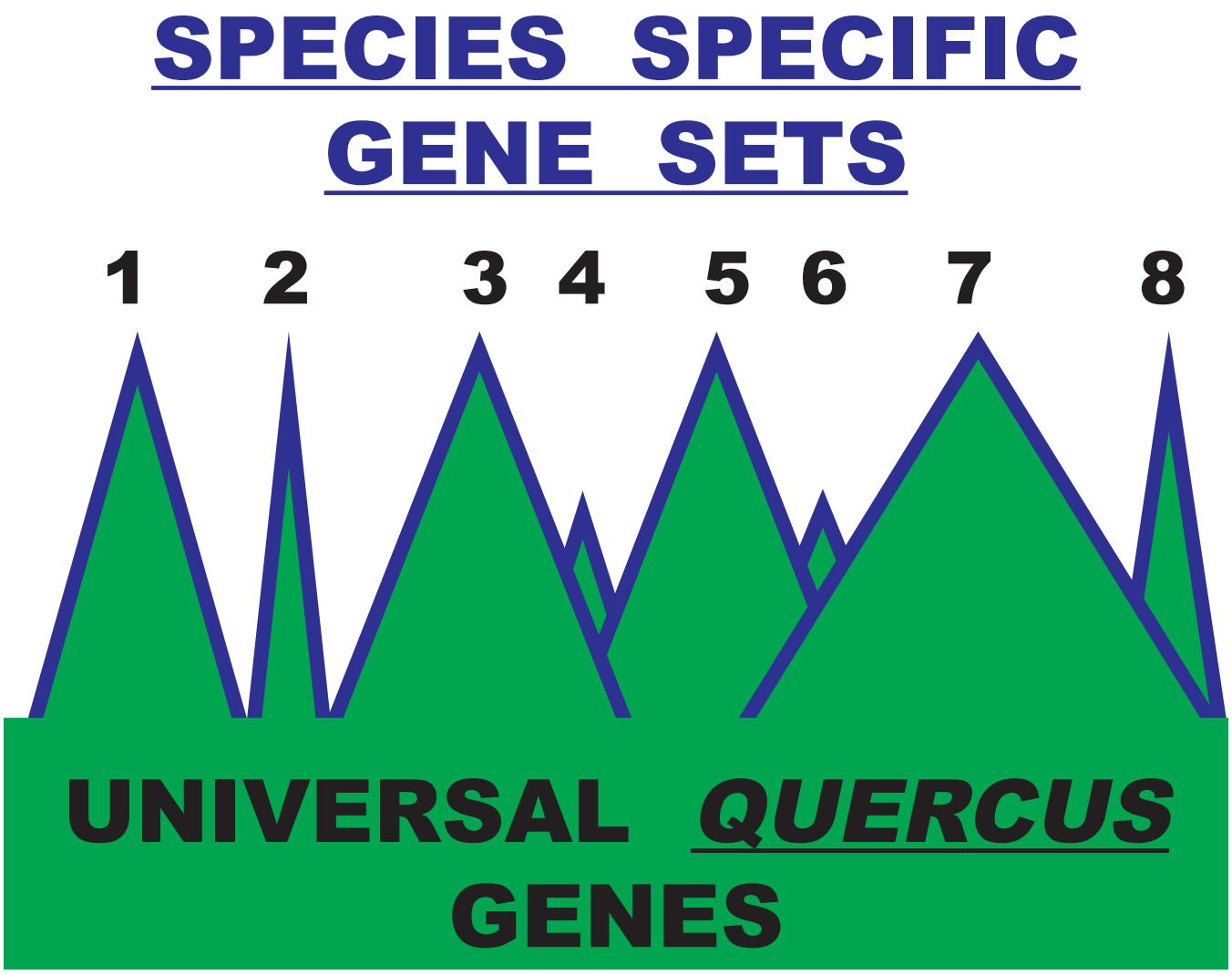

Figure 2: Simple diagram of eight (8) *Quercus* (oak) species unique and shared gene pools. For eample, #1 & #2 are seperate species; #4 is a hybrid of 3 & 5; #7 shares genes with #5, #6, & #8; & #6 is a hybrid of #5, & #7.

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RED OAK RELATIVES

1	*Quercus palustris*	pin oak
2	*Quercus velutina*	black oak
3	*Quercus coccinea*	scarlet oak
4	*Quercus rubra*	Northern red oak
5	*Quercus shumardii*	Shumard's oak
6	*Quercus pagoda*	cherrybark oak
7	*Quercus imbricaria*	shingle oak
8	*Quercus georgiana*	Georgia oak
9	*Quercus falcata*	Southern red oak
10	*Quercus marilandica*	blackjack oak
11	*Quercus laevis*	turkey oak
12	*Quercus laurifolia*	swamp laurel oak
13	*Quercus phellos*	willow oak
14	*Quercus arkansana*	Arkansas oak
15	*Quercus nigra*	water oak
16	*Quercus incana*	bluejack oak
17	*Quercus hemisphaerica*	laurel oak
18	*Quercus myrtifolia*	myrtle oak

Figure 3: Nearest relatives / species groups in order of relatedness within the genus *Quercus* for native red oaks of Georgia. (Hipp et.al. 2017)

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WHITE OAK RELATIVES

1	*Quercus minima*	dwarf live oak
2	*Quercus virginiana*	live oak
3	*Quercus geminata*	sand live oak
4	*Quercus muehlenbergii*	chinquapin oak
5	*Quercus prinoides*	dwarf chinquapin oak
6	*Quercus lyrata*	overcup oak
7	*Quercus montana*	chestnut oak
8	*Quercus alba*	white oak
9	*Quercus michauxii*	swamp chestnut oak
10	*Quercus sinuata*	bastard (Durand) oak
11	*Quercus oglethorpensis*	Oglethorpe oak
12	*Quercus similis*	swamp post oak
13	*Quercus stellata*	post oak
14	*Quercus margarettae*	sand post oak
15	*Quercus chapmanii*	Chapman oak
16	*Quercus austrina*	bluff oak

Figure 4: Nearest relatives / species groups in order of relatedness within the genus *Quercus* for native white oaks of Georgia. (Hipp et.al. 2017)

Figure 5: Checklist of red oaks (*Quercus* spp.) of Georgia with cited hybrids & historic names.

scientific name	common name
Quercus x anceps [*falcata x imbricaria*]	hybrid oak
Quercus arkansana	**Arkansas oak**
Quercus x ashei [*incana × laevis*]	hybrid oak
Quercus x atlantica [*incana × laurifolia*]	hybrid oak
Quercus x blufftonensis [*falcata x laevis*]	hybrid oak
Quercus x bushii [*marilandica × velutina*]	Bush oak
Quercus x caduca [*incana × nigra*]	hybrid oak
Quercus x capesii [*nigra x phellos*]	hybrid oak
Quercus coccinea	**scarlet oak**
Quercus coccinea var. *coccinea*	scarlet oak
Quercus coccinea var. *tuberculata*	scarlet oak
Quercus x cocksii [*laurifolia x velutina*]	hybrid oak
Quercus x comptoniae [*lyrata x virginiana*]	Compton oak
Quercus x cravenensis [*incana × marilandica*]	Craven oak
Quercus x demarei [*nigra x velutina*]	hybrid oak
Quercus x discreta [*shumardii x velutina*]	hybrid oak
Quercus x diversiloba [*laurifolia x marilandica*]	hybrid oak
Quercus falcata	**southern red oak**
Quercus falcata x Q. marilandica	hybrid oak
Quercus x fernaldii [*ilicifolia x rubra*]	hybrid oak
Quercus x filialis [*phellos x velutina*]	hybrid oak
Quercus x fontana [*coccinea x velutina*]	hybrid oak
Quercus x garlandensis [*falcata × nigra*]	hybrid oak
Quercus georgiana	**Georgia oak**
Quercus x hawkinsiae [*velutina x rubra*]	hybrid oak
Quercus hemisphaerica	**Darlington oak**
Quercus hemisphaerica var. *hemisphaerica*	Darlington oak
Quercus hemisphaerica var. *maritima*	Darlington oak
Quercus x heterophylla [*phellos x rubra*]	Bartram oak
Quercus ilicifolia	bear oak (non-native NE)
Quercus imbricaria	**shingle oak**
Quercus inopina	sandhill oak (non-native C-FL)
Quercus incana	**bluejack oak**
Quercus x incomita [*falcata x marilandica*]	hybrid oak
Quercus x joorii [*falcata x shumardii*]	hybrid oak
Quercus laevis	**turkey oak**

Figure 5: Checklist of red oaks (*Quercus* spp.) of Georgia with cited hybrids & historic names. (continued)

scientific name	common name
Quercus laurifolia	**swamp laurel oak**
Quercus x leana [*imbricaria x velutina*]	Lea oak
Quercus x ludoviciana [*pagoda × phellos*]	hybrid oak
Quercus x ludoviciana var. *subfalcata* [*falcata x phellos*]	Ludwig oak
Quercus marilandica	**blackjack oak**
Quercus marilandica var. *marilandica*	blackjack oak
Quercus x mellichampii [*laevis x hemisphaerica*]	hybrid oak
Quercus x moultonensis [*phellos x shumardii*]	hybrid oak
Quercus myrtifolia	**myrtle oak**
Quercus x neopalmeri [*nigra × shumardii*]	hybrid oak
Quercus nigra	**water oak**
Quercus x oviedoensis [*incana x myrtifolia*]	hybrid oak
Quercus x palmeriana [*falcata x imbricaria*]	hybrid oak
Quercus palustris	**pin oak**
Quercus palustris x Q. coccinea	hybrid oak
Quercus phellos	**willow oak**
Quercus x pinetorum [*falcata x velutina*]	hybrid oak
Quercus x podophylla [*incana x velutina*]	hybrid oak
Quercus pumila	**running oak**
Quercus x raineri [*nigra x rubra*]	hybrid oak
Quercus rubra	**northern red oak**
Quercus rubra var. *ambigua*	northern red oak
Quercus rubra var. *rubra*	northern red oak
Quercus x rudkinii [*marilandica × phellos*]	hybrid oak
Quercus x rugelii [*coccinea x palustris*]	hybrid oak
Quercus x runcinata [*imbricaria x rubra*]	hybrid oak
Quercus x schociana [*palustris x phellos*]	hybrid oak
Quercus shumardii	**shumard oak**
Quercus shumardii var. *schneckii*	Schneck oak
Quercus shumardii var. *shumardii*	Shumard oak
Quercus shumardii x Q. texana	hybrid oak
Quercus x smallii [*georgiana × marilandica*]	hybrid oak
Quercus x sterilis [*marilandica × nigra*]	hybrid oak
Quercus x subfalcata [*falcata x phellos*]	hybrid oak
Quercus x subimbricaria [*phellos x imbricaria*]	hybrid oak

Figure 5: Checklist of red oaks (*Quercus* spp.) of Georgia with cited hybrids & historic names. (continued)

scientific name	common name
Quercus x subintegra [*falcata* × *incana*]	hybrid oak
Quercus x sublaurifolia [hemisphaeric x incana]	hybrid oak
Quercus texana	Nuttall oak (non-native W)
Quercus velutina	**black oak**
Quercus x venulosa [*arkansana x incana*]	hybrid oak
Quercus x walteriana [*laevis* × *nigra*]	hybrid oak
Quercus x willdenowiana [*falcata* × *velutina*]	hybrid oak

Figure 6: Checklist of white oaks (*Quercus* spp.) of Georgia with cited hybrids & historic names.

scientific name	common name
Quercus alba	**white oak**
Quercus alba x Q. muehlenbergii	hybrid oak
Quercus alba x Q. virginiana	hybrid oak
Quercus austrina	**bluff oak**
Quercus x beadlei [alba × michauxii]	Beadle oak
Quercus x bebbiana [alba x macrocarpa]	Bebb oak
Quercus x bernardiensis [michauxii × stellata]	hybrid oak
Quercus bicolor	swamp white oak (non-native)
Quercus boyntonii	Boynton oak (non-native NC-AL)
Quercus boyntonii x Q. margarettae	hybrid oak
Quercus x burnetensis [macrocarpa x virginiana]	hybrid oak
Quercus x byarsii [*macrocarpa* × *michauxii*]	hybrid oak
Quercus chapmanii	**Chapman oak**
Quercus x comptoniae [lyrata x virginiana]	Compton oak
Quercus x deamii [macrocarpa x muehlenbergii]	hybrid oak
Quercus x drummondii [*margarettae x stellata*]	hybrid oak
Quercus x *fernowii* [*alba* × *stellata*]	Fernow oak
Quercus x guadalupensis [*stellata x sinuata*]	MacNab oak
Quercus geminata	**sand live oak**
Quercus x harbisonii [*stellata x virginiana*]	hybrid oak
Quercus x humidicola [*lyrata x bicolor*]	hybrid oak
Quercus x jackiana [*alba x (montana or bicolor)*]	Jack oak
Quercus x macnabiana [*stellata x sinuata*]	MacNab oak
Quercus macrocarpa	bur oak (non-native MidWest)
Quercus macrocarpa var. *macrocarpa*	bur oak (non-native MidWest)
Quercus margarettae	**sand post oak**
Quercus michauxii	**swamp chestnut oak**
Quercus minima	**dwarf live oak**
Quercus montana	**chestnut oak**
Quercus montana x Q. bicolor	hybrid oak
Quercus muehlenbergii	**chinquapin oak**
Quercus muehlenbergii x Q. prinoides	hybrid oak
Quercus oglethorpensis	**Oglethorpe oak**

Figure 6: Checklist of white oaks (*Quercus* spp.) of Georgia with cited hybrids & historic names. (continued)

scientific name	common name
Quercus prinoides	**dwarf chinquapin oak**
Quercus x pseudomargaretta [*stellata x margarettae*]	hybrid oak
Quercus x saulii [*alba x montana*]	Saul oak
Quercus similis	**bottomland post oak**
Quercus sinuata	**bastard oak**
Quercus sinuata var. *sinuata*	bastard oak
Quercus stellata	**post oak**
Quercus x sterrettii [*stellata x lyrata*]	hybrid oak
Quercus x succulenta [*geminata x minima*]	hybrid oak
Quercus x tottenii [*lyrata x michauxii*]	hybrid oak
Quercus virginiana	**live oak**
Quercus virginiana x Q. alba	hybrid oak
Quercus virginiana x Q. lyrata	hybrid oak
Quercus virginiana x Q. macrocarpa	hybrid oak
Quercus virginiana x Q. minima	hybrid oak

Figure 7: Cited hybrid network (for both named & unnamed hybrids) among native red oak *Quercus* species in Georgia.

RED OAKS

Q. arkansana

Q. falcata	2
Q. hemisphaerica	1
Q. incana	1
Q. laevis	2
Q. marilandica	2
Q. myrtifolia	1
Q. nigra	1*
Q. velutina	3

Q. coccinea

Q. imbricaria	1
Q. laevis	2
Q. palustris	1
Q. phellos	3
Q. rubra	1*
Q. velutina	1*

Q. falcata

Q. hemisphaerica	3
Q. imbricaria	1
Q. incana	3
Q. laevis	1
Q. marilandica	1*
Q. nigra	3
Q. pagoda	2
Q. phellos	2
Q. shumardii	3
Q. velutina	3

Q. georgiana

Q. marilandica	1

Q. hemisphaerica

Q. arkansana	1
Q. falcata	2
Q. inopina	--
Q. marilandica	3
Q. myrtifolia	1*
Q. nigra	1
Q. phellos	2
Q. pumilla	--
Q. shumardii	3

Q. imbricaria

Q. coccinea	1
Q. falcata	1
Q. ilicifolia	--
Q. marilandica	1
Q. palustris	2
Q. phellos	2
Q. rubra	1
Q. shumardii	1
Q. velutina	1

Figure 7: Cited hybrid network (for both named & unnamed hybrids) among native red oak *Quercus* species in Georgia.
(continued)

Q. incana

Q. arkansana	*1*
Q. falcata	*3*
Q. hemisphaerica	*1**
Q. laevis	*3*
Q. laurifolia	*2*
Q. marilandica	*3*
Q. myrtifolia	*1**
Q. nigra	*1*
Q. phellos	*2*
Q. pumila	*--*
Q. velutina	*3*

Q. laevis

Q. arkansana	*2*
Q. coccinea	*2*
Q. falcata	*1**
Q. hemisphaerica	*3*
Q. incana	*3*
Q. laurifolia	*1*
Q. marilandica	*1**
Q. myrtifolia	*3*
Q. nigra	*2*
Q. phellos	*1*
Q. shumardii	*2*
Q. velutina	*2*

Q. laurifolia

Q. falcata	*1*
Q. hemispaerica	*2*
Q. incana	*2*
Q. laevis	*1*
Q. marilandica	*1*
Q. myrtifolia	*2*
Q. nigra	*1*
Q. phellos	*1**
Q. shumardii	*3*
Q. velutina	*3*

Q. marilandica

Q. arkansana	*2*
Q. falcata	*1**
Q. georgiana	*1*
Q. hemisphaerica	*3*
Q. incana	*3*
Q. laevis	*1**
Q. laurifolia	*1*
Q. myrtifolia	*3*
Q. nigra	*2*
Q. palustris	*3*
Q. phellos	*1*
Q. rubra	*2*
Q. velutina	*2*

Q. myrtifolia

Q. arkansana	*1*
Q. hemisphaerica	*1**
Q. incana	*1**
Q. inopina	*--*
Q. laurifolia	*2*
Q. marilandica	*3*
Q. nigra	*1*
Q. pumila	*--*

Figure 7: Cited hybrid network (for both named & unnamed hybrids) among native red oak *Quercus* species in Georgia.

(continued)

Q. nigra

Q. arkansana	*1**
Q. falcata	*2*
Q. georgiana	*3*
Q. hemisphaerica	*1*
Q. incana	*1*
Q. laevis	*2*
Q. laurifolia	*1*
Q. marilandica	*2*
Q. myrtifolia	*1*
Q. palustris	*3*
Q. phellos	*1*
Q. rubra	*3*
Q. shumardii	*3*
Q. texana	*--*
Q. velutina	*3*

Q. pagoda

Q. falcata	*1*
Q. phellos	*2*

Q. palustris

Q. coccinea	*1*
Q. phellos	*3*

Q. phellos

Q. coccinea	*3*
Q. falcata	*1*
Q. hemisphaerica	*2*
Q. imbricaria	*2*
Q. incana	*2*
Q. laurifolia	*1**
Q. marilandica	*1*
Q. nigra	*1*
Q. pagoda	*2*
Q. palustris	*3*
Q. pumila	*--*
Q. rubra	*3*
Q. shumardii	*3*
Q. velutina	*3*

Q. pumila

Q. hemisphaerica	*--*
Q. incana	*--*
Q. myrtifolia	*--*
Q. phellos	*--*

Q. rubra

Q. ilicifolia	*--*
Q. imbricaria	*1*
Q. marilandica	*2*
Q. nigra	*3*
Q. phellos	*3*
Q. velutina	*1**

Figure 7: Cited hybrid network (for both named & unnamed hybrids) among native red oak *Quercus* species in Georgia.

(continued)

Q. shumardii

Q. falcata	*2*
Q. hemisphaerica	*3*
Q. imbricaria	*1*
Q. laevis	*2*
Q. laurifolia	*3*
Q. marilandica	*2*
Q. nigra	*3*
Q. phellos	*3*
Q. rubra	*1**
Q. texana	*--*
Q. velutina	*1**

Q. velutina

Q. arkansana	*3*
Q. coccinea	*1**
Q. falcata	*2*
Q. imbricaria	*1*
Q. incana	*3*
Q. laevis	*2*
Q. laurifolia	*3*
Q. marilandica	*2*
Q. nigra	*3*
Q. phellos	*3*
Q. rubra	*1**
Q. shumardii	*1**

Numeric values represent the genetic distance apart for these Georgia native hybrid trees, and can suggest most likely hybrids present.

1* = closest neighbor / within same species group
1 = close species group
2 = intermediate distance species group
3 = farthest away species group

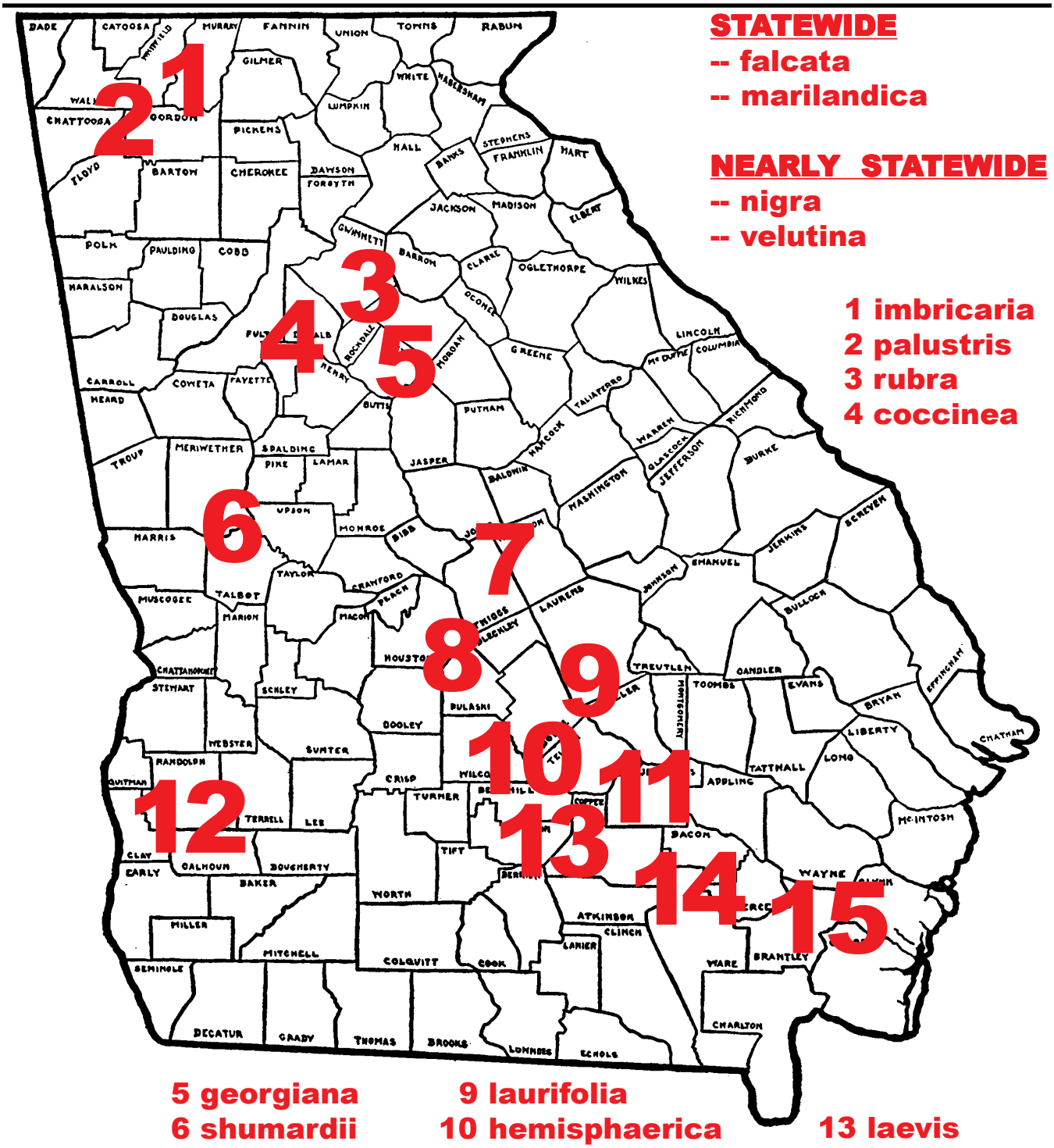

Figure 8: Center of each native red oak species (*Quercus* spp.) range in Georgia. Four red oak group species are found nearly everywhere statewide.

Figure 9: Cited hybrid network (for both named & unnamed hybrids) among native white oak *Quercus* species in Georgia.

WHITE OAKS

Q. alba

Q. lyrata	*1*
Q. macrocarpa	*--*
Q. michauxii	*1**
Q. montana	*1**
Q. muehlenbergii	*1*
Q. sinuata	*1*
Q. stellata	*1*
Q. virginiana	*2*

Q. chapmanii

Q. minima	*3*

Q. geminata

Q. minima	*1**

Q. lyrata

Q. alba	*1*
Q. bicolor	*--*
Q. michauxii	*1*
Q. sinuata	*2*
Q. stellata	*2*
Q. virginiana	*1*

Q. michauxii

Q. alba	*1*
Q. lyrata	*1*
Q. macrocarpa	*--*
Q. stellata	*1*

Q. margaretta

Q. boyntonii	*--*
Q. stellata	*1*

Q. minima

Q. chapmanii	*3*
Q. geminata	*1**

Q. montana

Q. alba	*1**
Q. bicolor	*--*

Q. muehlenbergii

Q. alba	*1*
Q. macrocarpa	*--*
Q. prinoides	*1**

Q. prinoides

Q. muehlenbergii	*1**

Q. sinuata

Q. alba	*1*
Q. lyrata	*2*
Q. stellata	*1**
Q. virginiana	*3*

Figure 9: Cited hybrid network (for both named & unnamed hybrids) among native white oak *Quercus* species in Georgia.
(continued)

Q. stellata

Q. alba	*1*
Q. lyrata	*2*
Q. margaretta	*1*
Q. michauxii	*1*
Q. sinuata	*1**
Q. virginiana	*3*

Q. virginiana

Q. alba	*2*
Q. geminata	*1**
Q. lyrata	*1*
Q. macrocarpa	*--*
Q. minima	*1**
Q. sinuata	*3*
Q. stellata	*3*

Numeric values represent the genetic distance apart for these Georgia native hybrid trees, and can suggest most likely hybrids present.

1*	=	closest neighbor / within same species group
1	=	close species group
2	=	intermediate distance species group
3	=	farthest away species group

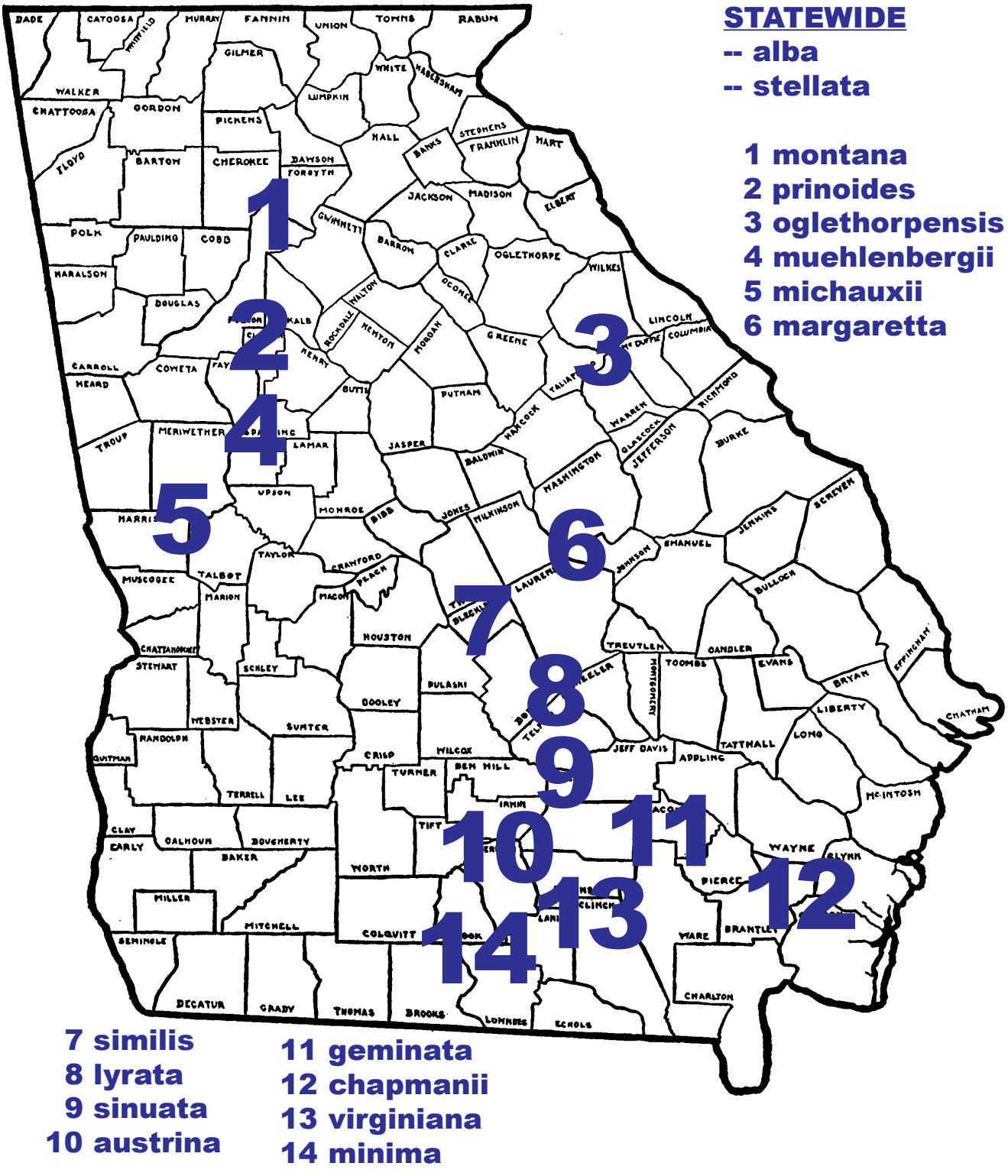

Figure 10: Center of each native white oak species (*Quercus* spp.) range in Georgia. Two white oak group species are found statewide.

RED OAKS

Quercus arkansana	**Arkansas oak**	**8**
Quercus coccinea	**scarlet oak**	**6**
Quercus falcata	**Southern red oak**	**10**
Quercus georgiana	**Georgia oak**	**1**
Quercus hemisphaerica	**laurel oak**	**9**
Quercus imbricaria	**shingle oak**	**9**
Quercus incana	**bluejack oak**	**11**
Quercus laevis	**turkey oak**	**12**
Quercus laurifolia	**swamp laurel oak**	**10**
Quercus marilandica	**blackjack oak**	**13**
Quercus myrtifolia	**myrtle oak**	**8**
Quercus nigra	**water oak**	**15**
Quercus pagoda	**cherrybark oak**	**2**
Quercus palustris	**pin oak**	**2**
Quercus phellos	**willow oak**	**14**
Quercus pumila	**running oak**	**4**
Quercus rubra	**Northern red oak**	**6**
Quercus shumardii	**Shumard's oak**	**11**
Quercus velutina	**black oak**	**12**

continued

Figure 11: Number of reported hybrids for native oak species.

WHITE OAKS		
Quercus alba	white oak	8
Quercus austrina	bluff oak	0
Quercus chapmanii	Chapman oak	1
Quercus geminata	sand live oak	1
Quercus lyrata	overcup oak	6
Quercus margarettae	sand post oak	2
Quercus michauxii	swamp chestnut oak	4
Quercus minima	dwarf live oak	2
Quercus montana	chestnut oak	2
Quercus muehlenbergii	chinquapin oak	3
Quercus oglethorpensis	Oglethorpe oak	0
Quercus prinoides	dwarf chinquapin oak	1
Quercus similis	swamp post oak	0
Quercus sinuata	bastard (Durand) oak	4
Quercus stellata	post oak	6
Quercus virginiana	live oak	7

Figure 11: Number of reported hybrids for native oak species.
(continued)

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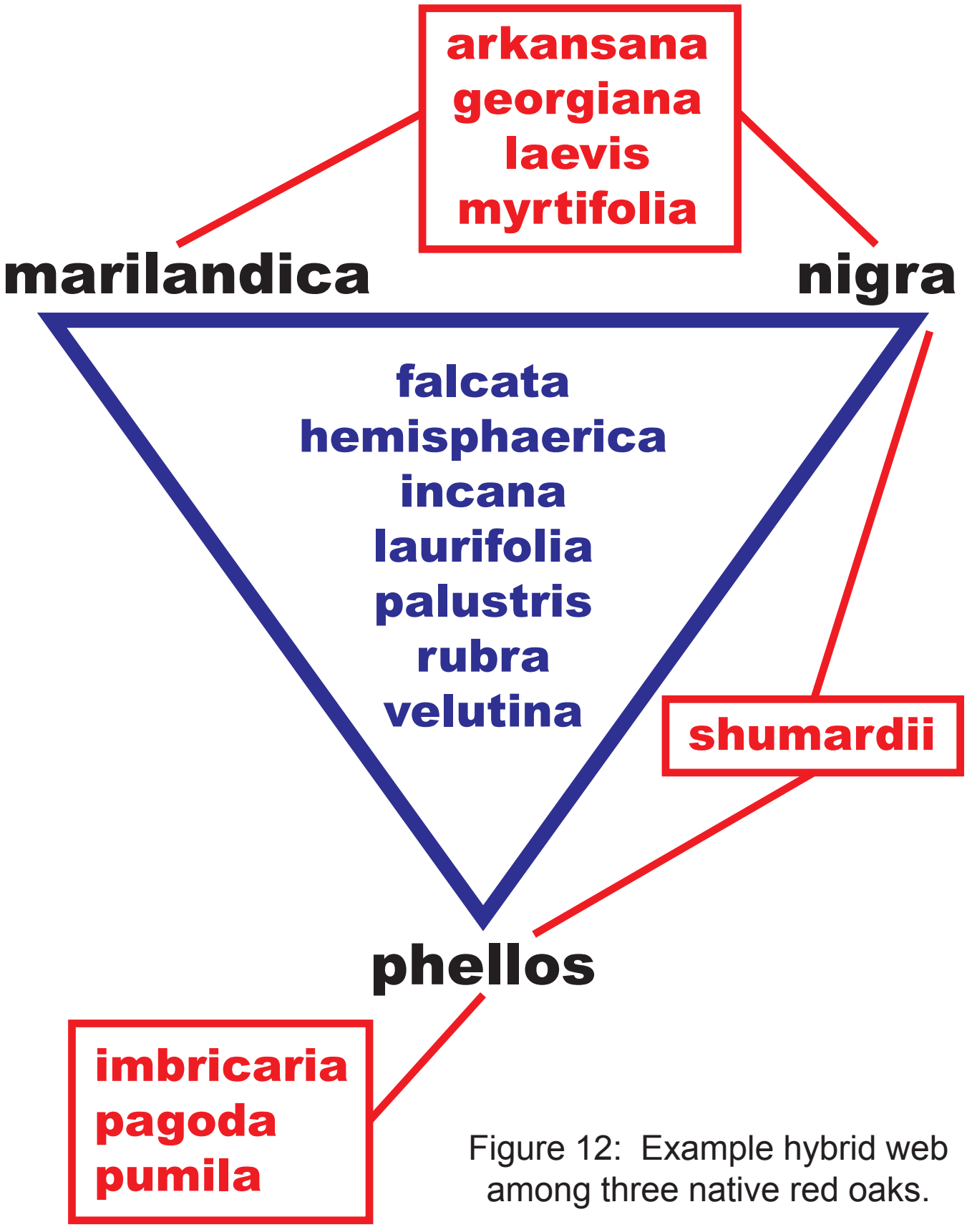

Figure 12: Example hybrid web among three native red oaks.