

Conservation assessment of Lecythidaceae from eastern Brazil

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Summary. This work evaluates the conservation status of the 22 species of Lecythidaceae native to eastern Brazil. Assessments based on current IUCN criteria, distribution maps, and an identification key to the native and non-native species from the area are provided. The results of this study suggest that over half of the species are threatened (vulnerable or endangered), four species should be added to the IUCN Red List, and the status of seven species currently on this list should be changed. It was found that nearly all collections of endangered species are from or occur within 20 km of a reserve, which clearly shows that protected areas are of vital importance for the survival of most endangered Lecythidaceae from this region.

Key Words. Atlantic Forest, Brazil nut family, endangered species, IUCN Red List.

Introduction

Lecythidaceae are found mostly in tropical regions. Worldwide the family comprises approximately 325 species within 22 genera (Prance 2012); 11 genera and around 210 described species occur in the Western Hemisphere (Mori *et al.* 2010). Famous for the Brazil nut, spectacular flowers and large-fruited species, this small family is one of the most dominant groups of trees in northern South America (ter Steege *et al.* 2006, 2013). In Brazil, there are 10 genera and around 120 species of Lecythidaceae (Smith *et al.* 2014). Approximately 45% of these species are endemic to the country and the main centre of diversity for the family (worldwide) is in the state of Amazonas where there are more than 75 species (Smith *et al.* 2014).

Several monographs have been published that include Lecythidaceae species from Brazil (Miers 1874; Knuth 1939; Prance & Mori 1979; Mori & Prance 1990). The most recent and comprehensive works about the neotropical taxa were published by Prance & Mori (1979) and Mori & Prance (1990). These works have served as the foundation of subsequent morphological and molecular phylogenetic studies (e.g., Morton *et al.* 1997; Mori *et al.* 2007; Huang *et al.* 2008, 2015; Mori *et al.* 2015) that resulted in a better understanding of the genera and included some taxonomic changes. For example, Huang *et al.* (2008) transferred the *Cariniana* Casar. species (*sensu*

Prance in Prance & Mori 1979) with actinomorphic androecia to *Allantoma* Miers, and the results of a recent study by Huang *et al.* (2015) suggest that *Lecythis* Loefl. and *Eschweilera* Mart. ex DC. (*sensu* Mori in Mori & Prance 1990) are not monophyletic; however, additional studies are needed to further test this hypothesis. More information about these studies, as well as current descriptions of all neotropical genera and species, can be found on the Lecythidaceae Pages (Mori *et al.* 2010).

There are 22 native species (Table 1) in eastern Brazil that occur between the states of Santa Catarina and Rio Grande do Norte (Map 1). Of the 11 genera that occur in the Western Hemisphere, five (*Cariniana*, *Couratari* Aubl., *Eschweilera*, *Gustavia* L., and *Lecythis*) are native in eastern Brazil and two non-native genera (*Bertholletia* Bonpl. and *Couroupita* Aubl.) are cultivated. The native species range from small trees (e.g., *Eschweilera nana* (O. Berg) Miers) to some of the tallest trees in South America, which can reach 60 m (e.g., *Cariniana estrellensis* (Raddi) Kuntze).

Lecythidaceae have some of the most morphologically complex flowers in the world. In eastern Brazil, flowers of this family range from less than 0.5 cm (e.g., *Cariniana legalis* (Mart.) Kuntze) to over 15 cm diam. (*Gustavia augusta* L.), can be radially symmetric to highly asymmetric, and many have a unique structure called a ligule that arches over the fertile stamens and

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Table 1. Comparison of recent conservation assessments for species of Lecythidaceae from eastern Brazil^a

Species	Present study ^b	IUCN ^c	Lima da Venda <i>et al.</i> 2013	Endemic to eastern Brazil
<i>Cariniana estrellensis</i>	LC	-	-	no
<i>Cariniana ianeirensis</i>	EN C1	EN B1+2c	EN A2cd	no
<i>Cariniana legalis</i>	LC	VU A1ac	EN A2cd	yes
<i>Cariniana parvifolia</i>	EN B1a+2b(iii)	-	EN B1ab(iii,v)	yes
<i>Couratari asterophora</i>	EN B1(i, iii)	CR B1+2c	-	yes
<i>Couratari asterotricha</i>	EN B1(i, iii)+2(iii)	CR B1+2d	EN B1ab(iii,v)	yes
<i>Couratari macrosperma</i>	LC	-	-	no
<i>Couratari pyramidata</i>	EN B1(i, iii)+2(iii)	EN B1+2c	EN B1ab(iii,v)	yes
<i>Eschweilera alvimii</i>	CR B2ab(iii)	VU B1+2c	EN A2cd	yes
<i>Eschweilera complanata</i>	EN B1ab(iii)+2ab(iii)	-	-	yes
<i>Eschweilera compressa</i>	EN B2ab(iii)	CR B1+2cd	EN B1+2cd	yes
<i>Eschweilera mattos-silvae</i>	NT	-	-	yes
<i>Eschweilera nana</i>	LC	-	-	no
<i>Eschweilera ovata</i>	LC	-	-	no
<i>Eschweilera tetrapetala</i>	EN B1ab(iii)+2ab(iii)	VU D2	EN B1ab(i,ii,iii,iv,v)	yes
<i>Gustavia augusta</i>	LC	-	-	no
<i>Lecythis ibiriba</i>	VU B1ab(ii, iii)	-	-	yes
<i>Lecythis lanceolata</i>	VU B2ab(ii, iii)	Lower Risk	-	yes
<i>Lecythis lurida</i>	LC	Lower Risk	-	no
<i>Lecythis maragraaviana</i>	LC	-	-	yes
<i>Lecythis pisonis</i>	LC	-	-	no
<i>Lecythis schwackei</i>	EN D	VU D2	EN A2c	yes

^aAbbreviations in table: LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered; hyphen(-) = not included on list.

^bAssessments are based on current IUCN Red List criteria (ver. 3.1).

^cIUCN Red List (ver. 2.3 for Lecythidaceae). List accessed in Sept. 2014.

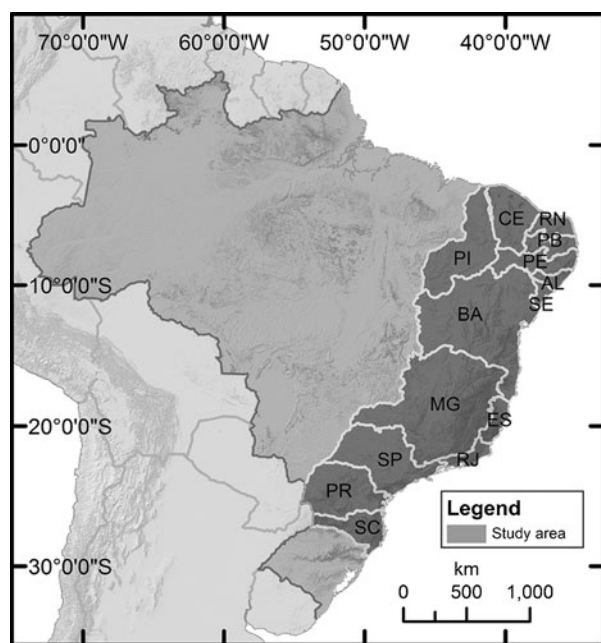
provides sterile pollen and/or nectar as rewards to pollinators (e.g., bees). Many of the species have large dehiscent fruits and seeds with arils that are an important food source for bats and monkeys. Others have dehiscent fruits that produce winged, wind-dispersed seeds (*Cariniana* and *Couratari*), and the fruits of *Gustavia augusta* are indehiscent and have seeds embedded in a pulp that is eaten by mammals (e.g., monkeys).

In eastern Brazil, at least six species of Lecythidaceae are cultivated as ornamentals. *Couroupita guianensis* Aubl., also known as the cannonball tree, castanha de macaco (Portuguese), or bolo de cañon (Spanish), is the most common ornamental Lecythidaceae. This species is native to Amazonia but is cultivated in botanical gardens worldwide because of its large, unusual flowers and cannonball-like fruits that hang from its trunk. *Couroupita guianensis* is often found in city parks and as a street tree. *Bertholletia excelsa* Bonpl. (the Brazil nut), also native to Amazonia, is occasionally cultivated as an ornamental or as a source of edible seeds. At least four species native to eastern Brazil, *Cariniana estrellensis*, *C. legalis*, *Lecythis lanceolata* Poir. and *L. pisonis* Cambess., are also cultivated as ornamentals in some states (e.g., Espírito Santo, Rio de Janeiro and São Paulo) and *C. legalis* is considered a symbolic tree in the states of Espírito Santo (Espírito Santo 2000) and São Paulo.

For centuries Brazil has had a largely commodity dependent economy related to the export of agricul-

tural products (Skidmore 1999) and the Atlantic Forest in many areas throughout Brazil's coastal states has been depleted as the country has reshaped its landscape to exploit native timber and raise livestock and crops, such as cattle, sugarcane, coffee, *Eucalyptus*, and *Pinus*. Today, only 11% to 16% of the Atlantic Forest remains; some of this is secondary forest and less than 10% of this forest is found in reserves (Ribeiro *et al.* 2009). As with many other groups of organisms, the growth of agriculture and urban development in eastern Brazil has had a detrimental effect on the native populations of most species of Lecythidaceae, many of which were harvested for their valuable timber (e.g., species of *Cariniana*).

There are recent publications that discuss Lecythidaceae from eastern Brazil. Mori (1995) published a review of the eastern Brazilian taxa, which included several new species, Ribeiro *et al.* (2014) published an article about the species of Lecythidaceae from Espírito Santo State, and the *Livro Vermelho da Flora do Brasil* (Lima da Venda *et al.* 2013) evaluated nine of the 22 species from eastern Brazil. However, Mori (1995) does not include conservation assessments of the species, Ribeiro *et al.* (2014) only focuses on one state, and the *Livro Vermelho da Flora do Brasil* only discusses the status of the Lecythidaceae species on the IUCN Red List (2014). The present study suggests that additional Lecythidaceae species from eastern Brazil should be included on this list and that the status of others should be changed. There-



Map 1. Study area (eastern Brazil).

fore, the goals of this article are to provide (1) a review of the conservation status of each species of Lecythidaceae native to eastern Brazil (including extent of occurrence, area of occupancy, distribution comments, maps, and an IUCN assessment based on current IUCN criteria) and (2) an identification key to the 22 native and two non-native species found in this region. For additional information about each species, including detailed descriptions, taxonomic discussions, images of diagnostic characters and representative specimens, consult Mori *et al.* (2010).

Materials and methods

The genera and species in this work are based on the monographs by Prance & Mori (1979) and Mori & Prance (1990), and subsequent morphological and molecular phylogenetic studies by Mori *et al.* (2007) and Huang *et al.* (2008, 2015). To assess the conservation status of each species, all Lecythidaceae specimens from NY (from the study area; Map 1) were reviewed, their determinations were confirmed, and (if possible) those that did not have coordinates in the NY database were georeferenced. The study area (Map 1) included the following states: Alagoas (AL), Bahia (BA), Ceará (CE), Espírito Santo (ES), Minas Gerais (MG), Paraíba (PB), Paraná (PR), Pernambuco (PE), Piauí (PI), Rio de Janeiro (RJ), Rio Grande do Norte (RN), Santa Catarina (SC), São Paulo (SP), and Sergipe (SE).

To better understand the distribution of many of the species, fieldwork was conducted in the states of Bahia, Espírito Santo, Minas Gerais, Paraíba, Rio de Janeiro, São Paulo, and Santa Catarina between 2008 and 2014. The following Brazilian herbaria were also

visited during this time: BHCB, CEPEC, CVRD, FLOR, GUA, HUEFS, MBML, R, RB, SP, SPF, UFP, and VIES (Thiers, continuously updated). Collections from the Brazilian herbaria that were not in the NY database and extended the distribution of a species, or represented a rare taxon, were added to the database. All collections used in this study can be consulted on the Lecythidaceae Pages (Mori *et al.* 2010).

The final database of specimens was used to generate the maps and conservation assessments, which were mostly based on the extent of occurrence (EOO) and area of occupancy (AOO) of each species. To the best of our knowledge, all collections of cultivated individuals were removed before generating the maps and estimates. It is possible that collections that fall outside of the estimated distributions were overlooked; however, based on years of field and herbarium work the authors believe that this margin of error is small and would not influence the assessments in this work. For species that occur outside of eastern Brazil, EOO and AOO estimates were generated for the entire distribution and for the distribution within the study area. This was done because some species with disjunct distributions (e.g., *Lecythis pisonis* and *Couratari macrosperma* A. C. Sm.) might represent more than one taxon. In the future, if one of these species is split, the estimates for only eastern Brazil could be used to reassess the species.

The assessments were based on IUCN criteria ver. 3.1 (IUCN 2014). Population size is poorly understood for most species of Lecythidaceae; however, population size of mature individuals was estimated to help determine the status of *Cariniana ianeirensis* R. Knuth and *Lecythis schwackei* (R. Knuth) S. A. Mori. This was done because mature individuals of *C. ianeirensis* and *L. schwackei* are fairly rare even though these species have AOO and EOO values that suggest they are not endangered.

Lecythidaceae are often misidentified on herbarium sheets, which has led to numerous erroneous determinations within large databases of collections shared by multiple institutions. For this reason, the estimates in this work were based on collections that were identified or confirmed by an expert in the family. The only exception was for collections of *Gustavia augusta* where data for some collections from eastern Brazil were taken from Species Link (2014). We did this because *G. augusta* is very difficult to confuse with other Lecythidaceae and our collection data for this species in the Northeast Region of Brazil was sparse even though it is well known that *G. augusta* occurs in this area.

Locality data for specimens was entered into a project geodatabase that was imported into ArcGIS 10 (ESRI 2010). All specimens with geographic coordinates were projected to a Cylindrical Equal Area projection with the World Geodetic System 1984 datum. Extent of occurrence was estimated for all species by creating a convex hull polygon (using the

Minimum Bounding Geometry tool in the ArcGIS data management tools), which was the smallest convex polygon enclosing all specimen localities and had no angles that exceeded 180 degrees (IUCN 2014). If the polygon included an area of ocean, the area was clipped from the EOO estimation using the clip function in ArcGIS 10 (ESRI 2010; IUCN 2014). Area of occupancy was estimated using the Cartographic method by Conglomerates (CMC) (Hernández & Navarro 2007). This method allowed us to sum each area of conglomerates individually, as well as include isolated single localities that, for this study, were assigned a constant area of 10 km².

All maps were created using ArcGIS 10 (ESRI 2010). Maps for each of the species (Maps 2 – 23) display the localities of each collection, EEO, and protected areas as provided by the World Database on Protected Areas (IUCN and UNEP-WCMC 2013). Protected areas that occurred exclusively in the ocean were removed. Those that occurred only on land, or both on land and water, were kept so the percentage of collections that occur in reserves could be calculated for each endangered species (see discussion). For the endangered species, a shapefile featuring a 20 km buffer was created around each locality and joined with the protected areas layer to examine the species that do not occur within or near reserves. To create the species diversity map (Map 24), projected specimens were joined with an overlay of one-degree grid cells. The

number of species per area was calculated for each of these cells in order to identify centres of species richness.

Species assessments

***Cariniana estrellensis* (Raddi) Kuntze (1898: 89).**

EOO: 3,953,000 km². AOO: 210,370 km².

IUCN ASSESSMENT: Least Concern.

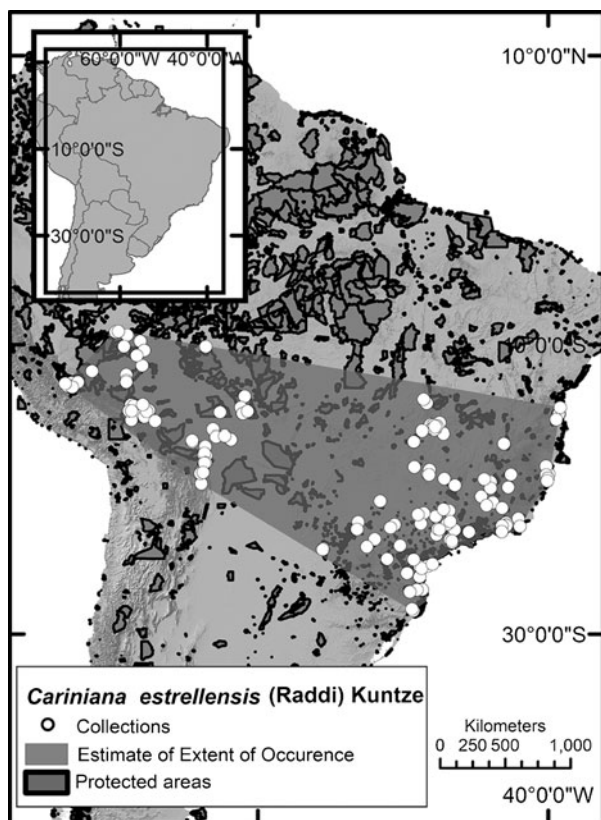
Known from Santa Catarina to Bahia (eastern Brazil), central and western Brazil, Bolivia, and eastern Peru (Map 2). In eastern Brazil this species is threatened in many regions due to habitat loss and because many individuals were harvested for their valuable timber. Although extremely large individuals are fairly rare, *Cariniana estrellensis* can be locally abundant. See Leite (2007) for more information about the conservation of this species.

***Cariniana ianeirensis* R. Knuth (1934: 340).**

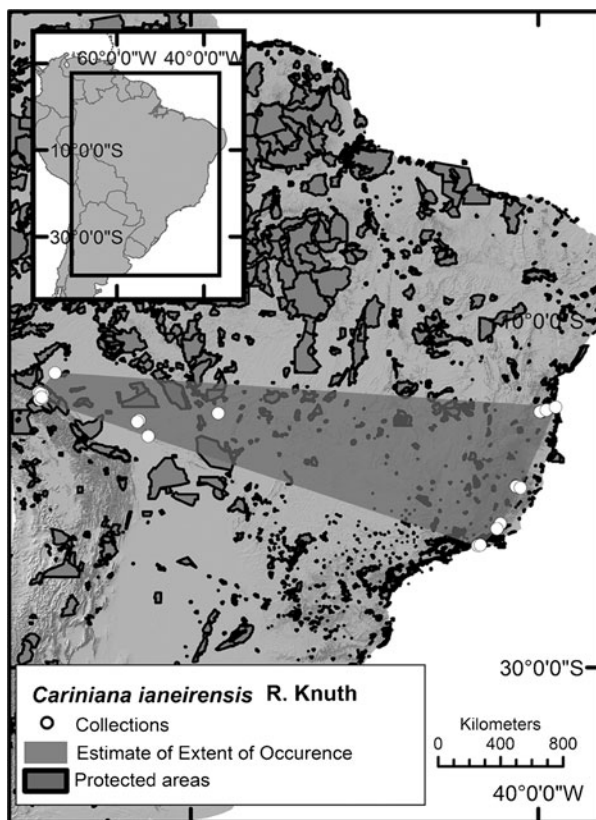
EOO: 170,700 km² (all populations); 70,949 km² (eastern Brazil). AOO: 12,538 km² (all populations); 1,465 km² (eastern Brazil).

IUCN ASSESSMENT: Endangered — EN C1.

This species is found from Rio de Janeiro to Bahia (eastern Brazil), in Mato Grosso (central Brazil), and in Bolivia (Map 3). *Cariniana ianeirensis* is presently



Map 2. Distribution of *Cariniana estrellensis*.



Map 3. Distribution of *Cariniana ianeirensis*.

listed as endangered (B1+2c ver. 2.3) on the IUCN Red List (IUCN 2014; Varty 1998). Recent fieldwork (pers. comm., M. Lemes and R. Gribel, 2013, and fieldwork for this study) has shown that *C. ianeirensis* has a wider distribution than previously thought. Although the AOO and EOO estimates exceed those required for an endangered status, the population size of mature individuals of *C. ianeirensis* is thought to be less than 2,500 individuals and over 90% of the collections analysed are from outside of protected areas where they are at risk. Therefore, we recommend maintaining *C. ianeirensis* as endangered until additional studies about its distribution are made.

***Cariniana legalis* (Mart.) Kuntze (1898: 89).**

EOO: 939,500 km². AOO: 38,989 km².

IUCN ASSESSMENT: Least Concern.

Cariniana legalis is endemic to eastern Brazil, from Paraná to Paraíba (Map 4). Other evaluations have assessed this species as vulnerable (IUCN 2014) and endangered (Lima da Venda *et al.* 2013); however, recent fieldwork and our distribution estimates suggest that this species is fairly common. As with other species of *Cariniana*, the wood of *C. legalis* is very valuable and populations of this species have been diminished by

timber extraction. However *C. legalis* is locally abundant in some reserves (e.g., in northern Espírito Santo) and it is not unusual to find very large, conserved individuals that produce viable seeds on the sides of roads, in forest fragments on farms, and in towns.

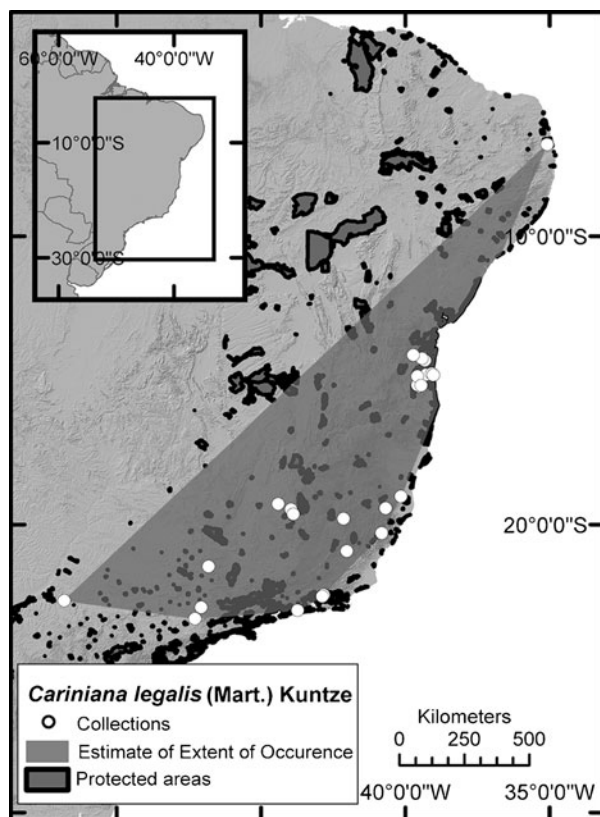
Very little is known about the distribution of *Cariniana legalis* between Bahia and Paraíba. A small population grows in the Reserva Biológica Guaribas, Rio Tinto (Paraíba), which suggests that at one point the distribution of this species might have been more widespread than it is today; however, it is not known if this population originated from planted trees.

***Cariniana parvifolia* S. A. Mori, Prance & Menandro** (Mori *et al.* 1995: 8).

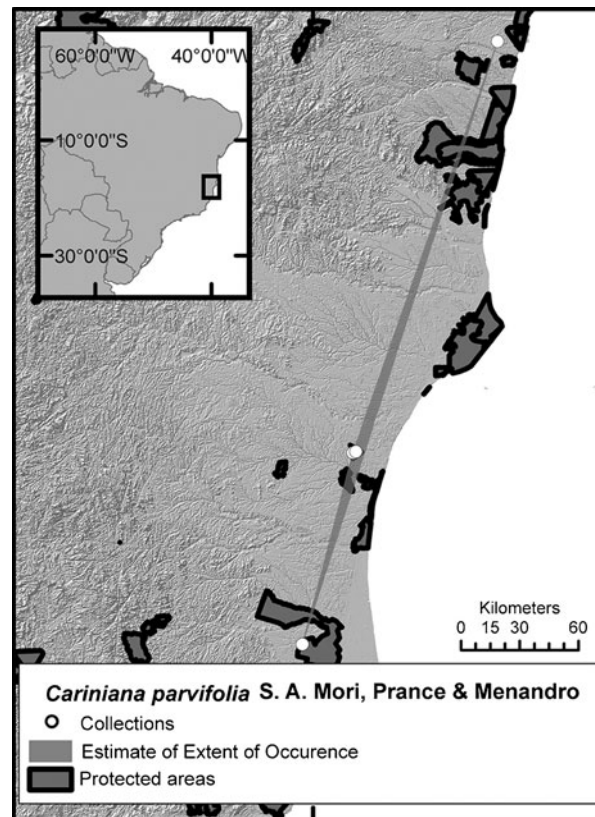
EOO: 850 km². AOO: 104 km².

IUCN ASSESSMENT: Endangered — EN B1a+2b(iii).

Cariniana parvifolia is endemic to northern Espírito Santo and southern Bahia in eastern Brazil (Map 5). This species is known from only three localities and very few collections. Although our estimates differ, our overall assessment of this species is in agreement with Lima da Venda *et al.* (2013). Future fieldwork will probably reveal that there are additional populations



Map 4. Distribution of *Cariniana legalis*.



Map 5. Distribution of *Cariniana parvifolia*.

of *C. parvifolia*; however, this species should be included as endangered on the IUCN Red List.

***Couratari asterophora* Rizzini (1976: 177).**

EOO: 4,713 km². AOO: 686 km².

IUCN ASSESSMENT: Endangered — EN B1(i, iii).

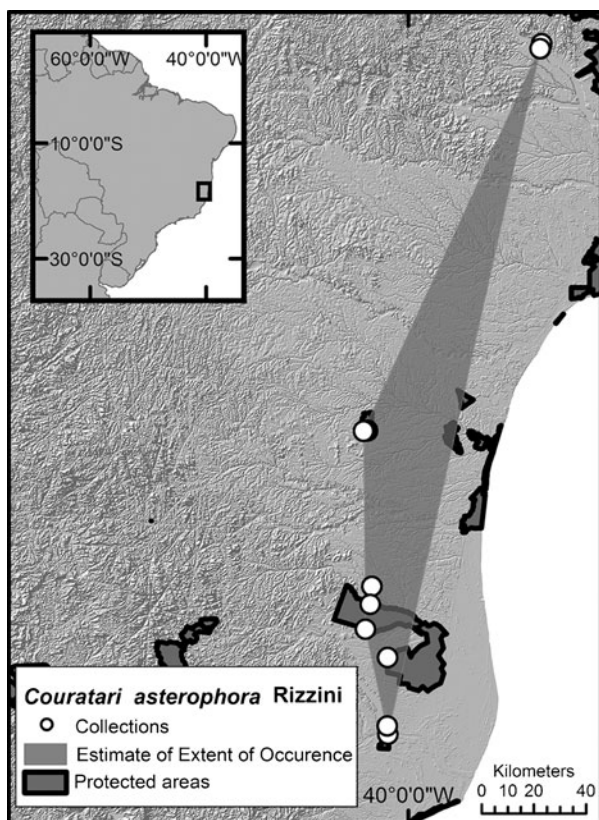
Couratari asterophora is endemic to Bahia and Espírito Santo (Map 6). Until recently, this species was known only from a few collections and was thought to be extremely rare. Recent fieldwork in northern Espírito Santo has revealed that *C. asterophora* occurs in some reserves and also grows in disturbed areas near these reserves (Ribeiro *et al.* 2014). Our assessment suggests that this species should be moved from critically endangered (IUCN 2014; Pires O'Brien 1998a) to endangered.

***Couratari asterotricha* Prance (1981: 17).**

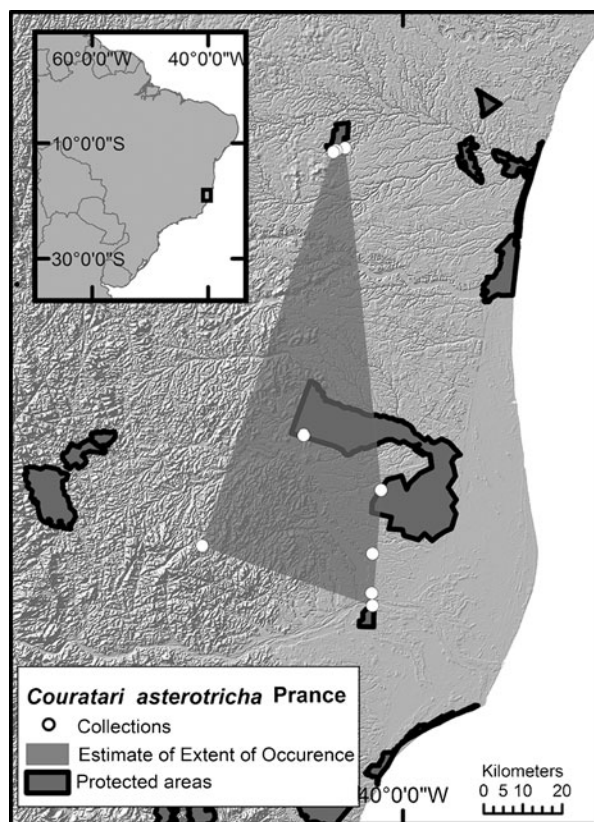
EOO: 2,705 km². AOO: 109 km².

IUCN ASSESSMENT: Endangered — EN B1(i, iii)+2(iii).

Couratari asterotricha is endemic to Espírito Santo (Map 7). Ribeiro *et al.* (2014) noted that this species is restricted to the northern part of the state and is only known from a small number of collections, mostly from three reserves, even though there has been a



Map 6. Distribution of *Couratari asterophora*.



Map 7. Distribution of *Couratari asterotricha*.

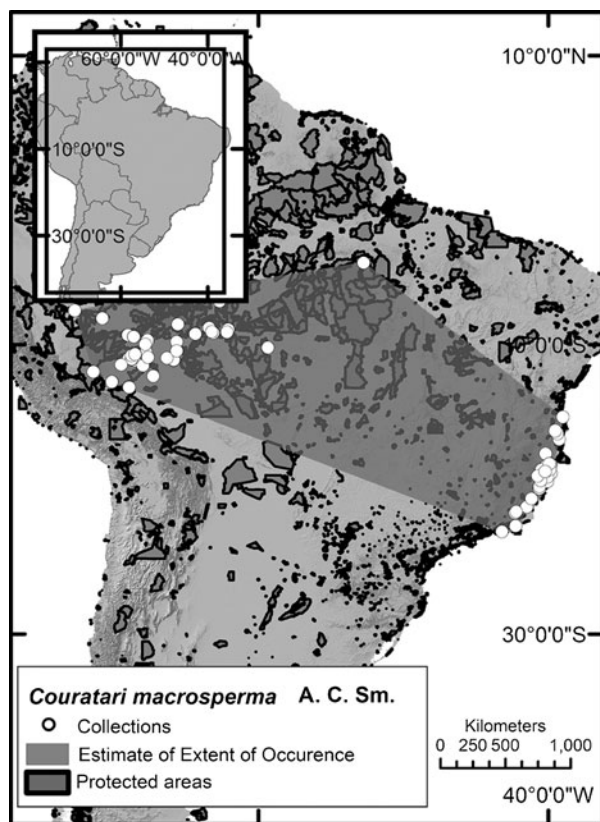
considerable amount of recent fieldwork in this region to collect Lecythidaceae. The EOO and AOO assessments suggest that this species should be moved from critically endangered (IUCN 2014; Pires O'Brien 1998b) to endangered, which agrees with a recent assessment made by Lima da Venda *et al.* (2013). However, the distribution and population size of *C. asterotricha* remain unclear and, therefore, we suggest leaving it as critically endangered until further studies can be made.

***Couratari macrosperma* A. C. Sm. (Smith 1933: 383).**

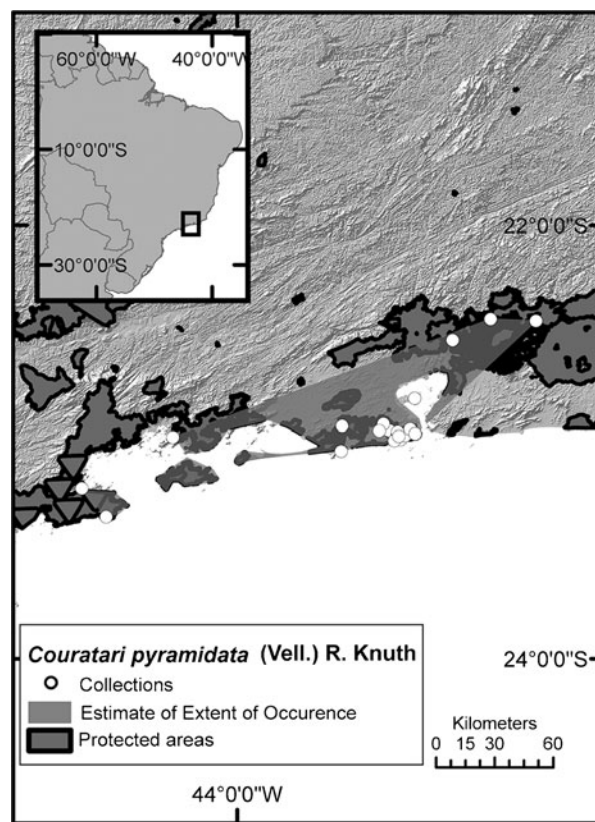
EOO: 4,058,000 km² (all populations); 77,482 km² (eastern Brazil). AOO: 355,463 km² (all populations); 6,619 km² (eastern Brazil).

IUCN ASSESSMENT: Least Concern.

Couratari macrosperma is known from Bahia, Espírito Santo, and Rio de Janeiro (eastern Brazil), Pará (one collection, which might be misidentified), western Amazonian Brazil, northern Bolivia, and Peru (Map 8). In eastern Brazil, this species is fairly common in several reserves, in pastures and forest fragments on farms, and on roadsides. Individuals of *C. macrosperma* from Amazonia sometimes have much larger fruits compared to those in eastern Brazil. For now, we



Map 8. Distribution of *Couratari macrosperma*.



Map 9. Distribution of *Couratari pyramidata*.

consider the populations in Amazonia and eastern Brazil to be the same species; however, further studies might reveal that these populations represent distinct taxa.

***Couratari pyramidata* (Vell.) R. Knuth (1939: 129).**

EOO: 4,244 km². AOO: 279 km².

IUCN ASSESSMENT: Endangered — EN B1(i, iii)+2(iii).

Couratari pyramidata is endemic to the state of Rio de Janeiro (Map 9). Our assessment is in agreement with both the IUCN Red List (IUCN 2014; Pires O'Brien, 1998c) and Lima da Venda *et al.* (2013). Until recently, this species was one of the most poorly understood Lecythidaceae from eastern Brazil, and was mostly represented by a small number of collections made within or near the city of Rio de Janeiro. Recent fieldwork has shown that *C. pyramidata* also occurs in additional reserves and submontane regions in the state, but large individuals are rare, even within protected areas.

***Eschweilera alvimii* S. A. Mori (1981: 469).**

EOO: 2 km². AOO: 8 km².

IUCN ASSESSMENT: Critically Endangered — CR B2ab(iii).

Eschweilera alvimii is endemic to eastern Brazil and known only from the vicinity of Santa Cruz de

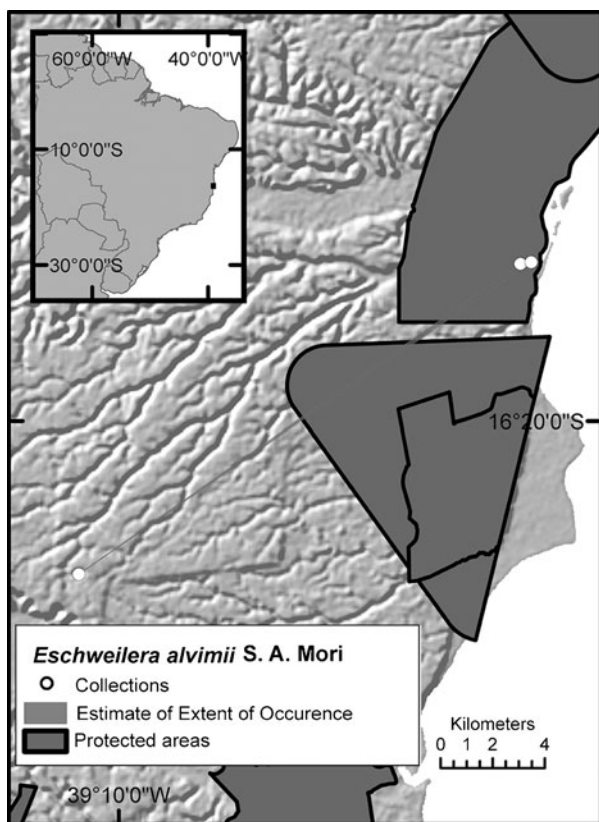
Cabrália, Bahia (Map 10). The collection points for *E. alvimii* form a linear area of occurrence, which results in a very narrow bounding polygon and a smaller EOO estimate compared to the AOO. Therefore, only the AOO was used for the assessment of this species. Another assessment of *E. alvimii* by Lima da Venda *et al.* (2013) suggests that this species is endangered; however, during our study it was discovered that *E. alvimii*, as circumscribed by Mori (in Mori & Prance 1990), probably contains more than one species. Our assessment is only of *E. alvimii* s.s., which has a much smaller distribution and critically endangered status. Additional fieldwork might reveal that *E. alvimii* s.s. has a wider distribution, but presently it is only represented by a few collections and should be considered critically endangered until more is known.

***Eschweilera complanata* S. A. Mori (1995: 16).**

EOO: 4,236 km². AOO: 355 km².

IUCN ASSESSMENT: Endangered — EN B1ab(iii)+2ab(iii).

Eschweilera complanata is endemic to eastern Brazil and known only from the state of Bahia where it has been collected in the vicinity of Porto Seguro to just north of Salvador (Map 11). *E. complanata* is not on the IUCN Red List (IUCN 2014) but the low EOO and AOO estimates, as well as the fragmented and continuing decline of its habitat, indicate that this species is endangered.



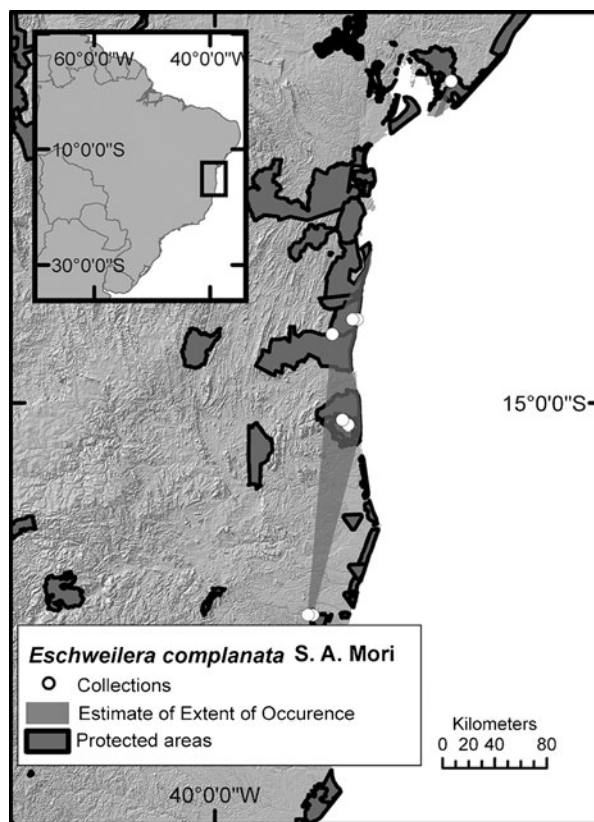
Map 10. Distribution of *Eschweilera alvimii*.

Eschweilera compressa (Vell.) Miers (1874: 248).
 EOO: 13,575 km². AOO: 136 km².
IUCN ASSESSMENT: Endangered — EN B2ab(iii).

Eschweilera compressa is known only from forests around the city of Rio de Janeiro (e.g., in the Tijuca National Forest) and just north of this region (e.g., near Cabo Frio), as well as two recent collections from Espírito Santo (Map 12). This species is presently listed as critically endangered (IUCN 2014) but our estimates, as well as a recent evaluation by Lima da Venda *et al.* (2013), suggest that it should be classified as endangered. The habitat where *E. compressa* grows, especially around Rio de Janeiro, has been severely altered in recent years due to urban development and additional studies are needed to determine how threatened this species is.

Eschweilera mattos-silvae S. A. Mori (1995: 22).
 EOO: 28,883 km². AOO: 2,218 km².
IUCN ASSESSMENT: Near Threatened.

Eschweilera mattos-silvae is endemic to eastern Brazil and known only from a few localities between Ilhéus and Salvador, Bahia (Map 13). The low AOO estimate indicates that this species might become threatened if its habitat continues to decline.



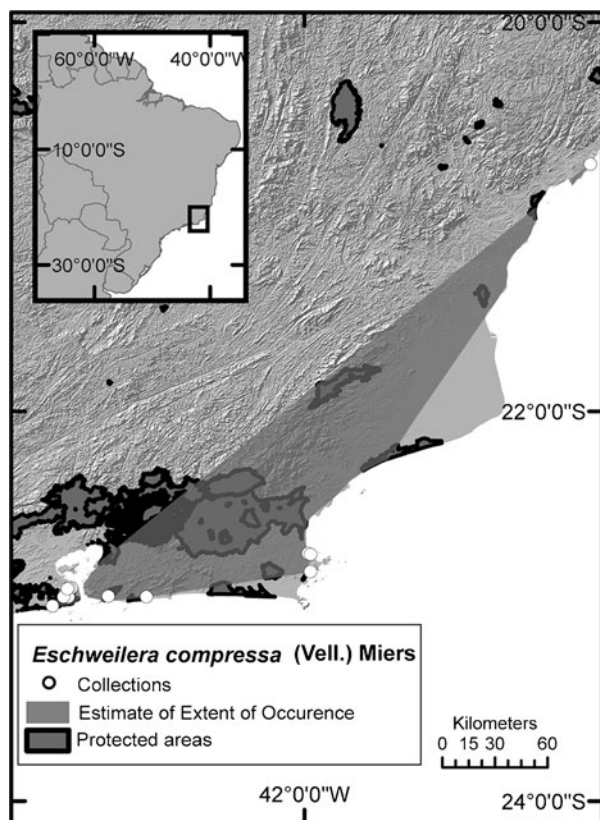
Map 11. Distribution of *Eschweilera complanata*.

Eschweilera nana (O. Berg) Miers (1874: 261).
 EOO: 1,522,000 km². AOO: 67,391 km².
IUCN ASSESSMENT: Least Concern.

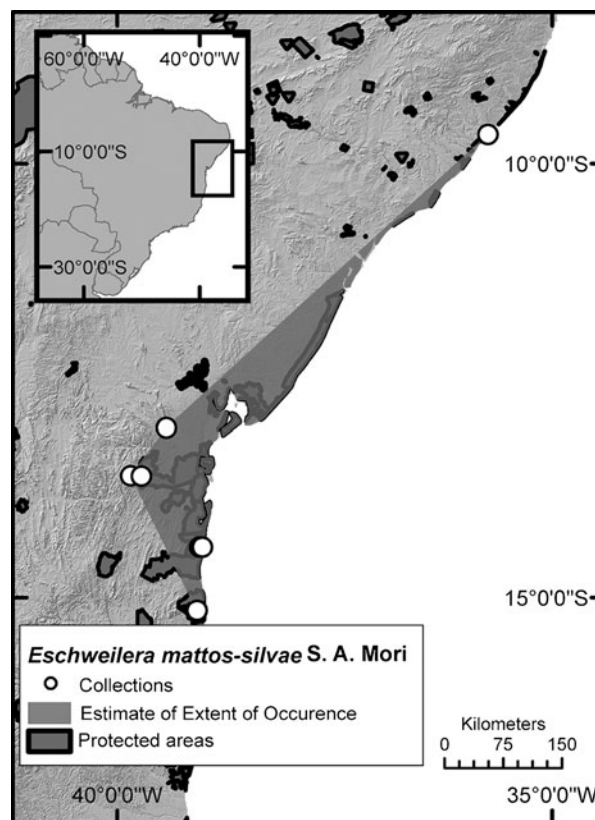
Eschweilera nana is endemic to Brazil (Map 14). In eastern Brazil this species is mostly concentrated in northwestern Bahia. This species is also fairly common in the Central-West Region of Brazil (e.g., in the states of Mato Grosso and Mato Grosso do Sul) and is mostly restricted to cerrado.

Eschweilera ovata (Cambess.) Mart. ex Miers (1874: 257).
 EOO: 2,803,000 km² (all populations); 262,800 km² (eastern Brazil). AOO: 238,591 km² (all populations); 61,165 km² (eastern Brazil).
IUCN ASSESSMENT: Least Concern.

Eschweilera ovata is endemic to Brazil (Map 15) and is a very common species in coastal Atlantic Forest from Espírito Santo to Paraíba (and probably further north). Several collections of *E. ovata* from eastern Amazonia have been recorded. Presently we are treating these as *E. ovata* but additional fieldwork might confirm that the Amazonian populations are different from those of eastern Brazil. This species is a common small tree in disturbed areas along roadsides



Map 12. Distribution of *Eschweilera compressa*.



Map 13. Distribution of *Eschweilera mattos-silvae*.

but fairly large individuals exist (mostly in protected areas) and were probably more common before most of eastern Brazil was deforested.

Eschweilera tetrapetala S. A. Mori (1981: 467).

EOO: 4,456 km². AOO: 91 km².

IUCN ASSESSMENT: Endangered — EN B1ab(iii)+2ab(iii).

Eschweilera tetrapetala is endemic to eastern Brazil and known mostly from forests in the vicinity of Lençóis, Bahia (Map 16). Although it is locally common around Lençóis, *E. tetrapetala* is a narrow endemic that could reach near extinction if there was severe habitat loss in the future (e.g., from fire). The EOO estimate for this species was higher than the estimate provided by Lima da Venda *et al.* (2013), which is probably because our review of specimens revealed there are a few populations outside the vicinity of Lençóis. As suggested by Lima da Venda *et al.* (2013), this species should be moved from its current status of vulnerable to endangered.

Gustavia augusta L. (Linnaeus 1775: 17).

EOO: 7,560,000 km² (all populations); 457,390 km² (eastern Brazil). AOO: 221,400 km² (all populations); 22,673 km² (eastern Brazil).

IUCN ASSESSMENT: Least Concern.

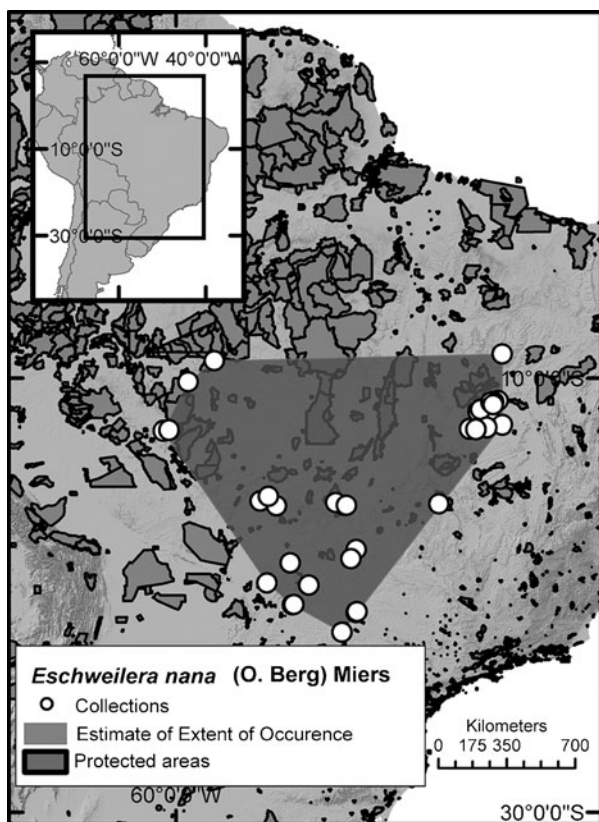
Gustavia augusta is a widespread species known from Alagoas, Ceará, Paraíba, Pernambuco, Sergipe (eastern Brazil), Amazonian Brazil, Bolivia, Colombia, French Guiana, Guyana, Peru, Suriname, and Venezuela (Map 17).

Lecythis ibiriba (Miers) N. P. Sm., S. A. Mori & Popovkin (Smith *et al.* 2012: 447).

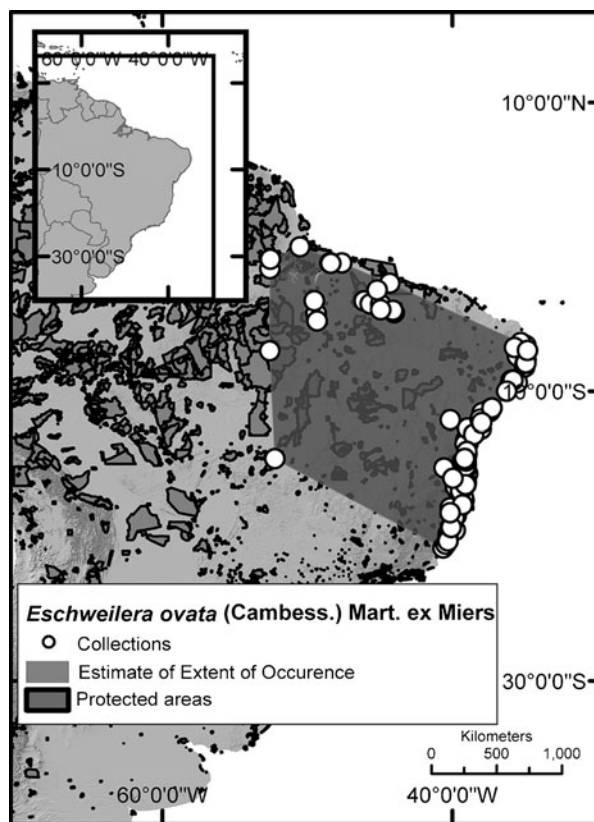
EOO: 8,579 km². AOO: 2,594 km².

IUCN ASSESSMENT: Vulnerable — VU B1ab(ii, iii).

Lecythis ibiriba is endemic to eastern Brazil and known only from the states of Alagoas, Bahia, and Sergipe (Map 18). It is locally common in certain regions of Bahia (e.g., Entre Rios) but very few collections are known from Sergipe and Alagoas. This is the first IUCN assessment for *L. ibiriba*, which until recently (Smith *et al.* 2012) was treated as a synonym of *Eschweilera ovata* (as *Chytroma ibiriba* Miers in Mori & Prance 1990). Although the AOO is greater than 2,000 km², the EOO for *L. ibiriba* is much lower than the 20,000 km² needed to classify this species as threatened. This and the fragmented and continuing decline of its habitat indicate that *L. ibiriba* is vulnerable.



Map 14. Distribution of *Eschweilera nana*.



Map 15. Distribution of *Eschweilera ovata*.

Lecythis lanceolata Poir. (Poiret 1804: 27).
 EOO: 322,400 km². AOO: 893 km².

IUCN ASSESSMENT: Vulnerable — VU B2ab(ii, iii).

Lecythis lanceolata is endemic to eastern Brazil and is a fairly widespread species that occurs from Rio de Janeiro to Pernambuco (Map 19). It is often found as a medium-sized tree in older secondary forest (e.g., Parque Nacional da Tijuca, Rio de Janeiro) and fragments on farms. Large individuals of *L. lanceolata* are fairly rare but have been recently documented in reserves in northern Espírito Santo (pers. obs. M. Ribeiro, 2014). This suggests that *L. lanceolata* was probably a more common canopy tree before most of the primary forest in eastern Brazil was logged. The species was previously assessed as Lower Risk/conservation dependent ver 2.3 (IUCN 2014). Although this species can be locally common, it is absent from many regions within its EOO, which can be seen in the extreme difference between its EOO and AOO. An AOO estimate below 2,000 km² in combination with the fragmented and continuing decline of its habitat indicate that *L. lanceolata* is vulnerable.

Lecythis lurida (Miers) S. A. Mori (1981: 362).

EOO: 2,735,000 km² (all populations); 227,700 km² (eastern Brazil). AOO: 185,037 km² (all populations); 100,176 km² (eastern Brazil).

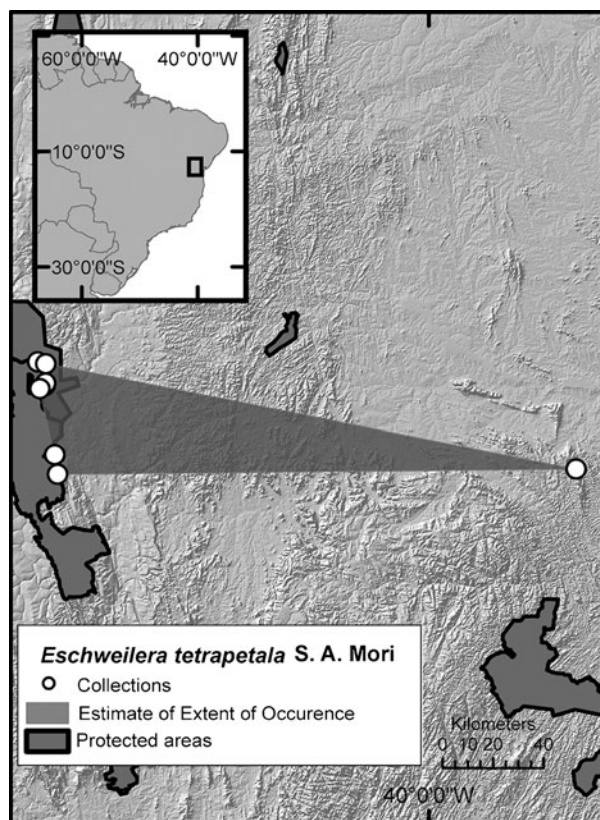
IUCN ASSESSMENT: Least Concern.

Lecythis lurida is endemic to Brazil and is found from Rio de Janeiro to Alagoas (eastern Brazil) and in eastern Amazonia (Map 20). In eastern Brazil, *L. lurida* probably occurs further north (e.g., to Pernambuco) but additional field and herbarium work is needed to confirm this. *L. lurida* is very common from northern Espírito Santo to southern Bahia where it often grows as a small tree in disturbed areas along roadsides and in pastures, and sometimes as a large tree in reserves. This species is listed as Lower Risk/conservation dependent ver 2.3 (IUCN 2014). Although we recommend that this species be classified as Least Concern, much of the habitat where *L. lurida* occurs is fragmented and continuing to decline.

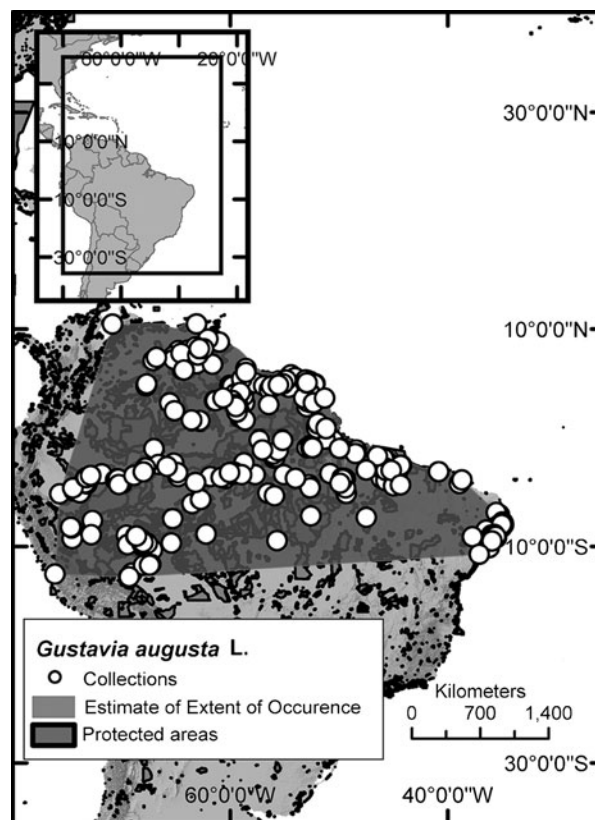
Lecythis marcgraaviana Miers (1874: 210).
 EOO: 88,609 km². AOO: 3,832 km².

IUCN ASSESSMENT: Least Concern.

Lecythis marcgraaviana is endemic to eastern Brazil and occurs from Espírito Santo to Rio Grande do Norte



Map 16. Distribution of *Eschweilera tetrapetala*.



Map 17. Distribution of *Gustavia augusta*.

(Map 21). The northern and southern distribution limits of *L. marcgraaviana* are poorly understood. This species is very common as a small to medium-sized tree in the northern part of its range (e.g., coastal Paraíba) and is less frequent, and often much taller, in the southern part (Bahia and Espírito Santo). This is the first IUCN assessment for *L. marcgraaviana*, which until recently (Smith *et al.* 2016) was placed as a synonym of *L. pisonis* by Mori & Prance (1990). *L. marcgraaviana* appears to do very well in disturbed areas (pers. observ. N. P. Smith, in Paraíba) and, therefore, the chance of it declining to a threatened status in the near future is improbable.

***Lecythis pisonis* Cambess.** (Cambessedes 1829: 377).
 EOO: 7,104,000 km² (all populations); 1,378,000 km² (eastern Brazil). AOO: 177,339 km² (all populations); 42,856 km² (eastern Brazil).
IUCN ASSESSMENT: Least Concern.

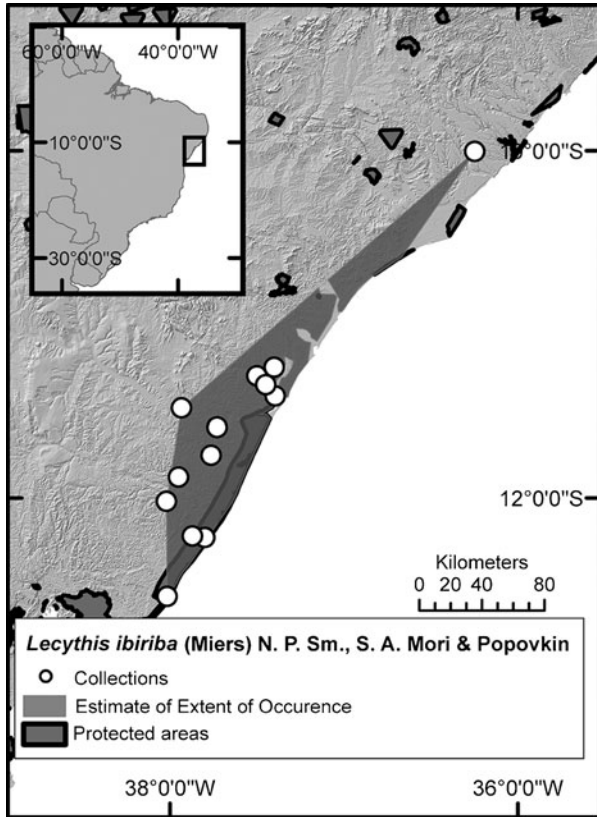
Lecythis pisonis is native to eastern Brazil and Amazonian Brazil (especially in eastern Amazonia along the Amazon River), Colombia, and Peru (Map 22). In eastern Brazil, *L. pisonis* is common in primary forest fragments and on farmland in Espírito Santo and Bahia. As with other species of Lecythidaceae, the

northern and southern distribution limits of *L. pisonis* in eastern Brazil are not well understood. *L. pisonis* is commonly cultivated as an ornamental, and for its edible seeds, and for this reason we are unsure if some of the most southern (in São Paulo and Rio de Janeiro) and northern (in Piauí and Paraíba) collections included in our estimates are from native individuals.

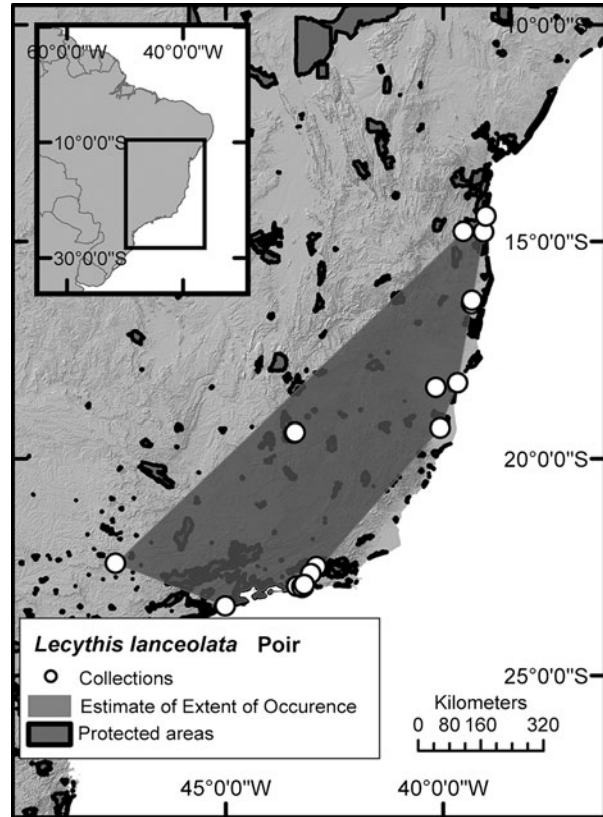
It is suspected that what is referred to as *Lecythis pisonis* in Amazonia represents one or two species that are different from the *L. pisonis* population in eastern Brazil. In the future, if *L. pisonis* is split into more than one species, the population from eastern Brazil will remain as *L. pisonis* because the type is from Espírito Santo.

***Lecythis schwackei* (R. Knuth) S. A. Mori** (1981: 359).
 EOO: 1,896 km². AOO: 9,311 km².
IUCN ASSESSMENT: Endangered — EN D.

Lecythis schwackei is endemic to eastern Brazil and is known only from the states of Rio de Janeiro and Minas Gerais (Map 23). This species was previously classified as Vulnerable D2 ver 2.3 (IUCN 2014). For this species, we did not use the EOO in our assessment because the collection points form a narrow area of



Map 18. Distribution of *Lecythis ibiriba*.



Map 19. Distribution of *Lecythis lanceolata*.

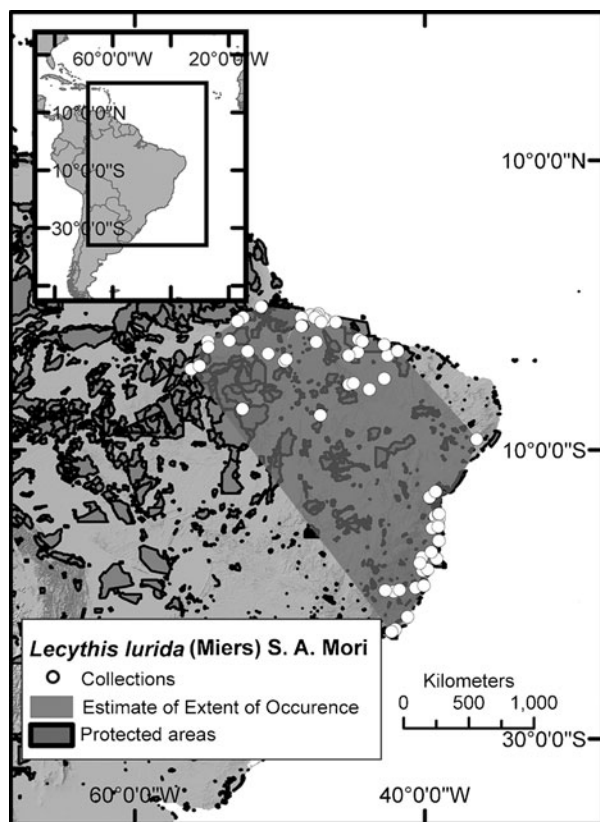
occurrence, which results in a very narrow bounding polygon and a smaller EOO estimate compared to the AOO. Although the AOO is an accurate estimate and suggests *L. schwackei* is vulnerable, this species is only known from small number of mature individuals

(fewer than 250) that do not occur in a protected area. Based on this, we recommend giving *L. schwackei* an endangered status until additional studies are made to better understand its distribution and population size.

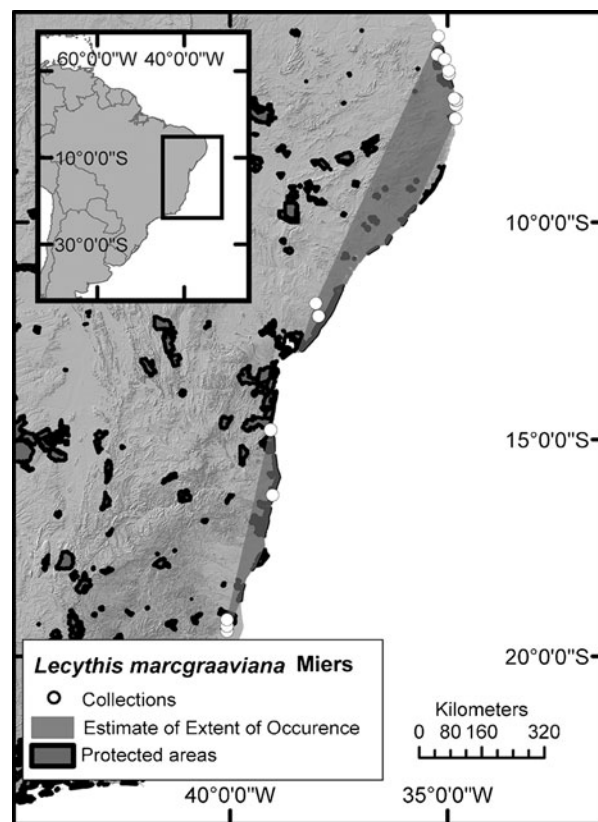
Key to native and non-native Lecythidaceae species in eastern Brazil

Clade names are based on Huang *et al.* (2015) and plates illustrating the clades are available in Mori *et al.* (2015) and Huang *et al.* (2015). Terms used in this key are defined and illustrated in the glossary on the Lecythidaceae Pages (Mori *et al.* 2010).

1. Leaf blades usually >30 cm long. Flowers >6 cm diam.; petals usually 8; androecium actinomorphic, stamens arising from rim of a broad staminal tube; anther dehiscence poricidal. Fruits indehiscent. Seeds with yellow, contorted aril; cotyledons fleshy, irregular **Gustavia augusta**
1. Leaf blades usually <30 cm long. Flowers 1 to 6 cm diam. (rarely >6 cm); petals 4 – 6; androecium zygomorphic, stamens arising from inside a short, membranous staminal tube or without a tube and arranged in a staminal ring, anther dehiscence lateral. Fruits dehiscent or infrequently indehiscent. Seeds without yellow contorted aril; cotyledons leaf-like or absent.
 2. Flowers < 3.5 cm diam.; androecium zygomorphic, with short staminal tube prolonged on one side (sometimes only slightly), stamens arising from inside and rim of tube, staminal ring and hood absent. Fruits elongate and cylindrical, dehiscent. Seeds unilaterally winged. (*Cariniana*)
 3. Leaf blade bases revolute on each side of midrib. Flowers 0.40 – 0.70 cm diam. Fruits 3 – 9.5 cm long, pericarp not lenticellate, opercular opening c. 1 cm diam.
 4. Trees, to 60 m tall. Inner bark red. Leaf blades 4 – 8.5 × 2 – 3 cm. Occurs from Paraná to Paraíba **Cariniana legalis**
 4. Trees, to 25 m tall. Inner bark flesh-coloured. Leaf blades 2.7 – 4.5 × 1 – 1.7 cm long. Known only from northern Espírito Santo and southern Bahia. **Cariniana parvifolia**

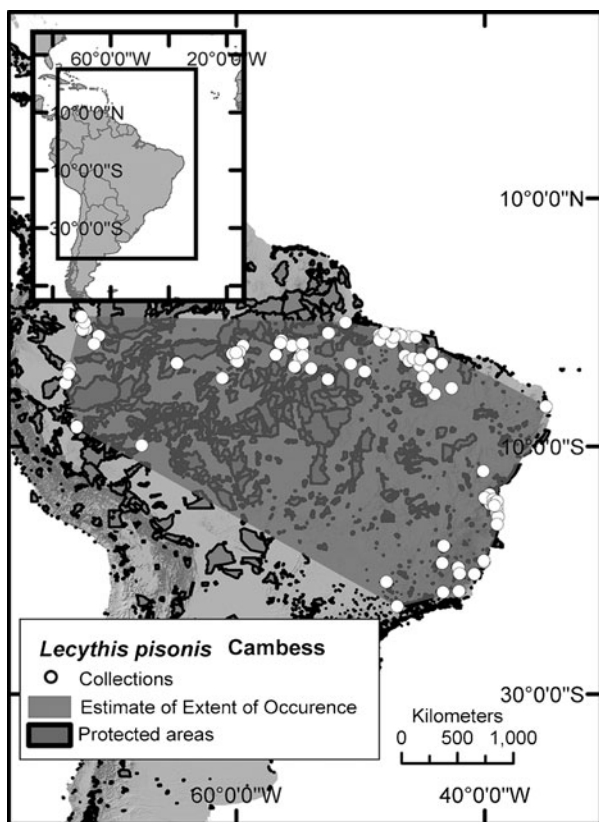


Map 20. Distribution of *Lecythis lurida*.

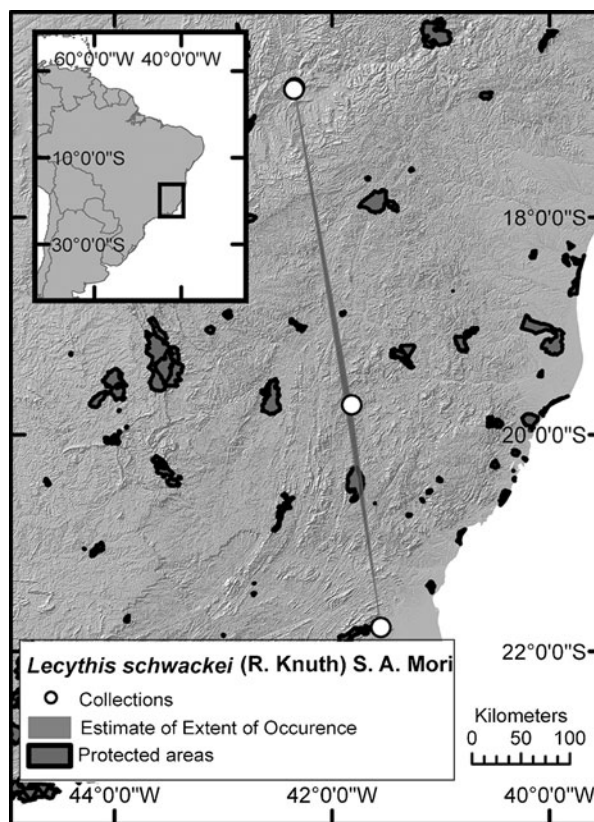


Map 21. Distribution of *Lecythis marcgraaviana*.

3. Leaf blade bases rarely revolute on each side of midrib. Flowers > 1 cm diam. Fruits 6.5 – 14 cm long, lenticellate, opercular opening >2 cm diam.
5. Leaf blade bases rounded, the margins with >30 teeth per side. Inflorescences arising from twigs. Flowers c. 1 cm diam., calyx lobes not basally imbricate at anthesis. Fruits with opercular rim muricate, the pericarp sparsely lenticellate **Cariniana estrellensis**
5. Leaf blade bases obtuse, the margins with <30 teeth per side. Inflorescences terminal or axillary. Flowers 1.5 – 3.4 cm diam., calyx lobes basally imbricate at anthesis. Fruits with opercular rim smooth, the pericarp densely lenticellate **Cariniana ianeirensis**
2. Flowers >3.5 cm diam.; androecium zygomorphic, without staminal tube, stamens arising from staminal ring, androecial hood present, staminodes and/or vestigial stamens present in hood. Fruits elongate, cylindrical, and dehiscent only in *Couratari*. Seeds circumferentially winged (*Couratari*) or not winged.
 6. Leaves, inflorescence rachises, and hypanthium never with stellate hairs. Flowers with >125 stamens in staminal ring; androecial hood without external flap. Fruits dehiscent, indehiscent, or secondarily indehiscent. Seeds usually thick, never winged, aril present or absent, cotyledons usually absent (leaf-like only in *Couroupita guianensis*).
 7. Flower and fruit tissue oxidising bluish-green when damaged. Androecial hood not coiled; style short, erect.
 8. Inflorescences arising from trunk. Flowers with androecial hood staminodes yellow at apex and white at base, stylar ring absent below stigma, stigma usually with 6 stigmatic lines. Fruits globose, indehiscent. Seeds embedded in pulp, testa (= seed coat) covered in trichomes; aril absent. **Couroupita guianensis** (cultivated only)
 8. Inflorescences terminal or axillary, arising from stems. Stylar ring present below stigma, without 6 stigmatic lines. Fruits not perfectly globose, dehiscent. Seeds not embedded in pulp, the testa glabrous; aril present, basal. (*Lecythis pisonis* clade)
 9. Trees, to 50 m tall. Hypanthium and calyx lobes purple, the lobes slightly convex but not thick and carinate. Petals purple and/or white (in this species purple and white-petalled flowers often occur on the same inflorescence; petal colour should be confirmed from flowers at anthesis) **Lecythis pisonis**



Map 22. Distribution of *Lecythis pisonis*.



Map 23. Distribution of *Lecythis schwackei*.

9. Shrubs (1.5 m tall) to large trees (to 30 m tall). Hypanthium and calyx lobes green, the lobes often carinate. Petals white, yellowish, dark red or pinkish white (petal colour should be confirmed from flowers at anthesis).
10. Leaf blades to 3.5 cm wide. Petals dark red to pinkish white (in flowers still on tree). Hypanthium usually pubescent ***Lecythis lanceolata***
10. Leaf blades >3.5 cm wide. Petals usually white, sometimes yellowish. Hypanthium usually glabrous. ***Lecythis marcgraaviana***
7. Flower and fruit tissue not oxidising bluish-green when damaged. Androecial hood not coiled or with 1 or 2 coils; style short or long, erect or oblique.
11. Androecial hood not coiled, anterior and posterior hood extensions present, locules usually 4 (– 6), style long, oblique. Fruits usually indehiscent or secondarily indehiscent. Seed venation slightly impressed, plane, or inconspicuous. Seeds lacking an aril or aril vestigial. (*Bertholletia* clade).
12. Leaf blades papillate abaxially. Flowers with 2 (3) calyx lobes, petals white. Fruits secondarily dehiscent; operculum smaller in diam. than diam. of seeds. Seeds 10–15 per fruit, seed coat thick and bony. ***Bertholletia excelsa*** (cultivated only)
12. Leaf blades papillate or non-papillate abaxially. Flowers with 6 calyx lobes, petals pink, pinkish white, or yellow. Fruits usually indehiscent; operculum greater in diam. than diam. of seeds (if fruit dehisces). Seeds 2–7 per fruit, seed coat thin. (Poiteau clade)
13. Abaxial surface of leaf blade non-papillate, brown punctations usually visible with 10× hand lens. Fruits usually indehiscent, sometimes dehiscent on tree. Aril vestigial or absent ***Lecythis ibiriba***
13. Abaxial surface of leaf blade papillate, brown punctations not visible with hand lens. Fruits indehiscent or secondarily indehiscent.
14. Shrub to small tree. Petals whitish pink to yellowish. Veins conspicuously impressed on adaxial surface of leaf blade (easier to see in dry material). Rare, known only from Rio de Janeiro and eastern Minas Gerais. ***Lecythis schwackei***

14. Small to large tree. Petals usually pink. Veins not conspicuously impressed on adaxial surface of leaf blade. Common in eastern Brazil and eastern Amazonia. **Lecythis lurida**
11. Androecial hood with 1 – 2 coils, anterior and posterior hood extensions absent; locules usually 2, style short, erect. Fruits dehiscent. Seeds with basal or lateral aril. (*Eschweilera*)
15. Inflorescence without horizontally oriented scales (squamae). Androecial hood with 2 coils, inner coil with vestigial stamen nectaries. Seeds with lateral aril. **Eschweilera ovata**
15. Inflorescence often covered with horizontally oriented scales (squamae). Androecial hood with 1 coil, vestigial stamen nectaries absent. Seeds with basal aril. (Tetrapetala clade)
16. Calyx-lobes not imbricate (calycine rim present).
17. Twigs slender, 0.2 cm diam. Leaf blades 4 – 10 cm long, chartaceous when dry, margins serrulate. Inflorescences 0.5 – 2.5 cm long, not branched. Flowers with white petals **Eschweilera compressa**
17. Twigs robust, 0.3 – 0.4 cm diam. Leaf blades 9 – 20 cm long, coriaceous when dry, margins entire. Inflorescences > 5 cm long, branched. Flowers with yellow petals.
18. Leaf blades elliptic to lanceolate, the apices markedly acuminate **Eschweilera mattosilvae**
18. Leaf blades elliptic or suborbicular to oblong, the apices not markedly acuminate **Eschweilera complanata**
16. Calyx-lobes imbricate (calycine rim not present).
19. Leaves with petioles 0.1 – 0.2 cm diam. at middle, blades 4.5 – 7 cm long, chartaceous. Inflorescences with main rachis to 10 cm long. Flowers with 4 petals **Eschweilera alvimii**
19. Petioles 0.2 – 0.4 cm diam. at middle, leaf blades 8 – 21 cm long, coriaceous. Inflorescences with main rachis to 27 cm long. Flowers with 4 or 6 petals.
20. Leaf blades usually widely oblong, 6 – 15 cm wide, the secondary veins impressed. Inflorescences usually unbranched. Flowers 5 – 6 cm diam., petals 6, stamens over 500 **Eschweilera nana**
20. Leaf blades elliptic to narrowly ovate, 6 – 9 cm wide, the secondary veins plane. Inflorescences branched. Flowers c. 4 cm diam., petals 4, stamens less than 200 **Eschweilera tetrapetala**
6. Stellate trichomes at least present on hypanthium. Flowers with 36 – 100 stamens in staminal ring; androecial hood with external flap. Fruits dehiscent. Seeds flattened, circumferentially winged, cotyledons leaf-like. (*COURATARI*)
21. Leaf blades with longitudinal striations, puberulous abaxially, secondary veins in 16 – 35 pairs.
22. Leaf blades 14 – 41 × 5 – 17 cm, oblong, with longitudinal striations present but not conspicuous. Flowers 3.0 – 4.3 cm diam., hypanthium densely tomentose, trichomes in tufts, petals with light pink apices, stamens 36 – 54 **Couratari asterophora**
22. Leaf blades 8 – 20 × 3 – 9 cm, oblong, obovate or elliptic, with longitudinal striations very conspicuous. Flowers 4.5 – 6.0 cm diam., hypanthium tomentulose, trichomes not in tufts, petals without light pink apices; stamens 60 – 101. **Couratari macrosperma**
21. Leaves without longitudinal striations, glabrous or pubescent abaxially; secondary veins in 12 – 19 pairs.
23. Leaf blades 7 – 13 × 3 – 6 cm, oblong or elliptic, both adaxial and abaxial surfaces glabrous. Hypanthium with well-developed tufts of trichomes. Known only from northern Espírito Santo **Couratari asterotricha**
23. Leaf blades 8 – 25 × 4 – 10 cm, oblong, elliptic or obovate, pilose abaxially, especially on base and midrib. Hypanthium with stellate trichomes but these not in well-developed tufts. Known only from Rio de Janeiro **Couratari pyramidata**

Results and discussion

Little is known about some of the species of Lecythidaceae from eastern Brazil. This is primarily because the region is large and the habitats where

these species grow are severely fragmented making it difficult to find some of the rare species and even more challenging to find fertile material for taxonomic research. Ribeiro *et al.* (2014) note that,

for Espírito Santo, the great height of some individuals, the lack of fieldwork in remote areas, the difficulty of collecting both flowers and fruits from the same tree, and the misconception that the group is sufficiently known as reasons why the family has been insufficiently sampled in many parts of the state.

Of the 22 described species native to eastern Brazil, 14 are endemic to this region and over 50% are vulnerable to or endangered with extinction (Table 1). The results of this study show that 12 of the species are critically endangered, endangered or vulnerable, one is near threatened (*Eschweilera mattos-silvae*), and one (*Cariniana legalis*) is listed as threatened but should be downgraded to near threatened or least concern. The non-endemic species have much wider, disjunct distributions. Several species also grow well in disturbed habitats and secondary forest (e.g., *Lecythis lurida*, *L. marcgraaviana*, *Couratari macrosperma*, *Eschweilera ovata*), which has helped them flourish in parts of eastern Brazil in spite of severe deforestation.

Based on the assessments from this study (Table 1), we recommend that the IUCN Red List add four species (*Cariniana parvifolia*, *Eschweilera complanata*, *E. mattos-silvae*, and *Lecythis ibiriba*) to the List and that the List change the status of seven species (*Cariniana legalis*, *Couratari asterophora*, *Eschweilera alvimii*, *E. compressa*, *E. tetrapetala*, *Lecythis lanceolata*, and *L. schwackei*). Although the results show that *Couratari asterotricha* is endangered, the distribution and population size of this species remain unclear and, therefore, we suggest leaving it as critically endangered until further studies can be made.

For each of the ten endangered species (Table 1), the percentage of collections known from protected areas is as follows: *Cariniana ianeirensis* (6.25%), *C. parvifolia* (100%), *Couratari asterophora* (53%), *C. asterotricha* (70%), *C. pyramidata* (58%), *Eschweilera alvimii* (100%), *E. complanata* (78%), *E. compressa* (37%), *E. tetrapetala* (73%), and *Lecythis schwackei* (0%). Nearly all of the collections analysed occur inside or within 20 km of a protected area. For the majority of the endangered species, the fact that most collections are known from reserves could partially be the result of collector bias (e.g., reserves vs privately owned land). Nevertheless, the data from this study clearly show that protected areas in eastern Brazil are of vital importance for the survival of nearly all of the endangered Lecythidaceae species from this region. This is especially true for protected areas of Atlantic Forest in the states of Rio de Janeiro, Espírito Santo and Bahia, which have the highest diversity of Lecythidaceae in the study area (Map 24).

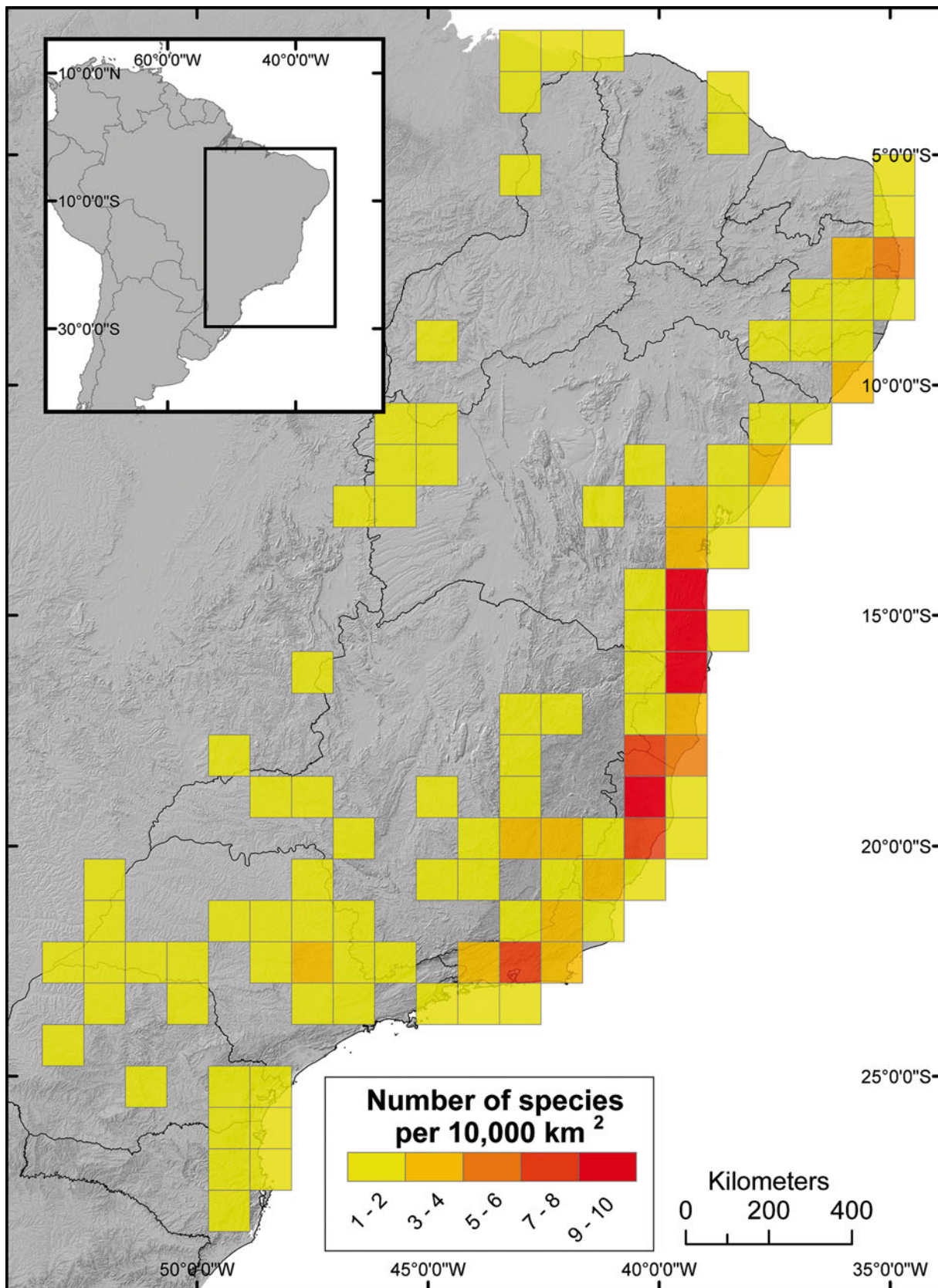
Cariniana, which has some of the tallest trees in the country, is relatively common in eastern Brazil, especially between Santa Catarina and Bahia. Compared to most of the other genera, the taxonomy of the genus within the study areas is well understood. Unlike *Cariniana*, most species of *Couratari* from

eastern Brazil are poorly understood. The only species that is not threatened is *C. macrosperma*, which is very common in northern Espírito Santo and southern Bahia and is also found in western Amazonia. A detailed study of *Couratari* might reveal that *C. macrosperma* from eastern Brazil is a distinct species from *C. macrosperma* from Amazonia. Collections of fertile material during this study contributed greatly to what is known about some of the eastern Brazilian *Couratari* species but our understanding of this genus would benefit from a phylogenetic analysis.

Gustavia augusta is common throughout its range in northern South America but less common in eastern Brazil where it could become threatened in the future if its habitat continues to decline. Some species of *Lecythis* are very common in eastern Brazil. This is especially true for *L. pisonis* in Espírito Santo and Bahia and *L. marcgraaviana* in Paraíba. This study also greatly improved what is known about *Lecythis* and led to the recognition of two species that were in synonymy, *Lecythis ibiriba* under *Eschweilera ovata* (Smith *et al.* 2012) and *L. marcgraaviana* under *L. pisonis* (Smith *et al.* 2016).

With the exception of *Eschweilera ovata*, species of *Eschweilera* in eastern Brazil belong to the Tetrapetala clade (Huang *et al.* 2015). This poorly understood group is mostly endemic to eastern Brazil but *E. nana* is widespread and occurs outside of the study area. The group includes several species known only from a small number of collections (e.g., *E. alvimii*, *E. complanata*, *E. compressa*). Other species in the clade are common with a wide distribution (*E. nana*) or common but narrowly endemic (*E. tetrapetala*). A detailed taxonomic analysis and conservation assessment of this group would most likely lead to the description of several new and endangered species and may even result in recognising this clade as a separate genus.

With over 50% of the species endangered or vulnerable (all endemic to the study area, except *Cariniana ianeirensis*, see Table 1), the overall future of Lecythidaceae in eastern Brazil is uncertain. The results of this study illustrate how much has been learned and how little is still known about these ecologically important and magnificent trees. Even after nearly four hundred years of botanical exploration (Marcgrave 1648) there are still species without scientific names and many aspects of their ecology (e.g., pollination and dispersal biology), biogeography (e.g., the origin of eastern Brazilian species), evolution (e.g., the relationships between Amazonian and eastern Brazilian species), and population biology (e.g., are extant populations large enough to ensure the survival of species?) still need to be addressed. Based on our experience we know it will take future students to fully understand the Lecythidaceae of eastern Brazil, and we hope that students and professionals use the information in this article to help them to learn about and protect these species and the habitats where they grow.



Map 24. Species richness within study area.

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