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Separation of *Dalbergia stevensonii* from *Dalbergia tucurensis*

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Dalbergia tucurensis ***Dalbergia stevensonii***

Abstract

Belize is home to two commercially important species of *Dalbergia*, *D. stevensonii* and *D. tucurensis*, whose overall appearance and wood anatomy are similar. *D. stevensonii* is protected from commercial harvesting, whereas *D. tucurensis* is not. Therefore, reliable methods for separating the two species are important. Comparison of samples from the Center for Wood Anatomy Research at the Forest Products Laboratory demonstrated that density can reliably separate the species. Freshly cut surfaces of *D. stevensonii* were sometimes fluorescent, but they never were in *D. tucurensis*. Ethanol extracts were sometimes violet in *D. stevensonii*, but never in *D. tucurensis*.

Keywords: *Dalbergia stevensonii*, *Dalbergia tucurensis*, Belize, density, fluorescence

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Contents

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Separation of *Dalbergia stevensonii* from *Dalbergia tucurensis*

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Introduction

The Gibson Guitar factory in Nashville, Tennessee, was raided in August 2011 because of alleged Lacey Act violations. This raid followed a confiscation of tropical hardwoods in November 2009 and has highlighted some of the problems that importers encounter if they use tropical woods in their products (Anonymous 2011). The Lacey Act of 1900, amended in 2008, prohibits trade in illegally taken wildlife, fish, and plants. More than 30,000 of these species, many of them large trees, are listed in the appendices of the Convention on International Trade in Endangered Species of Flora and Fauna (CITES) (Environment Canada 2002).

The Center for Wood Anatomy Research (CWAR) of the Forest Products Laboratory (FPL) in Madison, Wisconsin, regularly receives requests concerning the possible importation of wood species that are in violation of importation rules. To help ensure compliance with timber importation regulations, CWAR conducts research into methods that can be used to separate restricted species from similar but unrestricted species. For example, Miller and Wiemann (2006) reported on physical properties differences that can be used to separate two important Brazilian species, *Dalbergia nigra* (Vell.) Allem. ex Benth., restricted by CITES appendix I, and *Dalbergia spruceana* Benth., an unrestricted species.

Balick and others (2000) record seven species of *Dalbergia* from Belize. Four of them, *D. brownei* (Jacq.) Urb.; *D. ecastaphyllum* (L.) Taub.; *D. glabra* (Mill.) Standl.; and *D. monetaria* L.f. are lianas, shrubs, or small trees, and the others, *D. melanocardium* Pittier, *D. stevensonii* Standl., and *D. tucurensis* Donn. Sm. (syn. *D. cubilquitzensis* (Donn. Sm.) Pittier), are large trees that grow to 30 m in height (Balick and others 2000, Croat 1978, Parker 2008, Standley and Record 1936, Standley and Steyermark 1946). Although Balick and others (2000) list *D. melanocardium* Pittier as a tree of Belize, citing one herbarium voucher, Parker (2008) reports its range as Guatemala, Mexico, El Salvador, Honduras, and Costa Rica, but does not list it as a species of Belize. Dwyer and Spellman (1981) also did not include it as a species collected in Belize. A copy of the voucher cited by Balick and others (2000) has been seen by the first author of this research paper (MCW). This voucher (Percy H. Gentle No. 7073) was collected on June 13, 1950, in Columbia, Belize, and identified by M. Sousa in 1979. It contains flowers and only a few immature leaves, and comes from a tree 10 cm in diameter. The wood collections of the CWAR include only one specimen of *D. melanocardium*—a small (3.5 cm diameter) stem or branch from Mexico. Therefore we are doubtful that *D. melanocardium* is a large timber-producing tree of Belize.

This paper presents physical properties of the two species of *Dalbergia* that are commercially exploited for timber in Belize, *D. stevensonii* and *D. tucurensis*, and discusses the properties that might be useful for separating the species. *D. tucurensis* was first described by Donnell-Smith in 1908, and *D. stevensonii* was first described in 1927 by both Stevenson (1927) and Standley (1927). Guatemalan populations of *D. stevensonii* are on CITES appendix III (Gasson and others 2010, Gasson 2011), and Germany has proposed that all populations be included on this appendix. Therefore, methods for the reliable separation of *D. stevensonii* from other species of *Dalbergia* sourced in Belize are important to prevent illegal exploitation of the protected species.

Record and Hess (1943) provided the following descriptions of the two woods: *D. stevensonii* is hard and heavy (0.93–1.09 g/cm^3 when air dried) with pinkish-brown or purplish heartwood that has alternating light and dark zones that are independent of the growth rings; *D. tucurensis* is moderately hard, heavy, tough, and strong with orange-colored heartwood with more or less pronounced violet striping that becomes brown or purplish upon exposure. The images on the cover of this publication show the similarities in appearance of the two species. The top images depict natural color and grain, and the bottom images, stained and magnified about 30 times, show anatomical structure in cross section.

Richter and others (1996) presented anatomical, physical, and chemical differences that can be used to differentiate among four groups (nine species) of *Dalbergia* from Central America. Two of these are the species of this report, and a summary of their findings for these two species is given in Table 1. According to these data, *D. stevensonii* is pinker, heavier, and has larger vessels than *D. tucurensis*, but is the same in other respects. Of the data they presented, only density showed a clear separation between the two species. One problem with the use of density, however, is that it is dependent upon sample moisture content. For samples that have been stored at constant ambient temperature, such as those

Table 1—Comparison of physical, anatomical, and chemical features reported[a] for *Dalbergia stevensonii* and *D. tucurensis*

Feature	*Dalbergia stevensonii*	*Dalbergia tucurensis*
Heartwood color	Medium to dark pinkish brown, with dark streaks	Yellow brown to brown, with or without dark streaks
Odor of dry heartwood	Negative	Negative
Density (g/cm^3)	0.93–1.17	0.65–0.82
Intervessel pit diameter (μm)	8–10	8–10
Vessel diameter (μm)	± 220	± 270
Maximum vessel diameter (μm)	350	450
Vessel frequency (per mm^2)	3–6	3–6
Dominant parenchyma pattern	Paratracheal vasicentric to aliform and confluent	Paratracheal vasicentric to aliform and confluent
Heartwood fluorescence	Negative	Negative
Color of ethanol extract	Light yellow to light pinkish brown	Light yellow to light brown

[a]Source: Richter and others (1996).

in the CWAR wood collection, this is not a problem because all the samples are at the same equilibrium moisture content. For samples collected in other venues, especially those from log decks or sawmills prior to drying, density is much less useful unless it has been adjusted to a constant moisture standard. Figure 4-6, table 4-6, and equations 4-12, 4-13, and 4-14 of the *Wood Handbook* (FPL 2010) can be used to make the necessary adjustments. Chapter 4 of the online edition of this publication can be found at http://www.fpl.fs.fed.us/products/publications/several_pubs.php?grouping_id=100&header_id=p

Using the wood samples housed in the CWAR wood collection, we sought to find consistent differences between *D. stevensonii* and *D. tucurensis*. The CWAR wood collection consists of two parts. The original Madison collection (MADw) was started in 1911. The Samuel J. Record collection (SJRw) was started at Yale University in 1905 and was acquired by FPL in 1970 (Stern 1988). Together these collections contain more that 100,000 wood samples. The *D. stevensonii* and *D. tucurensis* samples seemed to have a wide range in density, and some samples were annotated to the effect that they showed fluorescence under ultraviolet (UV) light. The presence of fluorescent specimens is contrary to the report of Richter and others (1996), so we wanted to explore that discrepancy. Furthermore, Richter and others (1996) did not report color under UV light of the water and ethanol extracts, but these were useful for the separation of Brazilian *Dalbergias* (Miller and Wiemann 2006). Therefore, we decided to conduct our own study of the density and fluorescence of the two commercially important Belizean species.

Materials and Methods

We assembled all the specimens of *D. stevensonii* and *D. tucurensis* from the MADw and SJRw wood collections. Table 2 is a list of the specimens and their known collection data. Seventeen of them were labeled *Dalbergia stevensonii*, and 16 were labeled *Dalbergia tucurensis*. Six trees are represented by specimens in both collections; these are indicated in the column "Duplicate specimens." The table also lists the country of origin of each specimen ("Country of origin") as well as information on the collector, specific collection localities, provider of the specimens, and the status of herbarium vouchers, when such information was available ("Collector notes"). Vouchers are located at the Field Museum in Chicago (F), the New York Botanical Gardens (NY), and at the herbarium of the University of Wisconsin (WIS). Finally, the table also gives additional information on the origin and acquisition of the samples ("Specimen notes").

All the specimens were at the ambient equilibrium moisture content of the CWAR, which is 6% to 8%. The percentage of sapwood in each specimen was estimated and is recorded in Table 3. Density was measured using the entire specimen, but all the other observations were made on heartwood when possible.

The density of each sample was measured using water displacement, as follows. The air-dry weight of each sample was measured on a balance with a weighing range of 0–5,000 g and a precision of 0.1 g; these weights are recorded in Table 3. Each sample was then placed in a weighted, tared, wire mesh cage that was suspended from the weighing pan of the same balance. Below the balance was a large (45-cm-diameter, 40-cm-deep) plastic tub that contained water to about two-thirds of its depth. For each weighing, the empty cage was completely submerged, and the balance was tared to 100 g. The cage was then raised, a *Dalbergia* specimen was inserted, and the cage plus specimen was submerged to the top of the cage. The weight of the submerged sample was recorded. The submersions were quick, and the samples did not adsorb an appreciable amount of water because of their high density and low hygroscopicity. This method is based, with modification, on Designation D2395-07a of the Annual Book of ASTM Standards

Table 2—Information available on the specimens in the CWAR identified as *Dalbergia stevensonii* or *Dalbergia tucurensis*[a]

Collection and number	Duplicate specimens	Country of origin	Collector notes	Specimen notes
Dalbergia stevensonii				
SJRw 4092	—	Guatemala	Porto Barrios	Received from R. Tatto, Brazilian Forest Service, June 29, 1940
SJRw 4472	—	Honduras	—	—
SJRw 4799	—	Belize	South of Cockscomb Mountains	—
SJRw 6340	—	Honduras	—	Received from R. Tatto, Brazilian Forest Service, June 29, 1940; described by Record and Mell (1924) as *Dalbergia* spp.
SJRw 6589	MADw 31971	Belize	W.N. Bourne; voucher at WIS	Bark present on specimen; described by Record and Mell (1924) as *Dalbergia* spp.
SJRw 6590	—	Belize	—	Received from R. Tatto, Brazilian Forest Service, June 29, 1940; described by Record and Mell (1924) as *Dalbergia* spp.
SJRw 6591	—	Belize	—	Described by Record and Mell (1924) as *Dalbergia* spp.
SJRw 6592	—	Belize	—	Described by Record and Mell (1924) as *Dalbergia* spp.
SJRw 10696	—	Belize	N.S. Stevenson 38; August 27, 1927; isotype, voucher location not given	Received from R. Tatto, Brazilian Forest Service, June 29, 1940; described by Standley (1927)
SJRw 13663	—	Belize	—	Received from R. Tatto, Brazilian Forest Service, June 29, 1940
SJRw 35100	MADw 31969	Belize	N.S. Stevenson 178; no voucher listed, but may exist	Received N.S. Stevenson, Conservator of Forests, January 15, 1938
MADw 7396	—	Belize	Conservator of Forests; December 1, 1926	—
MADw 9928	—	Honduras	A. Wilson No. 1888; June 1954; no voucher listed, but may exist	—
MADw 11329	—	Honduras	—	Washington Office collection
MADw 31969	SJRw 35100	Belize	N.S. Stevenson 178; no voucher listed, but may exist	Received from Field Museum, 1971, 621809
MADw 31970	—	Belize	Conservator of Forests; no voucher listed, but may exist	Received from Field Museum, 1971, 614052
MADw 31971	SJRw 6589	Belize	W.N. Bourne; voucher at WIS	Received from Field Museum, 1971; bark present but separated from wood
Dalbergia tucurensis				
SJRw 3721	MADw 10836	Guatemala-Honduras boundary	H.N. Whitford and L.R. Stadtmiller 61; 1919; voucher at WIS	Received from R. Tatto, Brazilian Forest Service, June 29, 1940; described by Record and Kuylen (1926)
SJRw 3738	MADw 31973	Guatemala-Honduras boundary	H.N. Whitford and L.R. Stadtmiller 79; 1919; no voucher listed, but may exist	—
SJRw 6634	—	Honduras	P.H. Myers, Cuyamel Fruit Co., Puerto Cortés, Belize; no voucher listed, but may exist	Examined but unidentified by Record (1927)
SJRw 7020	—	Honduras	—	—
SJRw 8896	MADw 11011	Guatemala	H. Kuylen G-65; 1926; voucher at WIS	Received from R. Tatto, Brazilian Forest Service, June 29, 1940; described by Record and Kuylen (1926)
SJRw 10699	—	Belize	Collected by M.O. Hope, Forest Ranger; no voucher listed, but may exist	Stevenson (1927); Middlesex; bark present on specimen

Table 2—Information available on the specimens in the CWAR identified as *Dalbergia stevensonii* or *Dalbergia tucurensis*[a]—con.

Collection and number	Duplicate specimens	Country of origin	Collector notes	Specimen notes
Dalbergia tucurensis				
SJRw 10729	MADw 31975	Guatemala	Carlos Gallusser 9; Santa Inés; voucher at WIS	Received by Professor I.W. Bailey, January 18, 1938
SJRw 15665	—	Honduras	W.D. Hottle; 1929; voucher at F	—
SJRw 33749	—	Honduras	T.G. Yuncker, R.F. Dawson, and H.R. Youse; February 8, 1937; voucher at WIS	Bark present on specimen
MADw 7655	—	Honduras	—	Received from Timberlane Co., Eugene, Oregon
MADw 10836	SJRw 3721	Guatemala-Honduras boundary	H.N. Whitford and L.R. Stadtmiller 61; 1919; voucher at WIS	Transfer from Smithsonian, March 6, 1928
MADw 11011	SJRw 8896	Guatemala	H. Kuylen G-65; 1926; voucher at WIS	Transfer from Smithsonian, March 6, 1928
MADw 31973	SJRw 3738	Guatemala-Honduras boundary	H.N. Whitford and L.R. Stadtmiller 79; 1919; no voucher listed, but may exist	Received from Field Museum, 1971
MADw 31975	SJRw 10729	Guatemala	Carlos Gallusser 9; Santa Inés; voucher at WIS	Received from Field Museum, 1971
MADw 31976	—	Guatemala	Julian Steyermark 44646; Cubilguitz, Alta Verapas; vouchers at F, NY	Received from Field Museum, 1971; bark present on specimen
MADw 33885	—	Honduras	Olancho; no voucher listed, but may exist	Received from IICAw CHO-7A; tree no. ODN-H27

[a]Center for Wood Anatomy Research (CWAR), Forest Products Laboratory in Madison, Wisconsin. SJRw refers to the Samuel J. Record collection. MADw refers to the specimens in the original Madison collection. University of Wisconsin (WIS). Field Museum in Chicago (F). New York Botanical Gardens (NY).

(ASTM 2010), "Test Method B—Volume by Water Immersion, Mode III."

Sample density (Table 3) was then calculated for each sample using the following formula, where the weights are in grams and the density in g/cm^3:

$$\text{Density} = \text{Dry weight} / (\text{Dry weight} + 100\ \text{g} - \text{Submerged weight})$$

Alcohol extracts were prepared by placing a few shavings of each specimen in a small vial, adding 95% ethanol, and shaking the vial. The color of each of these extracts is recorded in Table 3.

The surface fluorescence of each sample was observed by making a fresh cut with a utility knife and holding the sample under a 2-A long-wave UV lamp. Response to UV was recorded in Table 3 as yes (fluorescent), weak (slightly fluorescent), or no (not fluorescent).

Water extracts were prepared in the same way as the alcohol extracts except that tap water was used instead of ethanol. Response to UV light was observed for each water and ethanol extract and was recorded in Table 3 as the color of the extract under UV light.

Results and Discussion

The density ranges of the two species did not overlap, so this criterion alone is sufficient to separate them if they are at the same moisture content (Table 3). At the equilibrium moisture content of the CWAR, the heartwood samples of these two species have density ranges of 0.99–1.14 g/cm^3 (mean 1.07 g/cm^3) for *D. stevensonii*, and 0.68–0.79 g/cm^3 (mean 0.72 g/cm^3) for *D. tucurensis*, so a simple flotation test using dry samples should suffice to separate the two species.

Among the samples of *D. stevensonii*, the presence of sapwood was associated with lower density (the three samples that were at least 90% sapwood had densities ≤ 1.0 g/cm^3), but other attributes besides sapwood are probably equally important. Two of the specimens (SJRw 6589 and MADw 31971) are 2-cm-thick, 6–7-cm-wide, sapwood slabs from the outer portion of the same tree, which we estimate to have been about 16 cm in diameter. The other specimen (SJRw 10696), which is 90% sapwood, is from the type tree described by Standley in 1927. We estimate that it must also have been about 16 cm in diameter. SJRw 6589 has bark attached, but it is less than 3 mm thick and could not have had much of an effect on density (Tables 2 and 3).

The effect of sapwood is unclear in *D. tucurensis*. Although the samples with the lowest densities (≤ 0.62 g/cm^3) were all sapwood, other samples with significant proportions (50%–100%) of sapwood had higher densities (0.66–0.73 g/cm^3). The samples with attached bark, SJRw 33749, MADw 31976, and SJRw 10699, had densities of 0.50, 0.62, and 0.73 g/cm^3, respectively. They also had sapwood proportions of 100%, 100%, and 35%, respectively. Bark was always less than 3 mm thick. The sapwood samples with bark, SJRw 33749 and MADw 31976, are both from

Table 3—Percentage sapwood, sample weights, sample densities, ethanol extract color, and fluorescence properties of specimens identified as *Dalbergia stevensonii* or *D. tucurensis*

Specimen[a]	Sapwood (%)	Air-dry weight (g)	Density[b] (g/cm^3)	Ethanol extract color	UV fluorescence		
					Surface	Water extract color	Ethanol extract color
Dalbergia stevensonii							
MADw 31971=	100	66.8	0.86	None	No	Blue	Light blue
SJRw 6589=	100	137.4	0.89*	None	No	Blue	Light blue
SJRw 4472	0	78.1	0.99	Light violet	Weak	Blue	Blue
MADw 9928	0	118.3	0.99	Violet	Weak	Blue	Blue
SJRw 10696	90	113.0	1.00	Violet	No	Blue	Blue
SJRw 35100=	0	43.9	1.02	None	No	Blue	Blue
SJRw 4092	0	27.5	1.05	Violet	Weak	Blue	Blue
SJRw 6591	0	162.4	1.05	Violet	Yes	Blue	Blue
MADw 31969=	0	95.8	1.07	Light yellow	Yes	Greenish-blue	Blue
MADw 7396	0	229.2	1.08	Light violet	Weak	Greenish-blue	Blue
MADw 11329	0	43.3	1.08	Brown	Weak	Blue	Blue
MADw 31970	0	128.9	1.09	None	Yes	Light blue	Greenish-blue
SJRw 6590	0	69.0	1.09	Light brown	No	Blue	Blue
SJRw 13663	0	115.4	1.09	Brown	No	Blue	Blue
SJRw 6340	0	167.8	1.10	Brownish violet	Yes	Blue	Blue
SJRw 4799	0	119.3	1.11	Violet	No	Blue	Blue
SJRw 6592	0	7.4	1.14	Violet	No	Blue	Blue
Mean	—	—	**1.04**	—	—	—	—
Range	—	—	**0.86–1.14**	—	—	—	—
Dalbergia tucurensis							
SJRw 15665	100	56.0	0.47	None	No	Blue	Blue
SJRw 33749	100	62.0	0.50*	None	No	Greenish-blue	Blue
MADw 31976	100	38.0	0.62*	None	No	Greenish-blue	Blue
SJRw 10729=	60	115.0	0.66	Light yellow	No	Blue	Blue
SJRw 6634	0	230.9	0.68	Light brown	No	Blue	Blue
MADw 10836=	15	39.8	0.68	None	No	Blue	Blue
SJRw 3721=	20	39.6	0.69	Light brown	No	Blue	Blue
SJRw 3738=	0	50.8	0.69	Brown	No	Blue	Blue
MADw 11011=	50	101.3	0.70	None	No	Blue	Blue
SJRw 8896=	65	138.5	0.72	None	No	Blue	Blue
SJRw 10699	35	201.8	0.73*	Light yellow	No	Blue	Blue
MADw 31975=	100	72.0	0.73	None	No	Greenish-blue	Light blue
MADw 33885	20	52.0	0.73	Light yellow	No	Blue	Blue
MADw 31973=	0	66.0	0.74	Yellow	No	Blue	Blue
SJRw 7020	30	254.0	0.76	Brown	No	Blue	Blue
MADw 7655	0	104.8	0.79	Light brown	No	Blue	Blue
Mean	—	—	**0.68**	—	—	—	—
Range	—	—	**0.47–0.79**	—	—	—	—

[a]Specimens sorted by density within species. Specimens with duplicates marked by an equals sign (=).
[b]Density of specimens measured with bark attached marked by an asterisk (*).

3-cm-diameter stems, so they are completely atypical of mature wood.

The color of the ethanol extracts is of little value in separating the two species. Extracts from heartwood of both species were sometimes colorless, light yellow, light brown, or brown. *D. stevensonii* had violet color in some specimens (9 of 17) but *D. tucurensis* did not, so a violet extract is diagnostic for *D. stevensonii* (Table 3).

Surface fluorescence was also present in 9 of the 17 specimens of *D. stevensonii*, although it was weak in 5 of these. It was completely absent in *D. tucurensis* (Table 3). We can therefore conclude that if a specimen shows surface fluorescence, it is *D. stevensonii*.

The fluorescence of the water extracts is of no value in separating the two species. Both of them had blue or greenish-blue extracts. In the case of *D. tucurensis*, greenish-blue fluorescence was found only in sapwood specimens (Table 3).

The fluorescence of the ethanol extracts is also of no value in separating the two species. Both of them had blue fluorescence, although one specimen of *D. stevensonii* was greenish-blue (Table 3).

Comparisons of the matched samples (MADw and SJRw samples from the same tree) illustrate the variability

Table 4—Percentage sapwood, densities, ethanol extract color, and fluorescence properties of matched specimens

				UV fluorescence		
Specimen	Sapwood (%)	Density (g/cm^3)	Ethanol extract color	Surface	Water extract color	Ethanol extract color
Dalbergia stevensonii						
MADw 31971	100	0.86	None	No	Blue	Light blue
SJRw 6589	100	0.89	None	No	Blue	Light blue
SJRw 35100	0	1.02	None	No	Blue	Blue
MADw 31969	0	1.07	Light yellow	Yes	Greenish-blue	Blue
Dalbergia tucurensis						
SJRw 10729	60	0.66	Light yellow	No	Blue	Blue
MADw 31975	100	0.73	None	No	Greenish-blue	Light blue
MADw 10836	15	0.68	None	No	Blue	Blue
SJRw 3721	20	0.69	Light brown	No	Blue	Blue
SJRw 3738	0	0.69	Brown	No	Blue	Blue
MADw 31973	0	0.74	Yellow	No	Blue	Blue
MADw 11011	50	0.70	None	No	Blue	Blue
SJRw 8896	65	0.72	None	No	Blue	Blue

associated with the evaluation of wood physical properties. Table 4 compares the attributes of the samples from six trees represented in both collections. Density values differed within pairs by 1% to 11%, but even the largest between-specimen difference (SJRw 10729 and MADw 31975) was small compared with the between-species difference. Ethanol extract color was the same in two pairs, surface fluorescence was the same in five pairs, water extract fluorescence color was the same in four pairs, and ethanol extract fluorescence color was the same in five pairs. However, the differences in color evaluations were slight in almost every case and were what might be expected in judging a continuum of color.

Conclusions

If specimens are known to have come from Belizean trees, the CITES-protected species *Dalbergia stevensonii* can be reliably distinguished from the unprotected *Dalbergia tucurensis* by means of density, as long as variable moisture content does not interfere with the density comparisons. For an inspector who wishes to determine if an unknown from Belize is the prohibited species, the density measure is the most practical because it only requires accurate weight and volume measures. However, the specimen must be conditioned to a uniform moisture content of about 6% to 8%, or a suitable adjustment for moisture content must be made. If water immersion is impractical for volume measurement, the specimen must be machined to a size and shape that can be accurately measured.

Based on our limited sample of 33 specimens from 27 trees, if a freshly cut heartwood sample shows surface fluorescence it is *D. stevensonii*, but if surface fluorescence is absent the specimen might be either species. Color of ethanol extract is only useful if it is violet, in which case a specimen is *D. stevensonii*. Fluorescence of water or ethanol extracts cannot distinguish between the two species.

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