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Trees of Panama: A complete checklist with every geographic range

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Abstract

Background: Central America is one of the most diverse floristic provinces in the world, but comprehensive plant lists for the region are incomplete and need frequent updating. Full geographic ranges of individual species are seldom known. Our detailed forest inventory plots of Panama thus lack a global geographic perspective. In order to provide one, we assembled a thoroughly vetted checklist of all tree species of Panama, along with an estimate of each one's range size based on published specimen records.

Results: 1) Panama has 3043 tree species in 141 families and 752 genera; 57.6% were ≥ 10 m tall and 16.9% were 3-5 m tall.
2) The widest ranges were $> 1.5 \times 10^7$ km^2, covering the entire neotropics and reaching > 30° latitude; 12.4% of the species had ranges exceeding 10^7 km^2. The median range was 6.9×10^5 km^2.
3) At the other extreme, 16.2% of the species had a range $< 20,000$ km^2, a criterion suggesting endangered status.
4) Range size increased with a tree species' height and varied significantly among families.
5) Tree census plots, where we mapped and measured all individuals, captured 27.5% of the tree species, but a biased selection relative to range size; only 4.5% of the species in plots had ranges $< 20,000$ km^2.

Conclusions: Our checklist of the trees of Panama, based on rigorous criteria aimed at matching plot censuses, is 20% larger than previous. By recording species' maximum heights, we allow comparisons with other regions based on matching definitions, and the range sizes provide a quantitative basis for assessing extinction risk. Our next goal is to merge population density from plot censuses to add rigor to predictions of extinction risk of poorly-studied tropical tree species.

Introduction

Before human intervention, the nation of Panama was nearly all forest, and forest ecosystems in the moist tropics are diverse. The southern end of Central America, morever, falls within a region where plant species richness reaches a global maximum (Barthlott et al. 1996). Because conserving forest ecosystems requires an understanding of their component species, we set out to catalog the tree species of Panama and document their geographic ranges. Even to assemble a list of known species, however, is challenging because botanical knowledge across the Neotropics lags well behind North America, Europe, and China. Where detailed work is done, new species are frequently described and large range extensions are commonplace. Less appreciated is how much taxonomic revision continues, redefining existing species and genera and reidentifying specimens. Our knowledge is expanding greatly, though, thanks to large and readily available taxonomic and specimen databases, and we produce here the most rigorously assembled catalog to date of the tree species of Panama along with the exact range size of each.

We have been studying trees of Panama for 35 years at intensively surveyed research sites using fully censused plots (Hubbell and Foster 1986a; Condit 1998a; Condit et al. 2004; Condit et al. 2005; Condit et al. 2011; Condit et al. 2017). Our interest encompasses the entire assemblage of species, from those few that dominate the forest canopy to

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the hundreds appearing at very low density (Hubbell and Foster 1986b; Condit et al. 1996). The tree census plots, however, beg the question of further levels of rarity. Are there species altogether absent from the plots and, if so, where are they?

Our goal here is to document the full tree flora of Panama and compare it to the tree species found in our 66 fully censused plots (Condit et al. 2019b; Condit et al. 2019c). We advance previous checklists of Panama trees (D'Arcy 1987; Correa et al. 2004) first by using rigorous criteria for defining a tree: woody, free-standing, terrestrial species reaching 3-m tall. These criteria closely match the rules for inclusion in plots (Condit 1998b) and are consistently reported in taxonomic monographs. We explicitly omit any criteria relating to single- versus multiple-stems, often used to separate trees from shrubs, because stem number is seldom and inconsistently reported. We further advance the earlier checklists with many taxonomic updates of the past 20 years.

Once the species list was vetted, we assembled every Neotropical record from large published databases of herbaria, checklists, and plots, producing a range size estimate for every species. This is a substantial step forward for any diverse tropical region. Range sizes for complete tree flora are known for depauperate temperate areas (McGlone et al. 2010; Morin and Lechowicz 2011; 2013), but in the Neotropics, existing quantitative analyses are limited to the subsets of species encountered in local studies (Williams et al. 2010; Bemmels et al. 2018; Chacón-Madrigal et al. 2018). With the entire set of ranges, we address several basic biogeographic questions. What fraction of tropical trees are highly endemic, having ranges $< 20,000$ km^2? At the other extreme, how widely do the broadest ranges extend? Do range sizes vary taxonomically, i.e. do some families have more narrow endemics than others, and do ranges vary with the height of a tree species? We also report how many tree species in Panama have never been censused in plots.

Methods

A tree checklist

We started with the checklist for the entire Panama flora published by D'Arcy (1987) and updated by Correa et al. (2004). They both provide a code indicating trees and shrubs. To update the list, we consulted first the *Flora Mesoamericana*, a set of volumes published by Missouri Botanic Garden over the past 25 years that reviews all plant species, grouped by family, throughout Central America. Unfortunately, only 49 of 141 families of Panama trees are completed to date. For the missing families, we consulted first the *Manual de Plantas de Costa Rica*, which is more complete but omits Panama species whose ranges do not include Costa Rica. Between those two major sources, 23 families of Panama trees are not covered (All chapters we consulted from those two multivolume works are cited in Appendix 1). Next, there is a *Flora of Panama*, published over four decades in separate articles, but all before 1980; we only consulted it for those 23 missing families. Beyond those large sources, we consulted many monographs and other taxonomic treatments of families, genera, or single species (The *Flora of Panama* and all other monographs we consulted are cited in Appendix 2). To establish what species are present in Panama, we relied on the description of geographic range given in monographs. In species for which no monograph asserted a range, we had the previous checklists (D'Arcy 1987; Correa et al. 2004) and then consulted specimen records from the large data sources described below.

We also checked the Panama tree list published by Beech et al. (2017) as the Global Tree Search (Botanic Gardens Conservation International 2019). When we accessed the list (2 Oct 2019), it included 2757 tree taxa in Panama. We rejected 374 as not valid in Panama but added 26 to our list that we had missed. It was missing over 700 species we recognize.

Definition of a tree

Our goal was to employ a rigorous definition of a tree that could allow precise comparison among regions. Published definitions, however, are inconsistent, using height cutoffs from 2-10 m, and vague, indicating that trees usually but not always have a single main trunk (see for example Little and Jones 1980; Allaby 1992; Western Australian Herbarium 1998; Pell and Angell 2016; Beech et al. 2017; Missouri Botanical Garden 2020). All definitions omit forms that are largely tropical, such are stilts, stranglers, or clonal palms. Gschwantner et al. (2009) also sought consistency for the purpose of national forest inventories and reviewed a range of definitions but ended up omitting any height and retaining the vague 'typically' for a single trunk.

We have the additional goal of establishing a checklist of trees that matches species that would be included in our forest inventory plots in Panama, in which free-standing woody stems with diameter at breast height ≥ 1 cm are censused (Condit 1998b). To match this and to achieve rigor, we elected to omit the routine but always vague criterion of single versus multiple trunks. Instead, we set a strict height criterion of 3 m, a size which nearly always excludes herbs and corresponds approximately to the 1-cm dbh cutoff, but ignored multiple stems. We recognize that by ignoring stem number, species often considered shrubs are included in our checklist, but there is no alternative that allows consistency and precision, because too many species have multiple stems on some occasions. We also omitted epiphytes and lianas, neither of which are included in tree inventories. Most monographs provide for every species a maximum height, the presence of

wood, and whether epiphytic or lianoid. When available, we accepted the assertions on growth form and maximum height as stated in *Flora Mesoamericana*, *Manual de Costa Rica*, or *Flora of Panama*. If the expert reported that a species is sometimes epiphytic (or scandent) and other times free-standing, we accepted it as a tree. Likewise, we included species described as herbs sometimes and woody others if tall enough.

This left 19% of the species not appearing in monographs. We already had the assertion as tree or shrub from the Panama checklists for many species, and we accepted those. In new species, not reported in Correa et al. (2004), we consulted individual specimen labels at the Missouri Botanical Garden website (www.tropicos.org/Home.aspx) to determine whether they qualify as trees. As soon as we found one record of a tree or shrub taller than 3 m, we accepted it. In those species, we do not report a maximum height, and they are omitted from analyses based on tree size.

Data sources for individual occurrences

Herbarium records as well as other observations (plots, inventories) provide coordinates of individual trees. We used two different large online data sources to gather such records. The first was the 2018 BIEN database (version 4.1, October 2018; Maitner et al. 2017), the second the Tropicos database from the Missouri Botanic Garden. The BIEN database includes Tropicos plus GBIF (Global Biodiversity Information Facility) and many other sources and thus has many more records, but the direct Tropicos download (http://services.tropicos.org) has more recent records and cleaner taxonomy. BIEN is plagued with errors in taxonomy and range, especially from GBIF and checklists, though of course Tropicos has errors as well.

The BIEN database has the advantage of allowing extraction of all records by country or province. We thus extracted all records in the 46 American countries appearing in BIEN. We excluded, however, all but the eight southernmost U.S. states for practical reasons, since the northern states include an enormous number of records but only 10 species that reach Panama (Canada was included, since there are few records; Puerto Rico appears as a country). From this extraction (18,065,850 records), we only made use of records for tree species in our checklist, then discarded records placed at centroids of countries and duplicated coordinates, leaving 1,008,245 unique species-coordinate records. Limiting the BIEN analysis to our checklist was necessary because the BIEN extraction includes non-trees and because of the many erroneous records in BIEN for Panama: mistakes in taxonomy, identification, location, plus non-native species.

Because BIEN provides a thorough list of plant records in Panama, it provided a tool for adding new species relative to Correa et al. (2004). We checked all BIEN species in genera that are mostly trees and added them to the checklist if we found valid occurrences in Panama. This led us to add 485 tree species, mostly in families not covered by *Flora Mesoamericana*. In the end, we either incorporated BIEN tree species into our checklist or decided they do not belong in Panama. There were 810 of the latter: tree species appearing in BIEN-Panama but for which there are no valid records in the country (listed in the supplementary data, Condit et al. 2019a). There must be additional erroneous BIEN records outside Panama, but unfortunately, it was impractical to screen those as thoroughly as records in Panama.

Data must be extracted from Tropicos via species names, not via country. We captured data for every name in our checklist, including every synonym we have. From those, we discarded all records outside the Americas, records placed at centroids of countries, and duplicated coordinates, leaving 335,350 unique species-coordinate records. Tropicos is updated often; our data come from a download on 5 Feb 2020.

A feature provided by BIEN but not Tropicos is a column indicating whether a species is native in the given country for every individual record. Unfortunately, this designation is wrong for many species in central Panama, flagging some well-known native species as exotic. After extensive screening, we concluded that it is often wrong in Central America, Colombia, and Venezuela, while it is helpful in Canada, the USA, Mexico, Ecuador, Peru, Bolivia, Brazil, Chile, and Argentina. Thus, we excluded BIEN records from range calculations when designated as non-native in the latter nine countries but not elsewhere.

Geographic ranges

For every species, we extracted unique latitude-longitude pairs then converted them to kilometers, assuming that a degree latitude = 110.9463 km and a degree longitude at the equator = 111.3195 km. Longitude was then corrected with the cosine of latitude, so that, for example, at 30° latitude, a degree longitude = 96.4055 km. We constructed the minimum convex polygon at which each species was observed, subtracting large bodies of water, and calculated its area. This is known as the EOO, or extent-of-occurrence, and is often reported for tree species (Gaston and Fuller 2009; Morin and Lechowicz 2013). The EOO requires few assumptions and is easy to calculate in poorly known species with few records. We are thus presenting the realized range of each species, as opposed to the potential range. We calculated the range extent separately from the two data sources, BIEN and Tropicos, and a third time after merging them. The two databases are not independent, but this offers some measure of uncertainty about range estimates.

Of the 3043 tree species we found native in Panama, 48 had no records in BIEN and eight had no records

in Tropicos. Conveniently, those missing sets were non-overlapping, meaning that by combining the two sources we had at least one record with coordinates for every species.

Narrow geographic ranges

We were particularly interested in rare species, so sought to be as precise as possible about those with range extents $< 20 \times 10^3$ km^2. As a check for consistency, we examined 50 species whose range was $< 20 \times 10^3$ km^2 according to one source (BIEN or Tropicos) but $> 50 \times 10^3$ km^2 according to the other, and we examined all their records using the Tropicos web site (http://www.tropicos.org/Home.aspx). In most, errors were easy to spot, and in 80% of the cases, the wider range was correct. We thus decided to focus on narrow-range species using the merged specimen records, BIEN plus Tropicos.

From the merged data, there were 47 species with < 3 locations. For those with two records, the pair was within 10 km with one exception (a likely error in *Ardisia pulverulenta*). Since no polygon could be drawn, we arbitrarily assigned all 47 of those species a range $= 10$ km^2. Because of the political importance of managing rare species, we further considered species endemic to Panama, i.e unknown outside the country.

Plots and inventories

Our own tree data were collected in two ways. Most come from plots, our main research effort in central Panama. Plots are precisely surveyed rectangles inside which every individual woody stem at least 1 cm in diameter was identified, measured, and mapped (Condit 1998b). The earliest plot was a 50-ha rectangle on Barro Colorado Island (Hubbell and Foster 1983; Condit et al. 2017); full data available at Condit et al. (2019c). Since then we have added 65 more plots, most 1 ha in area (Condit et al. 2002; Turner et al. 2018); full data available at Condit et al. (2019b). Our second method for surveying trees was an inventory, in which all species present in a small area were noted, but no individuals were counted or measured (Condit et al. 2013; Turner et al. 2018). All plots and inventories together comprise a list of tree species with the exact locations observed (at a precision of 2 m in plots, 500 m in inventories).

Plot occurrence and range

We thoroughly matched all taxonomy in the checklist and the plots, so it was straightforward to count plot and inventory occurrences for all species in the Panama checklist. We tested whether species found within plots differed in range size from non-plot species using a *t*-test after log-transformation.

Tree height, taxonomy, and range

Based on the maximum height recorded from monographs, we tested whether taller species had wider ranges, simultaneously estimating family differences in range size. We used untransformed height as the predictor of log(range size) in a multi-level regression in which family was a random effect; parameters were estimated using the Metropolis algorithm in a Bayesian hierarchical framework (Condit et al. 2007; Condit et al. 2017), running the algorithm for 10,000 steps and discarding the first 2,000. Convergence was checked visually. Statistical inference was based on credible intervals for each family for the estimated median range size at 10 m or 30 m tall, using 95th percentiles of 8,000 parameter values from the Markov chain. The regression was repeated with alternative range estimates (BIEN, Tropicos), but results barely differed and we report only that from merged range sizes.

Data available

A supplementary data archive shows additional results and complete data tables for download (Condit et al. 2019a). These include the full species list with range sizes, all synonyms we located for each name, plus the entire table of coordinates from both BIEN and Tropicos.

Results

The flora

We identified 3043 tree species in Panama and recorded a maximum height for 2461 of those: 1418 (57.6%) were $\geq$ 10 m in height and 417 (16.9%) were < 5 m tall (Table 1). Extrapolating those percentages to the entire 3043 species leads to 1753 tree species $\geq$ 10 tall, 774 species 5-10 m tall, and 516 species 3-5 m tall. About 84 of the 3043 species barely qualify as trees, meaning they were described occasionally as a tree but often as non-tree forms (23 lianas, 42 herbs, 19 epiphytes). A downloadable electronic supplement includes all the species, their families, taxonomic authorities, heights, and recent Latin synonyms (Condit et al. 2019a).

The 3043 species represent 141 families and 752 genera. The biggest family was Rubiaceae with 348 species, or 11.4% of the tree flora, followed by Fabaceae then Melastomataceae (Table 2). The biggest genera were *Miconia* then *Palicourea* (Table 3).

Range sizes

A few species (2%) had ranges$> 1.5 \times 10^7$ km^2, but none reached 2×10^7 km^2 (Table 4). Those are ranges from the Americas, however, and a few species extend into the Old World so their full ranges would be higher (*Sambucus nigra* and *Dodonaea viscosa* occur widely in the Old World, and *Ceiba pentandra* in Africa). Another 10% of the species had ranges $1 \times 107 - 1.5 \times 10^7$ km^2 (Fig. 1). Some of the

Table 1 Panama tree species by maximum height

Height (m)	Number of species	Percent of species
2-3	11	0.4
3-4	231	9.4
4-5	175	7.1
5-6	192	7.8
6-7	162	6.6
7-8	93	3.8
8-9	153	6.2
9-10	26	1.1
10-15	357	14.5
15-20	277	11.3
20-30	383	15.6
30-40	257	10.4
40-50	103	4.2
50-60	41	1.7
Not recorded	582	

Each category $h_1 - h_2$ includes heights $\geq h_1$ and $< h_2$, except the 50-60 category includes the 9 species noted as exactly 60 m tall. The last category is the species for which no monograph provided a maximum height, and the percent of species is based only on the 2461 with height recorded. The 11 species with height < 3 m are included because they appear in our tree census plots

Table 3 Twenty most speciose genera among trees of Panama

Genus (Family)	Number of species	Percent of species
Miconia (Melastomataceae)	107	3.5
Palicourea (Rubiaceae)	92	3.0
Ardisia (Primulaceae)	65	2.1
Piper (Piperaceae)	63	2.1
Inga (Fabaceae)	54	1.8
Ocotea (Lauraceae)	46	1.5
Solanum (Solanaceae)	45	1.5
Conostegia (Melastomataceae)	42	1.4
Psychotria (Rubiaceae)	40	1.3
Eugenia (Myrtaceae)	38	1.2
Ficus (Moraceae)	37	1.2
Clusia (Clusiaceae)	31	1.0
Guatteria (Annonaceae)	26	0.9
Faramea (Rubiaceae)	25	0.8
Pouteria (Sapotaceae)	25	0.8

The appearance of *Palicourea* second instead of *Psychotria* reflects major taxonomic revisions moving species between the two genera (Taylor 2015; Borhidi 2017). The fourth ranking genus, *Piper*, is in the process of major revision and the species number will probably increase with the completion of the Piperaceae volume for *Flora Mesoamericana*

widest ranges reached both 30° S and 30° N latitude, and species with ranges well south also tended to occur far to the north (Figs. 2, 3). Several of the widest ranges belong to weedy and human adapted species (*Psidium guajava, Lantana camara, Manihot esculenta*), but those in Fig. 1 are tree species found in undisturbed forest.

The histogram of range-size across all 3043 species resembled log-normal to the left of a broad mode at 10^6 km^2, with a long tail of small ranges (Fig. 4). To the right of the mode, however, ranges were concentrated at an abrupt ceiling just above 10^7 km^2. The 55% with ranges $< 10^6$ km^2 were for the most part confined to Central America or northwest Colombia (Fig. 5). A total of 876 (28.8%) of the tree species had ranges limited to Nicaragua, Costa Rica, Panama, and northwestern Colombia (> 4.5° N, < 75° W).

The narrowest ranges included 492 tree species extending over $< 20 \times 10^3$ km^2, or 16.2% of the tree flora (pooling BIEN and Tropicos, Table 4). This included some seldom observed species, including 15 having only one record and 32 with two records. But there

Table 2 Twenty most speciose families among trees of Panama

Family	Number of species	Percent of species
Rubiaceae	348	11.4
Fabaceae	258	8.5
Melastomataceae	229	7.5
Lauraceae	116	3.8
Primulaceae	101	3.3
Annonaceae	99	3.3
Solanaceae	95	3.1
Myrtaceae	94	3.1
Malvaceae	90	3.0
Arecaceae	89	2.9
Euphorbiaceae	75	2.5
Moraceae	72	2.4
Asteraceae	67	2.2
Piperaceae	63	2.1
Clusiaceae	55	1.8

Table 4 Range sizes of Panama tree species comparing three data compilations

Range (10^3 km^2)	BIEN	(pct)	Tropicos	(pct)	Merged	(pct)
0-20	534	(17.5)	688	(22.6)	492	(16.2)
20-50	229	(7.5)	243	(8.0)	215	(7.1)
50-100	190	(6.2)	184	(6.0)	189	(6.2)
100-1000	823	(27.0)	762	(25.0)	791	(26.0)
1000-10000	920	(30.2)	981	(32.2)	979	(32.2)
10000-15000	294	(9.7)	172	(5.7)	313	(10.3)
15000-20000	53	(1.7)	13	(0.4)	64	(2.1)

Each row gives the count (and percent) of species whose geographic range falls within the given category, based only on BIEN records, Tropicos records, or the two sets merged

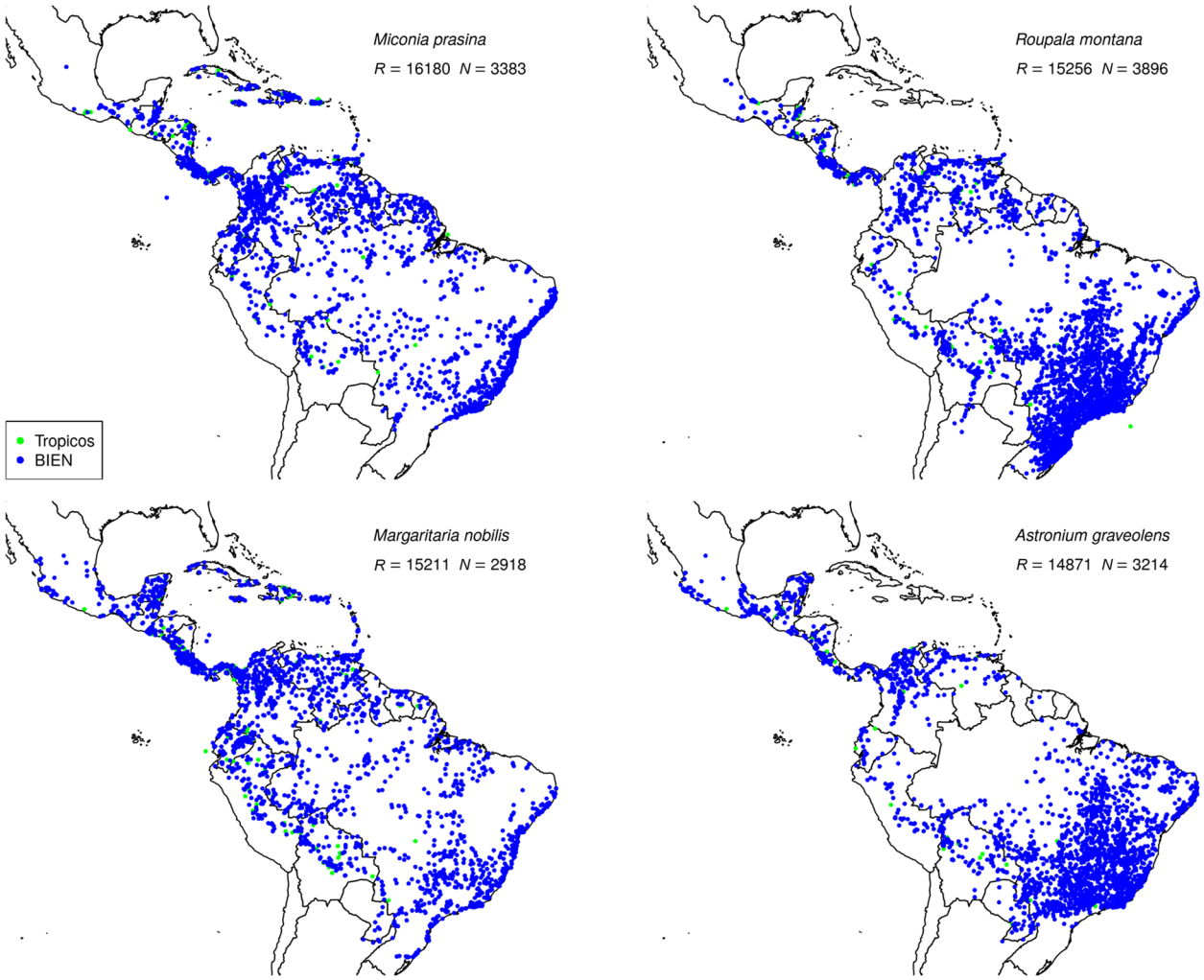

Fig. 1 Distribution maps of four species extending over most of the neotropics. Blue points come from the BIEN database and green from Tropicos (see details in Methods). Many green points are obscured by blue points, but the intent is only to show those places where the Tropicos data extend a range substantially; in these four cases, there is no such extension. *N* = the total number of unique coordinates, Tropicos and BIEN; *R* = range extent (10^3 km^2) from all those points

were 288 species with at least 10 records and a range $< 20 \times 10^3$ km^2 (Table 5). Those 492 narrow-range species included 274 endemic to Panama, 170 shared only with Costa Rica, and 34 shared only with Colombia; a few reached Nicaragua. There were 10 species endemic to Panama with ranges exceeding 20×10^3 km^2, bringing to 284 the total endemic to Panama (Table 5). Figure 6 shows sample distribution maps of narrow-range species.

Results from BIEN data without Tropicos differ little from the full merged data, but using Tropicos data alone led to narrower ranges, as indicated by considerably more species with ranges $< 20 \times 10^3$ km^2 and fewer species with ranges $> 10^7$ km^2 (Table 4). Regardless of which set of data were used, the number of species in the center of the histogram, 20×10^3 km^2 to 10^7 km^2, was similar (Table 4).

Plot occurrence

We identified 836 of Panama's tree species in the 66 plots, or 27.5% of the tree flora. An additional 215 species were observed in inventories, so 1051 species (34.5%) appeared in our surveys. Those found in plots were a biased sample of range sizes, lacking the narrow end of the distribution (Fig. 4). Of the 836 species found in plots, just (4.5%) had ranges $< 20 \times 10^3$ km^2, compared to 20.6% of the 2206 species never encountered in a plot. At the other extreme, 22.1% of those plot species had wide ranges, $> 10^7$ km^2, compared to 8.7% of the non-plot species, and the median

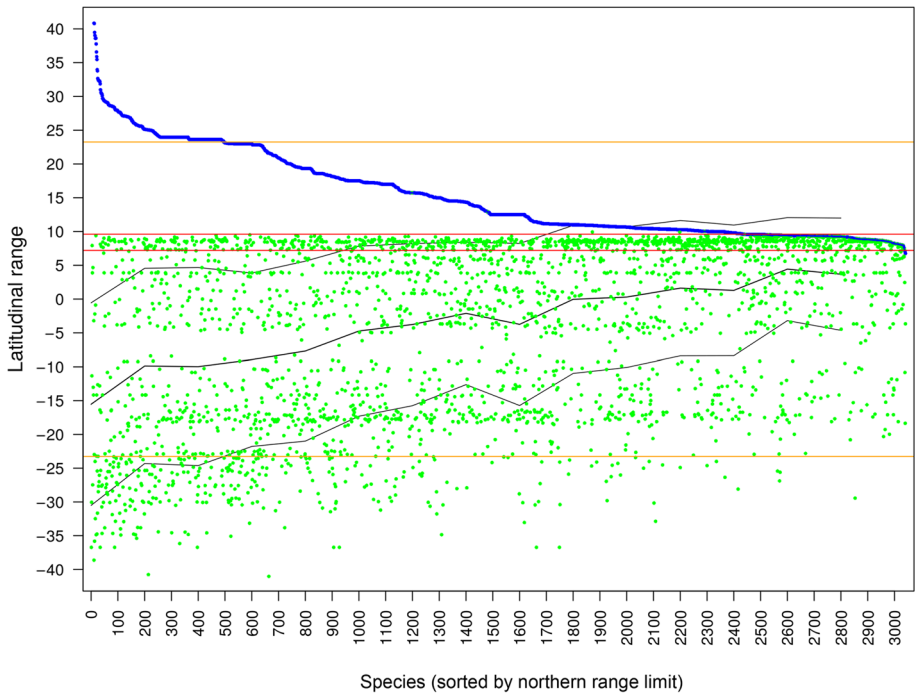

Fig. 2 Latitudinal range limits of Panama's 3043 tree species. Blue points are northern limits and green southern limits. The species are sorted by the northern limit, so the blue points form a smooth curve. Two red lines show Panama's latitude (7.2°-9.6°N), and two orange lines show the Tropics of Cancer and Capricorn (23.26°). The gray curves show mean ± SD of the southern limit for each successive group of 200 species. The increase in the southern limit across the graph shows that species whose ranges extend further north also extend further south. The difference is strong: 21% of the leftmost 1300 species on the graph (ranges extending north of Nicaragua at 14.9°N) have ranges extending beyond the Tropic of Capricorn; in contrast, only 1% of the rightmost 600 species (ranges not north of Panama) extend to the southern Tropic

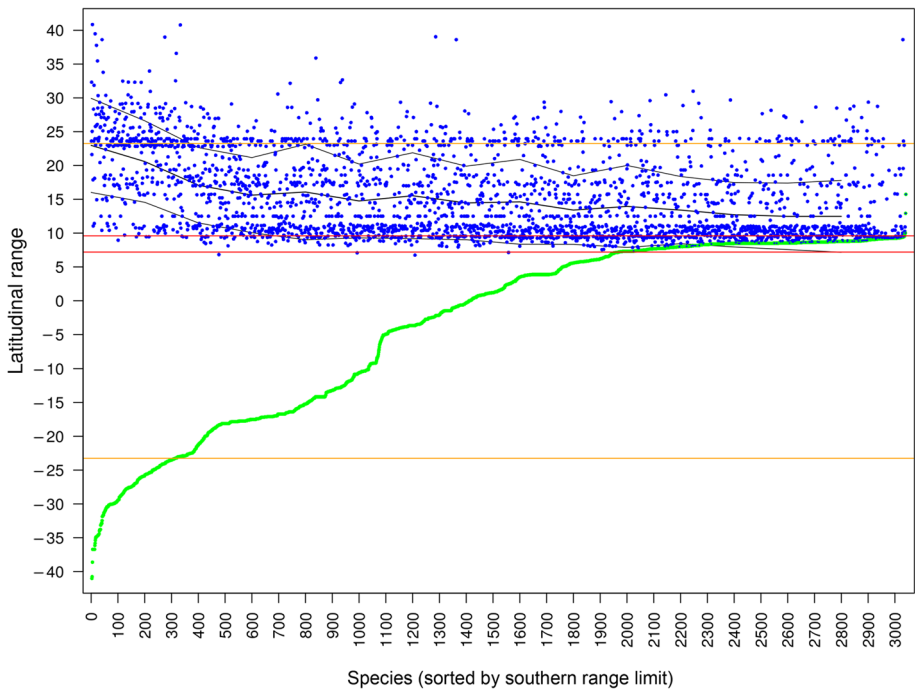

Fig. 3 Latitudinal range limits of Panama's 3043 tree species. Blue points are northern limits and green southern limits. The species are sorted by the southern range limit, so the green points form a smooth curve. Two red lines show Panama's latitude (7.2°-9.6°N), and two orange lines show the Tropics of Cancer and Capricorn (23.26°). The gray curves show mean ± SD of the northern limit for each successive group of 200 species

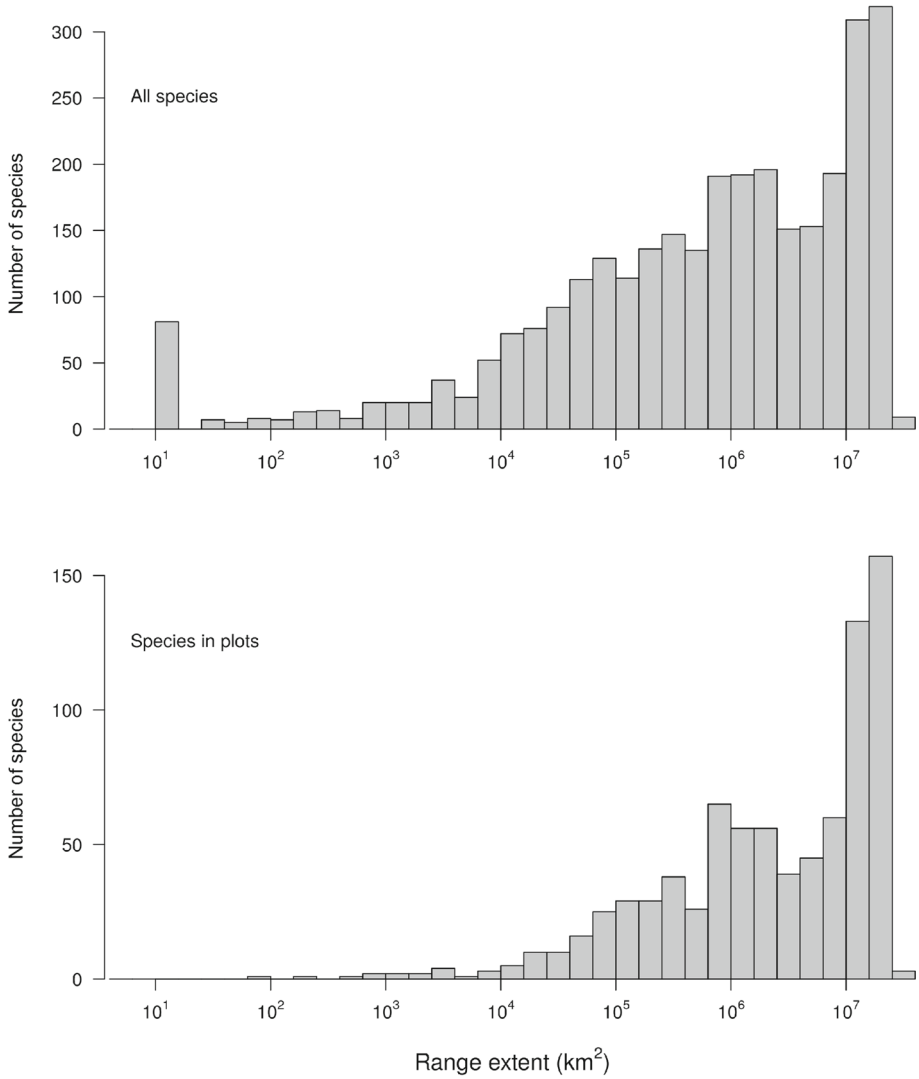

Fig. 4 Histogram of range sizes for all 3043 tree species in Panama (top) and for those 836 species identified in one of the plots (bottom), based on merged BIEN and Tropicos records. The far left bar (top panel) are those with too few records to calculate a polygon, for which the range was set to exactly 10 km^2. Median range sizes were 6.9 × 10^5 km^2 (all species), 4.1 × 10^5 km^2 (non-plot species), and 2.5 × 10^6 km^2 (plot species). The difference is highly significant (mean and confidence limits of the logarithm of range sizes were 6.15 ± 0.067 for plot species, 5.32 ± 0.063 for non-plot, based on *t*-statistics)

range size of plot species was six times higher than that of non-plot species (Fig. 4). Those results were based on the merged records, but differed little whether BIEN or Tropicos were used.

Taxonomy, tree height, and range

Range size was positively correlated with tree height (Fig. 7). This has a substantial effect on the proportion of narrow-range species: among species with maximum height < 5 m, 23.7% had ranges < 20 × 10^3 km^2, while of those ≥ 10 m tall, only 9.0% had small ranges. Most families showed the same pattern, but there were significant differences among families. For example, at the smallest heights, Annonaceae, Primulaceae, and Myrtaceae had median range extents of 10^4 km^2, while Fabaceae and Moraceae had medians of 10^6 km^2 (Fig. 7), and the fitted median range at 10 m tall varied significantly among families (Fig. 7). Supplemental results show fitted ranges at heights of 10 and 30 meters for all families and show the significant differences.

Discussion

With over 3000 tree species, Panama has much higher diversity than temperate tree flora. For example, Morin and Lechowicz (2013) found 598 species in North America, and McGlone et al. (2010) reported 582 trees species

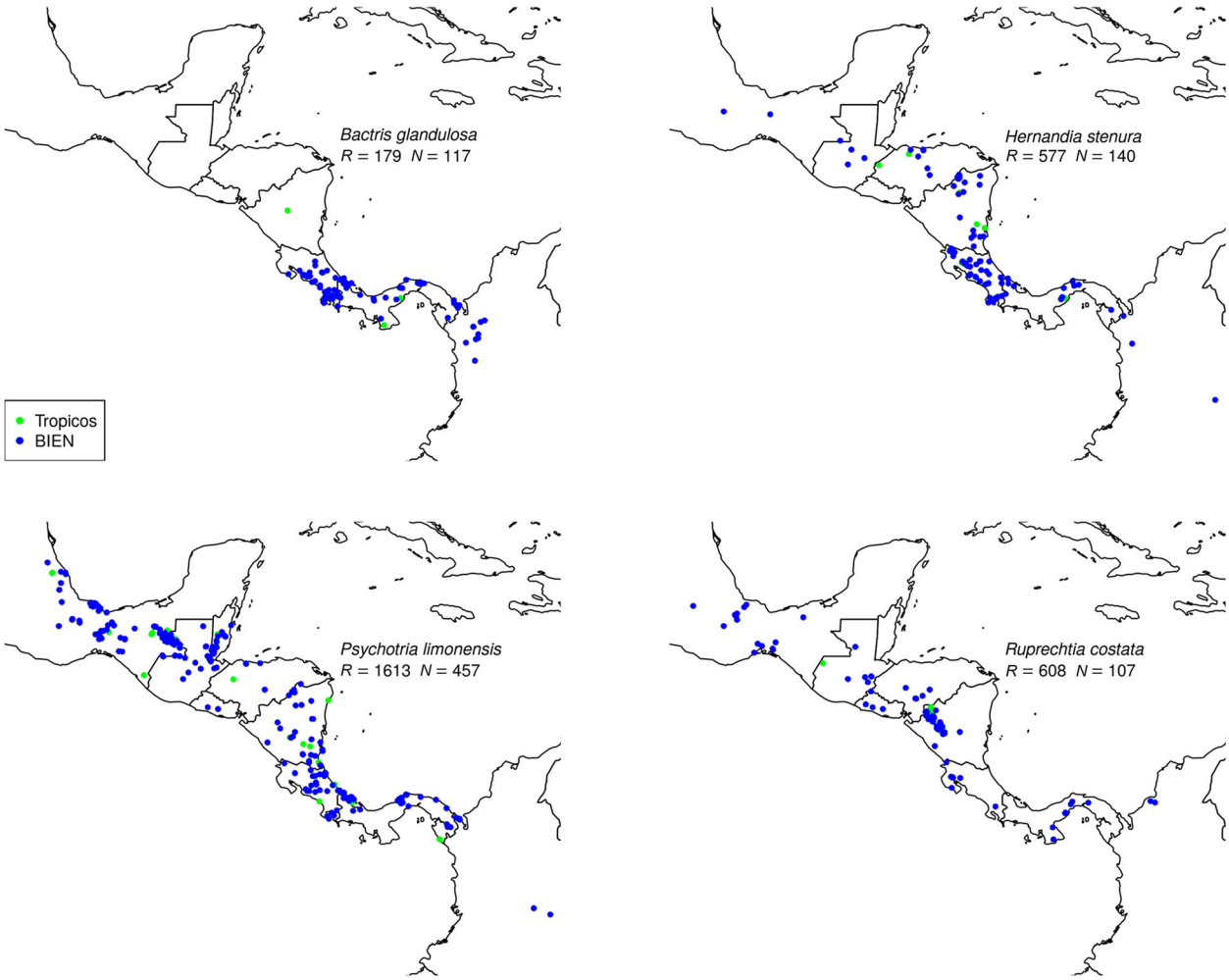

Fig. 5 Distribution maps of four species largely restricted to Central America. Blue points come from the BIEN database and green from Tropicos. Many green points are obscured by blue points, but the intent is only to show those places where the Tropicos data extend a range substantially, such as the northernmost record in *Bactris glandulosa*. *N* = the total number of unique coordinates, Tropicos and BIEN; *R* = range extent (10^3 km^2) from all those points

Table 5 Tally of rare species by the number of individual records (*N*) from which they are known

Range	$N = 1$	$N = 2$	$N \in [3, 4]$	$N \in [5, 9]$	$N \geq 10$
Narrow not endemic	0	4	12	34	168
Narrow and endemic	15	27	41	71	120
Endemic not narrow	0	0	0	0	10
Not endemic nor narrow	0	1	0	16	2524
Total narrow	15	31	53	105	288
Total endemic	15	27	41	71	130

The table entries are species counts, where narrow indicates species with range extent $< 20 \times 10^3$ km^2 and endemic are those species with records only in Panama. Each column is a count of species in a category of *N*, for example those with just one record ($N = 1$) or with 5-9 records ($N \in [5, 9]$). The top four rows comprise exhaustive and mutually exclusive categories; they add up to the total number of species, 3043. The bottom two rows give all narrow and endemic species, which are overlapping categories

in North America $\geq$ 6 m tall, as well as 215 species in New Zealand and 186 in Europe. Our tally of 3000 includes shrubby species, but by recording maximum heights, a precise comparison is possible: Panama has 2290 tree species $\geq$ 6 m tall (1851 with known height, the remaining extrapolated from those with unknown height). Panama's diversity, however, is not exceptional for the wet tropics. The Malay Peninsula has 3100 tree species in an area similar to Panama's (Kochummen et al. 1992), and Amazonia has about 15,000 tree species (ter Steege et al. 2015). The known flora of Panama, excluding ferns, is over 10,000 species (Correa et al. 2004), so trees make up more than a quarter. Contrast this with North America, where there are fewer than 1000 tree species out of a flora of 15,000 (Ulloa et al. 2017).

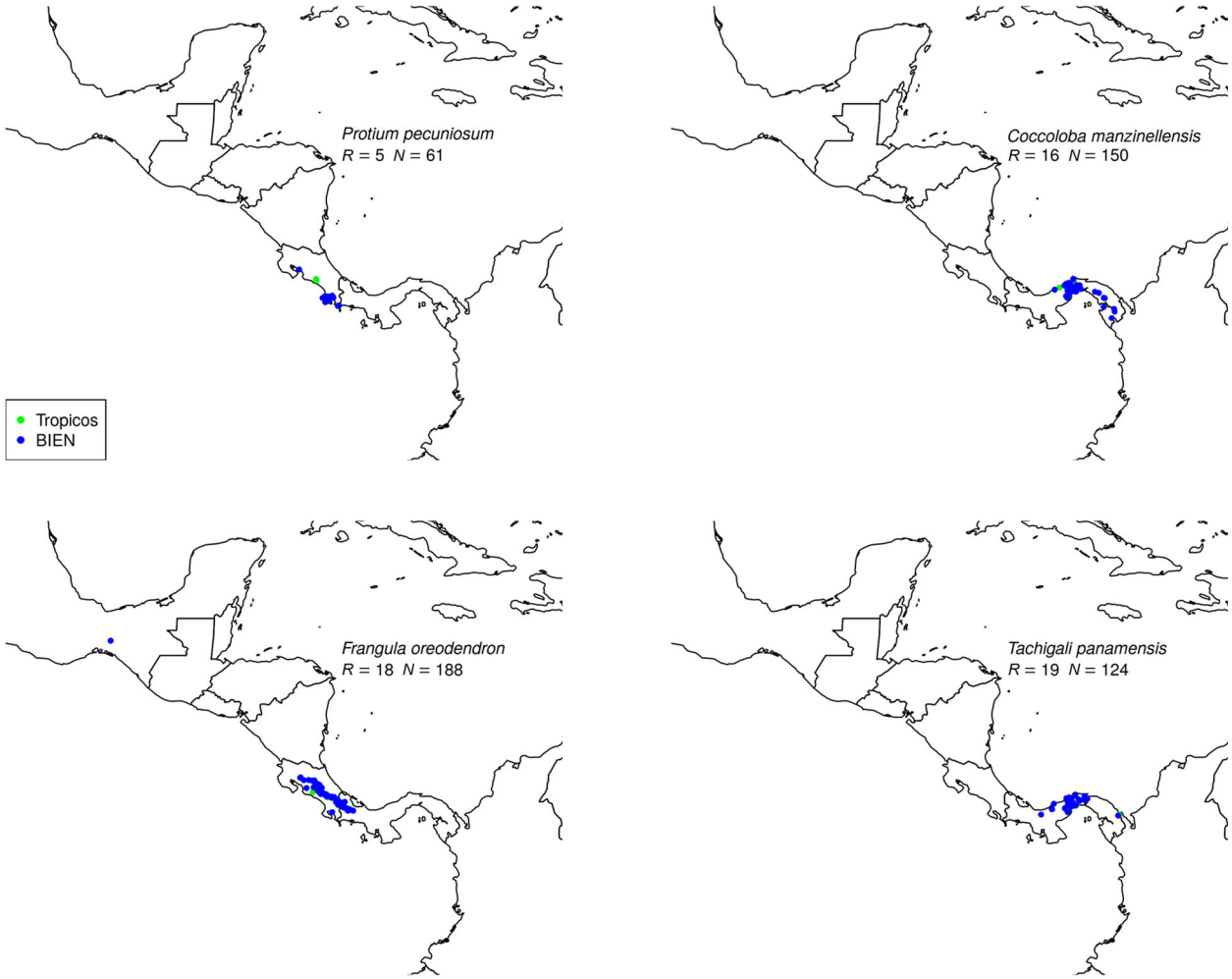

Fig. 6 Distribution maps of four species with ranges < 20 × 10^3 km^2. Blue points come from the BIEN database and green from Tropicos. Many green points are obscured by blue points, but the intent is only to show those places where the Tropicos data extend a range substantially, such as the northernmost record in *Protium pecuniosum*. *N* = the total number of unique coordinates, Tropicos and BIEN; *R* = range extent (10^3 km^2) from all those points

No tropical region has fully documented tree ranges, but we can compare range sizes in Panama with North American trees, for which estimates from detailed range maps are often calculated (Little Jr. 1971). Morin and Lechowicz (2011) present ranges in a histogram comparable to Fig. 4. The breadth of the distribution is similar, but the Panama histogram is so truncated near the maximum that it loses the log-normal form characteristic of range sizes (Morin and Lechowicz 2011; Ren et al. 2013). Panama thus has excess wide ranges, those reaching across the Neotropics to both 30°N and 30°S or beyond. Olmstead (2012) found that range limits of tropical lineages often reached both north and south to 35°latitude, and they linked this to the coldest monthly mean temperature of 10°C. Those latitudes reach from the southern USA to southern Brazil, covering nearly 2 × 10^7 km^2 and delimiting the widest ranges of Panama's trees.

At the other extreme, Panama has many narrow range tree species, but the histogram in Morin and Lechowicz (2011) also extends close to a minimum of 10 km^2. Reading from their histogram, there are 65 species (11% of the flora) with ranges less than 20,000 km^2 in North America. Among all Panama trees at least 3 m tall, we report 16% with comparable ranges, but if we consider only those 1851 known to be taller than 6 m, we find 195 species (10% of the flora). It thus appears that the frequency of narrow range trees in Panama does not differ from North America when height criteria match. This counters general wisdom about the high frequency of species with very small ranges in the tropics. Barthlott et al. (2005) and Linares-Palomino et al. (2011), for example, both tally >

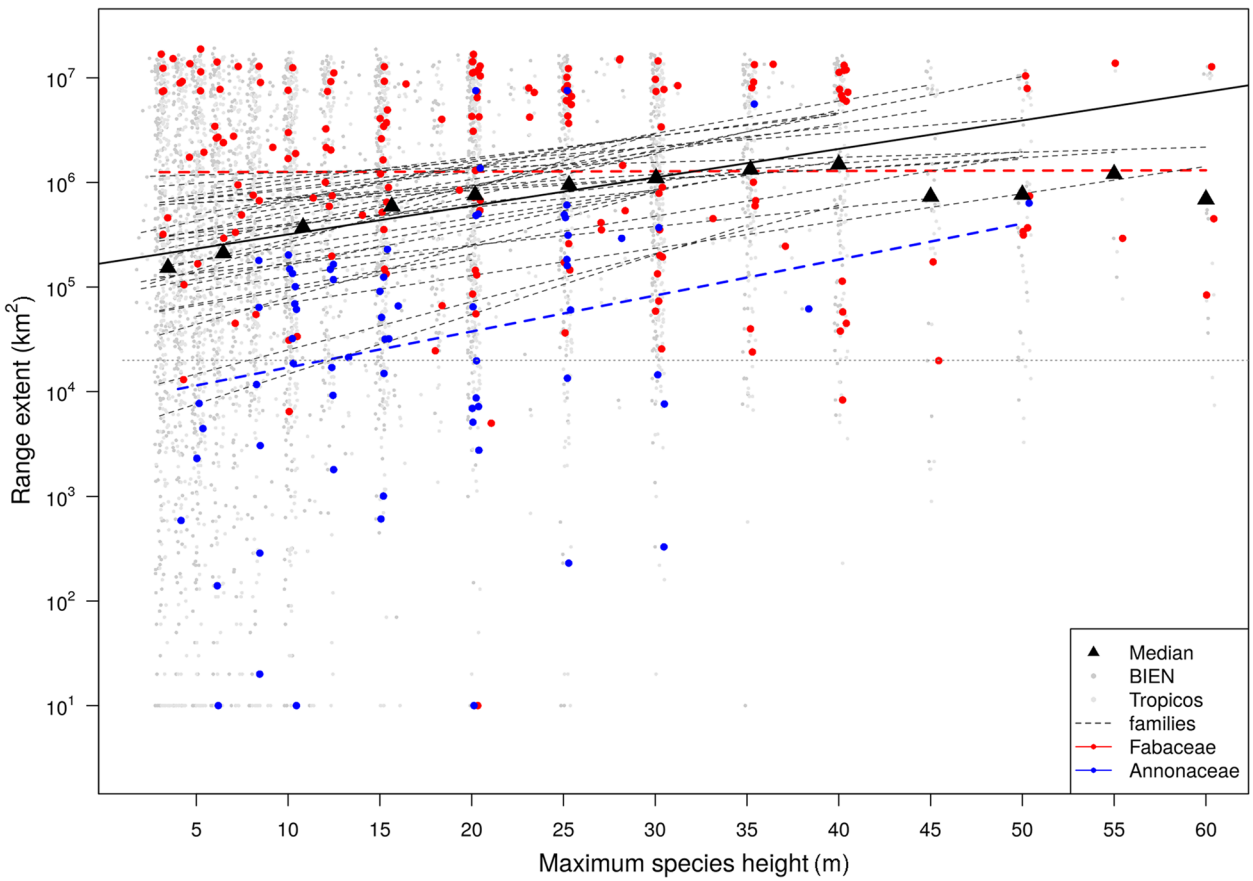

Fig. 7 Range extent vs. maximum height for 2461 tree species in Panama for which a maximum height was recorded. Faint gray points show individual species' ranges based on BIEN or Tropicos data. Large black triangles are the median range extent in 5-m height categories, using merged data (BIEN plus Tropicos). The solid black line is the overall regression (fixed effect) of log-transformed range extent (from merged data) against height; the slope is significantly > 0. Dashed lines are regressions for the 35 individual families (random effects) with at least 15 species. Two families illustrating taxonomic variation are highlighted with colored regression lines and points for species: Annonaceae with small ranges and a steep increase with height (blue) versus Fabaceae with large ranges and no increase with height variation (red). Among those 35 families, using fitted ranges at 10 m tall (ie where the family regression crosses height = 10), there were 12 significantly different from the median of 3.7×10^5 km^2. Among taller trees (the fitted range at 30 m tall), families converged in range size; only six were significantly different from the median of 1.2×10^6 km^2. The horizontal dashed line is at 20×10^3 km^2

40% of vascular plants as endemic to biogeographic zones of Central America similar in size to Panama. But these refer to all plants, not just trees. With rigorous comparisons using similar plant groups, it may simply not hold that the neotropics are home to an unusual concentration of narrow endemics.

Another consideration in broad comparisons is taxonomic. There are remarkable differences among families. One pair offers a striking example: among the Primulaceae (formerly the Myrsinaceae in the tropics), there are 101 tree species in Panama and 40 have ranges < 20,000 km^2, but of 66 Moraceae, there is not a single range size so narrow. We have to wonder how much of the variation between families is due to the specialists, which nearly always differ between taxonomic groups, and their inclination toward lumping versus splitting off new species.

In addition, we need to be careful about comparisons based on ranges of species represented in tree plots (Bemmels et al. 2018; Chacón-Madrigal et al. 2018). Our network of 66 tree plots crossing a climatic gradient in central Panama captured 27% of the tree flora of Panama, but only 7.5% of the narrow endemics. Plots thus provide a highly biased picture of range size. In retrospect, this should not be surprising, since the narrowest ranges are easily missed by plots whereas wide ranges will not be.

An important caveat to bear in mind is that Panama remains poorly known taxonomically and ecologically, and any range size estimate should be considered uncertain. Gentry (1992) described many cases where species once thought to be highly restricted were later discovered thousands of kilometers away, and we observed this often. As one example, *Tapirira rubrinervis* is on the red

list for Ecuador's trees based on its tiny range there (León Yánez et al. 2011), but now it is known from western Panama to Peru. On top of these extensions, we are working with many newly described species, typically known from one location (e.g. Maas et al. (2019); Santamaría-Aguilar et al. (2019) were published as we prepared this). Plus there are simple errors in identification, sometimes revealed by experts reversing each other (Morales and Zamora 2017; Garwood et al. 2018). We attempted to display some degree of uncertainty by presenting range calculations made with BIEN data versus Tropicos data, both widely used datasets that form the basis of many geographic studies. These give, for example, quite different counts of narrow-range species, but on the other hand, broad patterns of range sizes across the tree flora are similar, and both sources show at least 16% of tree species with ranges below 20,000 km^2.

Conclusions

The nation of Panama, with 78,000 km^2 of mostly forested land, has over 3000 tree species. This is based on a rigorous definition: all free-standing, terrestrial, woody plants at least 3 m tall. By tallying the maximum height known for those species, we conclude that 1753 are large trees, at least 10 m tall. Using readily available online sources of herbarium records, we calculated a geographic range for every one of those trees. The widest-ranging occur across the neotropics, over 1.5×10^7 km^2, while 15 species are known at only one location.

In tropical flora, the species range size is nearly always the basis of conservation assessment because no other information is available. The International Union for the Conservation of Nature red list of trees (Newton and Oldfield 2008) includes 6000 species, or 10% of the world's flora (Beech et al. 2017). We identified 492 tree species that occur over < 20,000 km^2, a range often signaling a status of endangered according to IUCN standards. An important step forward for these tree species, all poorly known, will be to estimate population sizes and make demographic assessments of extinction risk. Our tree plots in Panama offer details on local populations for 38 of those potential red-listed trees, and our next step is to assess the population size of those species.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s40663-020-00246-z.

Additional file 1: Supplemental Figures

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Authors' contributions
RC directed plot censuses and inventories, assembled and analyzed the data, and wrote the paper; RP and SA did field work identifying and collecting species and supervising plot censuses, and they commented on the manuscript. The author(s) read and approved the final manuscript.

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Availability of data and materials
A supplementary data archive shows additional results (Condit et al. 2019a). All species names, synonyms, and the full data, including all individual records and estimated range sizes, are available there for download.

Ethics approval and consent to participate
The research involved no human subjects. Permission from owners was always obtained for working in parks or on private land in Panama.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References

Allaby M (1992) The Concise Oxford Dictionary of Botany. Oxford University Press, Oxford
Barthlott W, Lauer W, Placke A (1996) Global distribution of species diversity in vascular plants: towards a world map of phytodiversity. Erdkunde 50:317–327
Barthlott W, Rafiqpoor D, Kier G, Kreft H (2005) Global centers of vascular plant diversity. Nova Acta Leopoldina 342:61–83
Beech E, Rivers M, Oldfield S, Smith PP (2017) GlobalTreeSearch: The first complete global database of tree species and country distributions. J Sustain For 36:454–489
Bemmels JB, Wright SJ, Garwood NC, Queenborough SA, Valencia R, Dick CW (2018) Filter-dispersal assembly of lowland Neotropical rainforests across the Andes. Ecography 41:1763–1775
Borhidi AL (2017) El subgénero Heteropsychotria (Rubiaceae, Palicoureeae) en México y Mesoamerica. Acta Bot Hung 59:13–23
Botanic Gardens Conservation International (2019). Global Tree Search. https://tools.bgci.org/global_tree_search.php. Visited 2 Oct 2019
Chacón-Madrigal E, Wanek W, Hietz P, Dullinger S (2018) Is local trait variation related to total range size of tropical trees? PLoS ONE 13:e193268
Condit R (1998a) Ecological implications of changes in drought patterns: shifts in forest composition in Panama. Clim Chang 39:413–427
Condit R (1998b) Tropical Forest Census Plots: Methods and Results from Barro Colorado Island, Panama and a Comparison with Other Plots. Springer-Verlag, Berlin
Condit R, Aguilar S, Hernandez A, Pérez R, Lao S, Angehr G, Hubbell S, Foster R (2004) Tropical forest dynamics across a rainfall gradient and the impact of an El Niño dry season. J Trop Ecol 20:51–72
Condit R, Engelbrecht BMJ, Pino D, Pérez R, Turner BL (2013) Species distributions in response to individual soil nutrients and seasonal drought across a community of tropical trees. Proc Natl Acad Sci 110:5064–5068
Condit R, Hubbell SP, Foster RB (1996) Changes in tree species abundance in a Neotropical forest: impact of climate change. J Trop Ecol 12:231–256
Condit R, Le Boeuf BJ, Morris PA, Sylvan M (2007) Estimating population size in asynchronous aggregations: a Bayesian approach and test with elephant seal censuses. Mar Mamm Sci 23:834–855

Condit R, Pérez R, Aguilar S (2019a) Complete Tree Species of Panama, DataONE, Dataset. https://doi.org/10.15146/R3M97W
Condit R, Pérez R, Aguilar S, Lao S (2019b) Census data from 65 tree plots in Panama:1994-2015. https://doi.org/10.15146/mdpr-pm59
Condit, R, Pérez R, Aguilar S, Lao S, Foster R, Hubbell S (2019c) Complete data from the Barro Colorado 50-ha plot: 423617 trees, 35 years, 2019 version. https://doi.org/10.15146/5xcp-0d46
Condit R, Pérez R, Aguilar S, Lao S, Hubbell SP (2017) Demographic trends and climate over 35 years in the Barro Colorado 50 ha plot. For Ecosyst 4:1–13
Condit R, Pérez R, Daguerre N (2011) Trees of Panama and Costa Rica. Princeton University Press
Condit R, Pérez R, Lao S, Aguilar S, Somoza A (2005) Geographic ranges and β-diversity: Discovering how many tree species there are where. Biol Skr 55:57–71
Condit R, Pitman N, Leigh EG, Chave J, Terborgh J, Foster RB, Núñez P, Aguilar S, Valencia R, Villa G, Muller-Landau HC, Losos E, Hubbell SP (2002) Beta-diversity in tropical forest trees. Science 295:666–669
Correa M, Galdames C, de Stapf MS (2004) Catálogo de las Plantas Vasculares de Panamá. Quebecor World Bogotá, Colombia
D'Arcy WG (1987) Flora of Panama. Checklist and Index. Part 1. The introduction and checklist. Monogr Syst Bot Mo Bot Gard 17. https://doi.org/10.5962/bhl.title.153180
Garwood NC, Jorna K, Flowers ND, Humphreys AM, Russell SJ, Neubig KM (2018) Trema domingensis rises like a Phoenix from the ashes of Trema integerrima: a reassessment of the entire-leaved species of neotropical Trema, (Cannabaceae). J Bot Res Inst Tex 12:555–577
Gaston KJ, Fuller RA (2009) The sizes of species' geographic ranges. J Appl Ecol 46:1–9
Gentry AH (1992) Tropical forest biodiversity: distributional patterns and their conservational significance. Oikos 63:19–28
Gschwantner T, Schadauer K, Vidal C, Lanz A, Tomppo E, di Cosmo L, Robert N, Englert Duursma D, Lawrence M (2009) Common tree definitions for National Forest Inventories in Europe. Silva Fenn 43:303–321
Hubbell SP, Foster RB (1983) Diversity of canopy trees in a neotropical forest and implications for conservation. In: Whitmore T, Chadwick A, Sutton A (eds). Tropical Rain Forest: Ecology and Management. The British Ecological Society, Oxford. pp 25–41
Hubbell SP, Foster RB (1986a) Biology, chance, and history and the structure of tropical rain forest tree communities. In: Diamond J, Case T (eds). Community Ecology. Harper and Row, New York. pp 314–329
Hubbell SP, Foster RB (1986b) Commonness and rarity in a Neotropical forest: implications for tropical tree conservation. In: Soulé M (ed). Conservation Biology: The Science of Scarcity and Diversity. Sinauer Associates, Inc, Sunderland, Massachusetts. pp 205–231
Kochummen KM, LaFrankie JV, Manokaran N (1992) Diversity of trees and shrubs in Malaya at regional and local levels. International Conference on Tropical Biodiversity 'In Harmony with Nature', Kuala Lumpur, Malaysia
León Yánez S, Valencia R, Pitman N, Endara L, Ulloa-Ulloa C, Navarrete H (2011) Libro Rojo de las Plantas Endémicas del Ecuador. Publicaciones del Herbario QCA, Pontificia Universidad Católica del Ecuador
Linares-Palomino R, Oliveira-Filho AT, Pennington RT (2011) Neotropical Seasonally Dry Forests: Diversity, Endemism, and Biogeography of Woody Plants. Island Press/Center for Resource Economics, Washington, DC
Little RJ, Jones CE (1980) A Dictionary of Botany. PNR Van Nostrand Reinhold Company, New York
Little Jr. EL (1971) Atlas of United States Trees. Volume 1. Conifers and important hardwoods. Misc. Publ. 1146. U.S. Department of Agriculture, Forest Service
Maas PJM, Westra LYT, Chatrou LW, Verspagen N, Rainer H, Zamora NA, Erkens RHJ (2019) Twelve new and exciting Annonaceae from the Neotropics. Phytokeys 126:25–69
Maitner BS, Boyle B, Casler N, Condit R, Donoghue J, Durán SM, Guaderrama D, Hinchliff CE, Jorgensen PM, Kraft NJ, McGill B, Merow C, Morueta-Holme N, Peet RK, Sandel B, Schildhauer M, Smith SA, Svenning J-C, Thiers B, Violle C, Wiser S, Enquist BJ (2017) The BIEN R package: A tool to access the Botanical Information and Ecology Network (BIEN) database. Methods Ecol Evol 9:373–379
McGlone MS, Richardson SJ, Jordan GJ (2010) Comparative biogeography of New Zealand trees: species richness, height, leaf traits and range sizes. N Z J Ecol 34:137–151
Missouri Botanical Garden (2020) Angiosperm Phylogeny Group Glossary. http://www.mobot.org/MOBOT/research/APweb/top/glossarya_h.html
Morales JF, Zamora NA (2017) A synopsis of Aspidosperma (Apocynaceae) in Mexico and Central America with a taxonomic clarification of Aspidosperma cruentum and a new cryptic species. Phytoneuron 68:1–13
Morin X, Lechowicz MJ (2011) Geographical and ecological patterns of range size in North American trees. Ecography 34:738–750
Morin X, Lechowicz MJ (2013) Niche breadth and range area in North American trees. Ecography 36:300–312
Newton AC, Oldfield S (2008) Red Listing the world's tree species: a review of recent progress. Endanger Species Res 6:137–147
Olmstead RG (2012) Phylogeny and biogeography in Solanaceae, Verbenaceae and Bignoniaceae: a comparison of continental and intercontinental diversification patterns. Bot J Linn Soc 171:80–102
Pell SK, Angell B (2016) Botanist's Vocabulary 1300 Terms Explained And Illustrated
Ren H, Condit R, Chen B, Mi X, Cao M, Ye W, Hao Z, Ma K (2013) Geographical Range and Local Abundance of Tree Species in China. PLoS One 8:e76374
Santamaría-Aguilar DA, Aguilar-Fernández R, Lagomarsino LP (2019) A taxonomic synopsis of Virola, (Myristicaceae) in Mesoamerica, including six new species. PhytoKeys 134:1–82
Taylor CM (2015) Rubiacearum Americanarum Magna Hama Pars XXXIV: The New Group Palicourea sect Tricephalium with eight new species and a new subspecies (Palicoureeae). Novon J Bot Nomenclature 24:55–95
ter Steege H, Pitman NCA, Killeen TJ, et al. (2015) Estimating the global conservation status of more than 15,000 Amazonian tree species. Sci Adv 1:e1500936
Turner BL, Brenes-Arguedas T, Condit R (2018) Pervasive phosphorus limitation of tree species but not communities in tropical forests. Nature 555:367–370
Ulloa CU, Acevedo-Rodríguez P, Beck S, Belgrano MJ, Bernal R, Berry PE, Brako L, Celis M, Davidse G, Forzza RC, Gradstein SR, Hokche O, León B, León-Yánez S, Magill RE, Neill DA, Nee M, Raven PH, Stimmel H, Strong MT, Villaseñor JL, Zarucchi JL, Zuloaga FO, Jørgensen PM (2017) An integrated assessment of the vascular plant species of the Americas. Science 358:1614–1617
Western Australian Herbarium (1998) FloraBase – the Western Australian Flora: Glossary of Botanical Terms. https://florabase.dpaw.wa.gov.au/
Williams JN, Viers JH, Schwartz MW (2010) Tropical dry forest trees and the relationship between local abundance and geographic range. J Biogeogr 37:951–959

Supplemental Figures

Figure S1. Fitted range extent at 10 m tall from the regression of range versus maximum height across 2461 tree species of Panama (all those with a height recorded). The model was hierarchical, with family as a random effect, so there is a regression for all 141 families; those were used to calculate an estimated range as well as 95% credible intervals at 10 m tall. Each family appears, with a black circle at the fitted height and a vertical gray line showing credible intervals; they are sorted from the smallest to largest fitted ranges. The 35 families having at least 15 species are highlighted with red circles and lines, and those families are labeled (some above, others below, in order to spread out the names). The horizontal orange line is at the median fitted height for all families.

Figure S2. Fitted range size at 30 m tall from the regression of range versus maximum height across 2461 tree species of Panama. See the legend for Supplemental Figure S1.

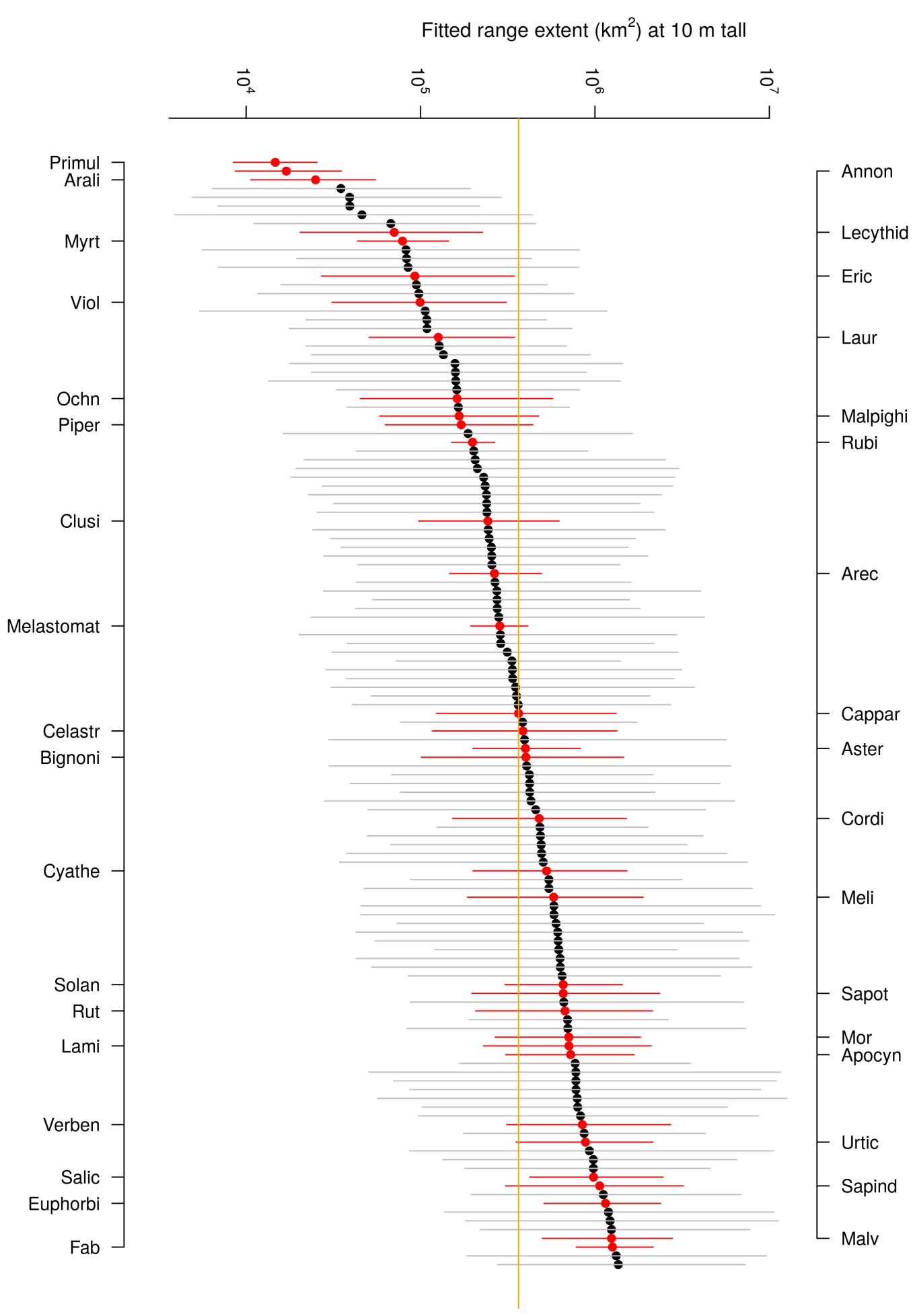
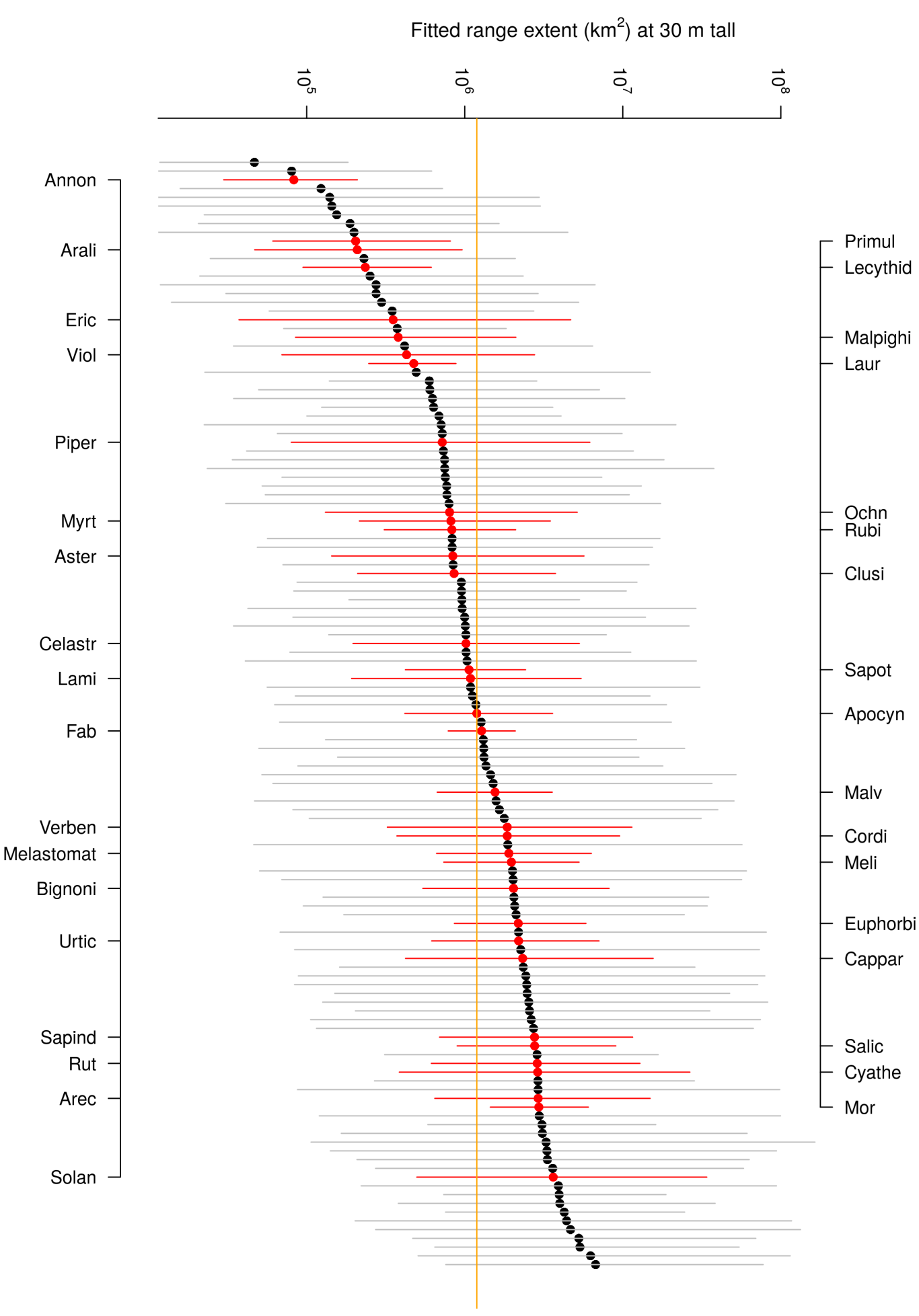

Fitted range extent (km^2) at 10 m tall
10^4
10^5
10^6
10^7
Primul
Arali
Myrt
Viol
Ochn
Piper
Clusi
Melastomat
Celastr
Bignoni
Cyathe
Solan
Rut
Lami
Verben
Salic
Euphorbi
Fab
Annon
Lecythid
Eric
Laur
Malpighi
Rubi
Arec
Cappar
Aster
Cordi
Meli
Sapot
Mor
Apocyn
Urtic
Sapind
Malv

Figure S1

Figure S2


Fitted range extent (km^2) at 30 m tall
10^5
10^6
10^7
10^8
Annon
Arali
Eric
Viol
Piper
Myrt
Aster
Celastr
Lami
Fab
Verben
Melastomat
Bignoni
Urtic
Sapind
Rut
Arec
Solan
Primul
Lecythid
Malpighi
Laur
Ochn
Rubi
Clusi
Sapot
Apocyn
Malv
Cordi
Meli
Euphorbi
Cappar
Salic
Cyathe
Mor

Appendix 1. Family monographs we consulted in the *Flora Mesoamericana* and the *Manual de Plantas de Costa Rica*. All 141 tree families from Panama appear, including 26 for which neither volume has been completed. All 49 published chapters from *Flora Mesoamericana* among those 141 families are included. For the Costa Rica Manual, only chapters we consulted are here, including those for which *Flora Mesoamericana* was not finished, plus a few more. Some of the chapters use different family names than ours. The Costa Rica Manual is completed for all families alphabetically after Clusiaceae, though the Arecaceae was covered in the volume on monocots; the Achariaceae, Calophyllaceae, and Cardiopteridaceae were covered because they were known under alternate names.

Family	Flora Mesoamericana	Manual Costa Rica
Acanthaceae	.	.
Achariaceae	.	González (2010c)
Actinidiaceae	.	.
Adoxaceae	.	.
Alzateaceae	Graham (2009b)	.
Amaranthaceae	.	.
Anacardiaceae	.	.
Annonaceae	.	.
Apiaceae	Constance & Affolter (2009)	.
Apocynaceae	Morales (2009)	.
Aquifoliaceae	.	.
Araliaceae	Cannon & Cannon (2009)	.
Arecaceae	.	Grayum (2003)
Asparagaceae	Lott & García-Mendoza (1994)	.
Asteraceae	Pruski & Robinson (2018)	.
Betulaceae	.	.
Bignoniaceae	.	.
Bixaceae	.	.
Brunelliaceae	.	.
Burseraceae	.	.
Buxaceae	.	.
Cactaceae	.	.

Appendix 1 (cont). Monographs for Panama tree families.

Family	Flora Mesoamericana	Manual Costa Rica
Calophyllaceae	.	Hammel (2010)
Campanulaceae	.	.
Cannabaceae	Nee (2015b)	.
Capparaceae	Cornejo & Iltis (2015)	.
Cardiopteridaceae	.	Hammel (2007b)
Caricaceae	Carvalho (2015)	.
Caryocaraceae	.	.
Celastraceae	Lombardi & Barrie (2015)	.
Chloranthaceae	.	.
Chrysobalanaceae	.	.
Clethraceae	Vickery (2009)	.
Clusiaceae	.	Hammel (2010)
Combretaceae	Stace (2009)	.
Connaraceae	.	Morales (2010a)
Cordiaceae	Miller (2012a)	.
Cornaceae	Hampshire (2009b)	.
Cunoniaceae	.	Morales (2010b)
Cyatheaceae	Moran (1995)	.
Cyrillaceae	.	.
Dichapetalaceae	.	Prance *et al.* (2010)
Dilleniaceae	.	González (2010a)
Dipentodontaceae	.	.
Ebenaceae	Whitefoord & Knapp (2012)	.
Ehretiaceae	Miller (2012b)	.
Elaeocarpaceae	.	Smith (2010)
Ericaceae	Luteyn & Wilbur (2009)	.
Erythroxylaceae	.	Plowman & Barrie (2010)
Escalloniaceae	.	Morales (2010d)
Euphorbiaceae	.	González (2010b)

Appendix 1 (cont). Monographs for Panama tree families.

Family	Flora Mesoamericana	Manual Costa Rica
Fabaceae	.	Zamora (2010)
Fagaceae	.	Morales (2010c)
Garryaceae	Hampshire (2009c)	González (2010d)
Gentianaceae	Wilbur (2009)	Sánchez (2010)
Gesneriaceae	.	Kriebel (2010)
Goupiaceae	.	.
Heliotropiaceae	Miller (2012c)	.
Hernandiaceae	.	González (2007a)
Humiriaceae	.	Zamora (2007)
Hydrophyllaceae	Ricketson (2012)	.
Hypericaceae	.	Hammel (2007a)
Icacinaceae	.	Hammel (2007b)
Juglandaceae	.	Morales (2007a)
Lacistemataceae	.	González (2007b)
Lamiaceae	Pool *et al.* (2012)	.
Lauraceae	.	Gonzáles & Poveda (2007)
Lecythidaceae	Mori & Prance (2009)	.
Lepidobotryaceae	Morales (2015a)	.
Loganiaceae	Huft (2009)	.
Loranthaceae	.	Morales (2007b)
Lythraceae	Graham (2009a)	.
Magnoliaceae	.	González (2007c)
Malpighiaceae	.	Anderson (2007)
Malvaceae	.	Rodríguez (2015b); Fryxell (2007); Rodríguez (2015a)
Melastomataceae	Almeda (2009)	.
Meliaceae	.	Jiménez (2007a)
Menispermaceae	.	Jiménez (2007b)
Metteniusaceae	.	Hammel (2007b)
Monimiaceae	.	Gómez-Laurito (2007)

Appendix 1 (cont). Monographs for Panama tree families.

Family	Flora Mesoamericana	Manual Costa Rica
Moraceae	Berg (2015)	.
Muntingiaceae	.	Rodríguez (2007)
Myricaceae	.	Morales (2007c)
Myristicaceae	.	Jiménez (2007c)
Myrtaceae	Landrum *et al.* (2009)	Barrie (2007)
Nyctaginaceae	.	González (2007d)
Nyssaceae	Hampshire (2009a)	.
Ochnaceae	.	Morales (2007e, 2014c)
Olacaceae	.	Jiménez (2007d)
Oleaceae	Green (2012)	.
Onagraceae	Hoch (2009)	.
Papaveraceae	.	Soto (2007)
Passifloraceae	.	González (2015); Rodríguez & Estrada (2007)
Pentaphylacaceae	.	Jiménez (2015b)
Peraceae	.	González (2010b)
Phyllanthaceae	.	González (2010b)
Phyllonomaceae	.	Morales (2010d)
Phytolaccaceae	.	Morales (2007f)
Picramniaceae	.	Martén-Rodríguez (2014)
Piperaceae	.	Callejas (2014)
Poaceae	.	Morales (2003)
Podocarpaceae	.	Merello (2013a)
Polygalaceae	.	Morales (2014a)
Polygonaceae	.	Soto (2014)
Primulaceae	Ricketson & Pipoly (2009); Ståhl (2009)	Morales (2007d)
Proteaceae	.	Morales (2014b)
Putranjivaceae	.	González (2010b)
Resedaceae	Knapp & Pena-Chocarro (2015)	.
Rhamnaceae	Pool (2015)	.

Appendix 1 (cont). Monographs for Panama tree families.

Family	Flora Mesoamericana	Manual Costa Rica
Rhizophoraceae	Barrie (2009)	.
Rosaceae	Barrie & Pérez-Zabala (2015)	.
Rubiaceae	Lorence & Taylor (2009)	Taylor (2014)
Rutaceae	.	Jiménez (2014)
Sabiaceae	.	Morales (2015b)
Salicaceae	.	González (2010c); Grayum (2015a)
Sapindaceae	.	Morales (2015c)
Sapotaceae	Penninton *et al.* (2009)	Morales (2015d)
Schlegeliaceae	.	Morales (2015e)
Schoepfiaceae	.	Jiménez (2007d)
Scrophulariaceae	.	.
Simaroubaceae	.	Rodríguez (2015c)
Siparunaceae	.	Morales (2015f)
Solanaceae	.	Bohs (2015)
Staphyleaceae	.	Morales (2015g)
Stemonuraceae	.	Hammel (2007b)
Styracaceae	Fritsch (2012)	Zamora (2015)
Symplocaceae	Kelly & Almeda (2012)	Kriebel & Almeda (2015)
Tapisciaceae	.	.
Tetrameristaceae	.	Jiménez (2015a)
Theaceae	.	Jiménez (2015b)
Thymelaeaceae	.	Grayum (2015b)
Ticodendraceae	.	Gómez-Laurito (2015)
Ulmaceae	Nee (2015a)	.
Urticaceae	Monro (2015); Berg (2015)	.
Verbenaceae	Rueda (2012)	.
Violaceae	.	Ballard (2015)
Vochysiaceae	.	Morales (2015h)
Winteraceae	.	Formoso (2015)

Appendix 1 (cont). Monographs for Panama tree families.

Family	Flora Mesoamericana	Manual Costa Rica
Ximeniaceae	.	Jiménez (2007d)
Zamiaceae	.	Merello (2013b)
Zygophyllaceae	Stafford (2015)	.

Appendix 2. Additional references consulted for each family of Panama's trees (ie excluding *Flora Mesoamericana* and the Costa Rica Manual, which appear in Appendix 1). Families are included only if additional references were checked. These are not necessarily family monographs; some cover genera or a few species.

Family	References
Acanthaceae	Durkee (1986, 1978); Daniel & McPherson (2014)
Actinidiaceae	Hunter (1965)
Adoxaceae	Bolli (1994); Applequist (2015); D'Arcy (1973)
Anacardiaceae	Blackwell & H. (1967); Mitchell & Daly (2015)
Annonaceae	Schatz *et al.* (2015); Maas *et al.* (1992); Rainer (2006); Pirie (2005); Murray (1993); Schatz *et al.* (2018); Maas *et al.* (2003, 2015, 2007); Chatrou (1998); Junikka *et al.* (2016); Erkens *et al.* (2006); Schatz *et al.* (2017); Schatz & Maas (2010); Maas *et al.* (2019)
Apocynaceae	Morales & Zamora (2017); Simões *et al.* (2010); Morales & Méndez G. (2005); Endress & Simões (2016); Spellman (1975)
Aquifoliaceae	Hahn (1993)
Araliaceae	Piedrahíta *et al.* (2015); Morales & Grayum (2009)
Arecaceae	Borchsenius & Bernal (1996); Henderson *et al.* (1997); Henderson (2005); Evans (2001); Henderson & Galeano (1996); Henderson (1990); Evans (1995); Henderson (2011); Galeano & Bernal (2017)
Asteraceae	King & Robinson (1977)
Bignoniaceae	Burger & Gentry (2005); Grose & Olmstead (2007)
Bixaceae	Moreira *et al.* (2015); Croat (1978)
Burseraceae	Daly (1993); Porter (1970); Daly & Fine (2018); Daly (2014, 2007)
Buxaceae	Gentry (1978a)
Cactaceae	Butterworth & Wallace (2005)
Calophyllaceae	D'Arcy (1980)
Cannabaceae	Garwood *et al.* (2018)
Celastraceae	Biral (2017); Biral & Lombardi (2016)
Chrysobalanaceae	Sothers *et al.* (2016); Santamaría-Aguilar *et al.* (2015)
Clusiaceae	Hammel (1999); Marinho *et al.* (2019); Gahagen *et al.* (2015); D'Arcy (1980); Hammel (1986); Maguire (1978)
Cunoniaceae	Morales (2010e)
Cyatheaceae	Rojas-Alvarado (2007, 2005)
Ericaceae	Luteyn & Wilbur (2005); Luteyn *et al.* (1995)
Erythroxylaceae	Plowman & Hensold (2004)
Euphorbiaceae	Webster & Huft (1988); Secco (2005); Dehgan (2012); McPherson (2011); Cardinal-McTeague & Gillespie (2016)
Fabaceae	Wunderlin (1983); Colín (2001); Gagnon *et al.* (2016); Barneby (1998); da Silva *et al.* (2012); Brummitt (2011); Torke & Schaal (2008); Pennington (1997); Sousa (1993); de Lourdes Rico Arce *et al.* (2008); van der Werff & Zamora V. (2010); Torke & Zamora (2010); Filardi *et al.* (2013); Radosavljevic (2019)
Fagaceae	Breedlove (2001); Nixon & Barrie (2017)
Gentianaceae	Struwe & Albert (2004)
Gesneriaceae	Skog (1978)

Appendix 2 (cont). Monographs for Panama tree families.

Family	References
Hypericaceae	Robson (1978)
Icacinaceae	Angula *et al.* (2013)
Lauraceae	Nishida (1999); Der Werff (2009); Rohwer (1993); Trofimov *et al.* (2016); van der Werff (2002); Zamora (2017); van der Werff (2009, 1993); Rohde *et al.* (2017)
Lecythidaceae	Mori *et al.* (2016); Batista G. & Mori (2017); Mori & Prance (1990); Prance (1979)
Magnoliaceae	Figlar & Nooteboom (2004); Azuma *et al.* (2001)
Malpighiaceae	Cuatrecasas *et al.* (1980); Anderson (1997); Anderson & Davis (2007)
Malvaceae	Donnell *et al.* (2012); Robyns (1964); Fernández-Alonso (2011)
Melastomataceae	Michelangeli *et al.* (2016); Gamba-Moreno & Almeda (2014); Judd *et al.* (2018a); Penneys *et al.* (2010); Kriebel (2016); Almeda & Penneys (2014); Gamba-Moreno & Almeda (2015); Penneys & Judd (2013); Kriebel & Almeda (2012, 2013); Almeda *et al.* (2014); Judd *et al.* (2018b)
Meliaceae	Pennington & Clarkson (2013); Pennington (2016)
Monimiaceae	Morales & Grayum (2009)
Moraceae	Berg (2001, 1972, 2007, 2009); Croat (1978); Machado *et al.* (2005)
Myristicaceae	Janovec & Harrison (2002); Santamaría-Aguilar *et al.* (2019)
Myrtaceae	Lourenco *et al.* (2018); Barrie (2004); Barrie *et al.* (2016); Flores *et al.* (2016)
Ochnaceae	Whitefoord (1992); Schneider & Zizka (2016)
Pentaphylacaceae	Gentry (1978b)
Phyllanthaceae	Huft (1989); Wurdack *et al.* (2004)
Picramniaceae	Thomas (2011)
Polygalaceae	Pastore *et al.* (2010); Taylor (1985)
Primulaceae	Ricketson & Pipoly (1997, 2003)
Rhamnaceae	Hauenschild *et al.* (2016)
Rosaceae	Pérez-Zabala (2007)
Rubiaceae	Berger (2017); Borhidi (2017); Persson & Delprete (2017); Taylor *et al.* (2010); Taylor (2017a); Borhidi (2017); Taylor (2015b); Taylor & Hollowell (2016); Taylor (2017b, 2015a); Dwyer (1980); Borhidi (2011); Standley (1940); Taylor *et al.* (2011a,b); Taylor (1992); Berger (2018)
Rutaceae	Kallunki & Pirani (1998); Groppo (2010); Reynel (2017); Kallunki (2009)
Salicaceae	Santamaría-Aguilar *et al.* (2015)
Sapotaceae	Alves-Araújo & Alves (2012)
Schlegeliaceae	D'Arcy (1979)
Simaroubaceae	Devecchi *et al.* (2018)
Siparunaceae	Renner & Hausner (2005)
Solanaceae	Croat (1978); Bohs (1994); de Carvalho (1991); Knapp S, Stafford M, Sousa Pena M, Martinez M (2005); Monro (2012)
Symplocaceae	Kelly *et al.* (2016)
Thymelaeaceae	Barringer & Nevling (1994)
Urticaceae	Berg *et al.* (2005); Monro (2012)

Appendix 2 (cont). Monographs for Panama tree families.

Family	References
Violaceae	Robyns (1967a); de Paula-Souza & Ballard Jr (2014); Todzia (1989); Wahlert & Ballard (2009); Wahlert *et al.* (2014)
Vochysiaceae	Robyns (1967b)

Taxonomic Literature Cited

Almeda, F. (2009). 180. Melastomataceae. *Flora Mesoamericana*, *Volume 4*, pp. 164–337.

Almeda, F., Marcela, A. & Mendoza, H. (2014). Two new species of *Graffenrieda* (Melastomataceae: Merianieae) from Colombia and Panama. *Phytotaxa*, **1**63, 39–47.

Almeda, F. & Penneys, D. S. (2014). New and reconsidered species of tropical American Melastomataceae. *Brittonia*, **6**6, 160–169.

Alves-Araújo, A. & Alves, M. (2012). Two new species and a new combination of Neotropical Sapotaceae. *Brittonia*, **6**4, 23–29.

Anderson, C. (1997). Revision of *Pterandra* (Malpighiaceae). *Contributions of the University of Michigan Herbarium*, **2**1, 1–27.

Anderson, W. R. (2007). Malpighiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 253–312.

Anderson, W. R. & Davis, C. C. (2007). Generic adjustments in neotropical Malpighiaceae. *Contributions of the University of Michigan Herbarium*, **2**5, 137–166.

Angula, D. F., Stefano, R. D. D. & Stull, G. W. (2013). Systematics of *Mappia* (Icacinaceae), an endemic genus of tropical America. *Phytotaxa*, **1**16, 1–18.

Applequist, W. (2015). A brief review of recent controversies in the taxonomy and nomenclature of *Sambucus nigra* sensu lato. *Acta Horticulturae*, **1**061, 25–33.

Azuma, H., García-Franco, J. G., Rico-Gray, V. & Thien, L. B. (2001). Molecular phylogeny of the Magnoliaceae: the biogeography of tropical and temperate disjunctions. *Am. J. Bot.*, **8**8, 2275–2285.

Ballard, H. E. (2015). Violaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 593–611.

Barneby, R. C. (1998). Silk tree, guanacaste, monkey's earring: a generic system of the synandrous Mimosaceae of the Americas. Part III. *Calliandra*. *Memoirs of the New York Botanical Garden*, **7**4, 223.

Barrie, F. (2009). 181. Rhizophoraceae. *Flora Mesoamericana*, *Volume 4*, pp. 49–65.

Barrie, F. & Pérez-Zabala, J. A. (2015). 99. Rosaceae. *Flora Mesoamericana*, *Volume 4*, pp. 49–65.

Barrie, F. R. (2004). Synopsis of *Plinia* (Myrtaceae) in Mesoamerica. *Novon*, **1**4, 380–400.

Barrie, F. R. (2007). Myrtaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 729–785.

Barrie, F. R., Ramos, C., Ortiz, O. O., Vergara-Pérez, I. & McPherson, G. (2016). Five new species of *Eugenia* (Myrtaceae) from Panama. *Novon: A Journal for Botanical Nomenclature*, **2**4, 333–342.

Barringer, K. & Nevling, L. I. (1994). New species of *Daphnopsis* (Thymeleaceae) from Panama. *Novon*, **4**, 9–15.

Batista G., J. E. & Mori, S. A. (2017). *Eschweilera correae* (Lecythidaceae), a new species from the cloud forests of Panama and Costa Rica. *Brittonia*, **6**9, 340–346.
Berg, C. C. (1972). Olmedieae Brosimeae (Moraceae). *Flora Neotropica*, **7**, 1–228.
Berg, C. C. (2001). Moreae, Artocarpeae, and *Dorstenia* (Moraceae). *Flora Neotropica*, **8**3, 1–347.
Berg, C. C. (2007). Proposals for treating four species complexes in *Ficus* subgenus Urostigma section Americanae (Moraceae). *Blumea-Biodiversity, Evolution and Biogeography of Plants*, **5**2, 295–312.
Berg, C. C. (2009). Moraceae. *Flora of Ecuador* (eds. G. Harling & C. Persson), *Volume 27C*.
Berg, C. C. (2015). 103. Moraceae. *Flora Mesoamericana*, *Volume 2*, pp. 90–116.
Berg, C. C., Rosselli, P. F. & Davidson, D. W. (2005). Cecropia. *Flora Neotropica*, **9**4, 1–230.
Berger, A. (2017). Two new combinations, lectotypifications and a new name for Costa Rican *Palicourea* s.l. *PhytoKeys*, **8**0, 53–63.
Berger, A. (2018). Synopsis and typification of Mexican and Central American *Palicourea* (Rubiaceae: Palicoureeae), part I: The entomophilous species. *Annalen des Naturhistorischen Museums in Wien. Serie B f ur Botanik und Zoologie*, **1**20, 59–140.
Biral, L. (2017). Systematics of New World *Maytenus* (Celastraceae) and a New Delimitation of the Genus. *Systematic Botany*, **4**2, 680–693.
Biral, L. & Lombardi, J. (2016). New synonyms and lectotypifications in the genus *Maytenus* (Celastroideae, Celastraceae) and a new name for the illegitimate *Maytenus nemorosa* from Brazil. *Phytotaxa*, **2**61, 97–100.
Blackwell, W. H. & H., D. C. (1967). Family 101. Anacardiaceae. *Flora of Panama, Part VI* (eds. R. E. Woodson & R. W. Schery), *Volume 54*, pp. 351–379. Missouri Botanical Garden Press.
Bohs, L. (1994). *Cyphomandra* (Solanaceae). *Flora Neotropica*, *Volume Monograph 63*, pp. 1–175.
Bohs, L. (2015). Solanaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 205–336.
Bolli, R. (1994). Revision of the Genus *Sambucus*. *Dissertationes Botanicae*, **2**23.
Borchsenius, F. & Bernal, R. (1996). *Aiphanes* (Palmae). *Flora Neotropica*, **7**0, 1–94.
Borhidi, A. (2011). Transfer of the Mexican species of *Psychotria* subgen. *Heteropsychotria* to *Palicourea* based on morphological and molecular evidences. *Acta Botanica Hungarica*, **5**3, 241–250.
Borhidi, A. L. (2017). El subgénero *Heteropsychotria* (Rubiaceae, Palicoureeae) en México y Mesoamerica. *Acta Botanica Hungarica*, **5**9, 13–23.
Breedlove, D. (2001). Fagaceae. *Flora de Nicaragua. Monographs in Systematic Botany. Missouri Botanical Garden*, **8**5, 1076–1084.
Brummitt, R. K. (2011). Report of the Nomenclature Committee for Vascular Plants: 62. *Taxon*, **6**0.
Burger, W. & Gentry, A. (2005). Bignoniaceae. *Flora Costaricensis*, pp. 77–161. Field Museum of Natural History.
Butterworth, C. A. & Wallace, R. S. (2005). Molecular phylogenetics of the leafy cactus genus *Pereskia* (Cactaceae). *Systematic Botany*, **3**0, 800–808.
Callejas, R. (2014). Piperaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 7*, pp. 6–326.
Cannon, M. J. & Cannon, J. F. M. (2009). 188. Araliaceae. *Flora Mesoamericana*, *Volume 4*, pp. 365–385.
Cardinal-McTeague, W. M. & Gillespie, L. J. (2016). Molecular Phylogeny and Pollen

Evolution of Euphorbiaceae Tribe Plukenetieae. *Systematic Botany*, **4**1, 329 – 347.
Carvalho, F. A. (2015). 113. Caricaceae. *Flora Mesoamericana*, *Volume 2*, pp. 236–239.
Chatrou, L. (1998). Revision of the *Malmea* alliance: *Malmea* and three new, Neotropical genera: *Klarobelia* , *Mosannona* , and *Pseudomalmea*. *Changing Genera: Systematic Studies in Neotropical and West African Annonaceae*, chapter 6, pp. 105–192. Herbarium Division, University of Utrecht.
Colín, R. T. (2001). Una especie nueva de *Bauhinia* (Fabaceae: Caesalpinioideae: Cercideae) de Panamá. *Novon*, **1**1, 143–145.
Constance, L. & Affolter, J. (2009). 189. Apiaceae. *Flora Mesoamericana*, *Volume 4*, pp. 386–407.
Cornejo, X. & Iltis, H. H. (2015). 117. Capparaceae. *Flora Mesoamericana*, *Volume 2*, pp. 242–256.
Croat, T. R. (1978). *Flora of Barro Colorado Island*. Stanford, California, Stanford University Press.
Cuatrecasas, J., Croat, T. B. & Vivaldi, J. (1980). Family 93. Malpighiaceae. *Flora of Panama. Part VI.* (eds. R. E. Woodson & R. W. Schery), *Volume 67*, pp. 851–945. Missouri Botanical Garden Press.
da Silva, M. J., de Queiroz, L. P., de Azevedo Tozzi, A. M. G., Lewis, G. P. & de Sousa, A. P. (2012). Phylogeny and biogeography of *Lonchocarpus* sensu lato and its allies in the tribe Millettieae (Leguminosae, Papilionoideae). *Taxon*, **6**1, 93–108.
Daly, D. C. (1993). Notes on *Bursera* in South America, Including a new species. Studies in Neotropical Burseraceae VII. *Brittonia*, **4**5, 240–246.
Daly, D. C. (2007). A New Section of *Protium* from the Neotropics. Studies in Neotropical Burseraceae XIII. *Brittonia*, **5**9, 1–24.
Daly, D. C. (2014). *Dacryodes patrona*, a new and endangered species, and new generic record for Central America. Studies in neotropical Burseraceae XIX. *Brittonia*, **6**6, 307–310.
Daly, D. C. & Fine, P. V. A. (2018). Generic limits re-visited and an updated sectional classification for *Protium* (tribe Protieae). Studies in Neotropical Burseraceae XXV. *Brittonia*, **7**0, 418–426.
Daniel, T. F. & McPherson, G. (2014). A new species of *Aphelandra* (Acanthaceae: Acantheae) from Panama with notes on some Colombian species. *Brittonia*, **6**6, 321–328.
D'Arcy, W. G. (1973). Family 180. Caprifoliaceae. *Flora of Panama. Part IX* (eds. R. E. Woodson & R. W. Schery), *Volume 60*, pp. 155–167. Missouri Botanical Garden Press.
D'Arcy, W. G. (1979). Family 171. Scrophulariaceae. *Flora of Panama. Part IX*, *Volume 66*, pp. 173–274. Missouri Botanical Garden Press.
D'Arcy, W. G. (1980). Family 123. Guttiferae. *Flora of Panama. Part VI* (eds. R. E. Woodson & R. W. Schery), *Volume 67*, pp. 969–1043. Missouri Botanical Garden Press.
de Carvalho, L. (1991). New taxa of *Solanum* (Solanaceae) from Brazil, Colombia, Central America, and Venezuela. *Annals of the Missouri Botanical Garden*, **7**8, 224–244.
de Lourdes Rico Arce, M., Gale, S. L. & Maxted, N. (2008). A taxonomic study of *Albizia* (Leguminosae: Mimosoideae: Ingeae) in Mexico and Central America. *Anales del Jardín Botánico de Madrid*, pp. 255–305.
de Paula-Souza, J. & Ballard Jr, H. E. (2014). Re-establishment of the name *Pombalia*, and new combinations from the polyphyletic *Hybanthus* (Violaceae). *Phytotaxa*, **1**83, 1–15.
Dehgan, B. (2012). *Jatropha* (Euphorbiaceae). *Flora Neotropica*, **1**10, 1–273.
Der Werff, H. V. (2009). Nine new species of *Licaria* (Lauraceae) from Tropical America. *Harvard papers in botany*, **1**4, 145–159.
Devecchi, M. F., Thomas, W. W., Plunkett, G. M. & Pirani, J. R. (2018). Testing the

monophyly of *Simaba* (Simaroubaceae): Evidence from five molecular regions and morphology. *Molecular Phylogenetics and Evolution*, **1**20, 63 – 82.
Donnell, A. A., Ballard, H. E. & Cantino, P. D. (2012). *Callianthe* (Malvaceae): A New Genus of Neotropical Malveae. *Systematic Botany*, **3**7, 712–722.
Durkee, L. H. (1978). Family 177. Acanthaceae. *Flora of Panama, Part VI* (eds. R. E. Woodson & R. W. Schery), *Volume 65*, pp. 155–283. Missouri Botanical Garden Press.
Durkee, L. H. (1986). Family 200. Acanthaceae. *Flora Costaricensis* (ed. W. Burger), 1371, pp. 1–87. Field Museum of Natural History.
Dwyer, J. D. (1980). Family 179. Rubiaceae. *Flora of Panama, Part IX*, *Volume 67*, pp. 1–256. Missouri Botanical Garden Press.
Endress, M. E. & Simões, A. O. (2016). A new name for a common and widespread species of *Tabernaemontana* (Apocynaceae). *J. Bot. Res. Inst. Texas*, **1**0, 31–32.
Erkens, R. H., Maas, P. J., Chatrou, L. W., Schatz, G. E. & Zamora, N. (2006). Seven taxonomic discoveries in Annonaceae from south-eastern Central America. *Blumea-Biodiversity, Evolution and Biogeography of Plants*, **5**1, 199–220.
Evans, R. J. (1995). Systematics of *Cryosophila* (Palmae). *Systematic Botany Monographs*, **4**6, 1–70.
Evans, R. J. (2001). Monograph of *Colpothrinax*. *Palms*, **4**5, 177–195.
Fernández-Alonso, J. L. (2011). Bombacaceae neotropicae Novae vel minus cognitae IX. A new species of *Matisia* Bonpl. from the Biogeographic Chocó. *Caldasia*, **3**3, 413–426.
Figlar, R. B. & Nooteboom, H. P. (2004). Notes on Magnoliaceae IV. *Blumea - Biodiversity, Evolution and Biogeography of Plants*, **4**9, 87–100.
Filardi, F. L. R., De Lima, H. C., Klitgaard, B. B. & Sartori, A. L. B. (2013). Taxonomy and nomenclature of the neotropical *Machaerium hirtum* complex (Leguminosae, Papilionoideae). *Brittonia*, **6**5, 154–170.
Flores, R., Ibáñez, A. & Correa, M. D. A. (2016). *Eugenia veraguensis* (Myrtaceae), a new species from Golfo de Chiriquí in Veraguas Province, Panama, with notes on *Eugenia rhombea*. *Phytotaxa*, **2**70.
Formoso, C. (2015). Winteraceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 631–632.
Fritsch, P. W. (2012). 198. Styracaceae. *Flora Mesoamericana*, *Volume 4*, pp. 617–620.
Fryxell, P. (2007). Malvaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 575–614.
Gagnon, E., Bruneau, A., Hughes, C. E., de Queiroz, L. P. & Lewis, G. P. (2016). A new generic system for the pantropical *Caesalpinia* group (Leguminosae). *PhytoKeys*, pp. 1–160.
Gahagen, B., Terbush, M. & Ballard, H. (2015). A taxonomic synthesis of the *Tovomita weddelliana* (Clusiaceae) species complex. *Systematic Botany*, **4**0, 968–988.
Galeano, G. & Bernal, R. (2017). *Sabinaria*, a new genus of palms (Cryosophileae, Coryphoideae, Arecaceae) from the Colombia-Panama border. *Phytotaxa*, **1**44, 27–44.
Gamba-Moreno, D. L. & Almeda, F. (2014). Systematics of the *Octopleura* clade of Miconia (Melastomataceae: Miconieae) in Tropical America. *Phytotaxa*, **1**79.
Gamba-Moreno, D. L. & Almeda, F. (2015). *Miconia solearis*, a new combination to replace the illegitimate *Miconia magnifolia* (Melastomataceae: Miconieae) in Tropical America. *Phytotaxa*, **2**19, 199–200.
Garwood, N. C., Jorna, K., Flowers, N. D., Humphreys, A. M., Russell, S. J. & Neubig, K. M. (2018). *Trema domingensis* rises like a Phoenix from the ashes of *Trema integerrima*: a reassessment of the entire-leaved species of neotropical *Trema* (Cannabaceae). *Journal of the Botanical Research Institute of Texas*, **1**2, 555–577.

Gentry, A. H. (1978a). Family 99. Buxaceae. *Flora of Panama. Part VI* (eds. R. E. Woodson & R. W. Schery), *Volume 65*, pp. 5–8. Missouri Botanical Garden Press.
Gentry, A. H. (1978b). A new *Freziera* (Theaceae) from the Panama/Colombia Border. *Annals of the Missouri Botanical Garden*, **6**5, 773–774.
Gómez-Laurito, J. (2007). Monimiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 632–634.
Gómez-Laurito, J. (2015). Ticodendraceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 416–417.
Gonzáles, J. & Poveda, L. J. (2007). Lauraceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 90–172.
González, J. (2007a). Hernandiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 6–10.
González, J. (2007b). Lacistemataceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 47–49.
González, J. (2007c). Magnoliaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 249–252.
González, J. (2007d). Nyctaginaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 785–796.
González, J. (2010a). Dilleniaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 203–212.
González, J. (2010b). Euphorbiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 290–394.
González, J. (2010c). Flacourtiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 782–816.
González, J. (2010d). Garryaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 819–820.
González, J. (2015). Turneraceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 454–459.
Graham, S. A. (2009a). 175. Lythraceae. *Flora Mesoamericana*, *Volume 4*, pp. 49–65.
Graham, S. A. (2009b). 176. Alzateaceae. *Flora Mesoamericana*, *Volume 2*, pp. –.
Grayum, M. H. (2003). Arecaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 2*, pp. 201–293.
Grayum, M. H. (2015a). Salicaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 11–12.
Grayum, M. H. (2015b). Thymeleaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 412–415.
Green, P. S. (2012). 200. Oleaceae. *Flora Mesoamericana*, *Volume 4*, pp. 626–631.
Groppo, M. (2010). New synonyms in *Hortia* and *Dictyloma* (Rutaceae), with validation of the name *Hortia badinii*. *Novon*, **2**0, 163–165.
Grose, S. O. & Olmstead, R. G. (2007). Evolution of a charismatic neotropical clade: Molecular phylogeny of *Tabebuia* s. l., Crescentieae, and allied genera (Bignoniaceae). *Systematic Botany*, **3**2, 650–659.
Hahn, W. J. (1993). A synopsis of the Panamanian species of *Ilex* (Aquifoliaceae). *Novon*, **3**, 34–45.
Hammel, B. E. (1986). New species of Clusiaceae from Central Aamerica with notes on *Clusia* and synonymy in the tribe Clusieae. *Selbyana*, **9**, 112–120.
Hammel, B. E. (1999). Synopsis of Chrysochlamys (Clusiaceae: Clusioideae: Clusieae) in Mesoamerica. *Novon*, **9**, 360–374.

Hammel, B. E. (2007a). Hypericaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 27–32.
Hammel, B. E. (2007b). Icacinaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 32–39.
Hammel, B. E. (2010). Clusiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 1–54.
Hampshire, R. J. (2009a). 184. Nyssaceae. *Flora Mesoamericana*, *Volume 4*, p. 185.
Hampshire, R. J. (2009b). 186. Cornaceae. *Flora Mesoamericana*, *Volume 4*, pp. 363–364.
Hampshire, R. J. (2009c). 187. Garryaceae. *Flora Mesoamericana*, *Volume 4*, p. 364.
Hauenschild, F., Matuszak, S., Muellner-Riehl, A. N. & Favre, A. (2016). Phylogenetic relationships within the cosmopolitan buckthorn family (Rhamnaceae) support the resurrection of *Sarcomphalus* and the description of *Pseudoziziphus* gen. nov. *Taxon*, **65**, 47–64.
Henderson, A. (1990). Arecaceae. Part I. Introduction and the Iriarteinae. *Flora Neotropica*, **53**, 1–100.
Henderson, A. (2005). A multivariate study of *Calyptrogyne* (Palmae). *Systematic Botany*, **30**, 60–83.
Henderson, A. & Galeano, G. (1996). *Euterpe*, *Prestoea*, and *Neonicholsonia* (Palmae). *Flora Neotropica*, **72**, 1–89.
Henderson, A., Galeano, G. & Bernal, R. (1997). *A Field Guide to Palms of the Americas*. Princeton University Press, 363 pages.
Henderson, A. J. (2011). A revision of *Geonoma* (Arecaceae). *Phytotaxa*, **17**, 1–271.
Hoch, P. C. (2009). 183. Onagraceae. *Flora Mesoamericana*, *Volume 4*, pp. 345–359.
Huft, M. J. (1989). New and critical taxa of Euphorbiaceae from South America. *Annals of the Missouri Botanical Garden*, **76**, 1077–1086.
Huft, M. J. (2009). 201. Loganiaceae. *Flora Mesoamericana*, *Volume 4*, pp. 631–639.
Hunter, G. E. (1965). Family 118. Dilleniaceae. *Flora of Panama, Part IV* (eds. R. E. Woodson & R. W. Schery), *Volume 52*, pp. 579–598. Missouri Botanical Garden Press.
Janovec, J. P. & Harrison, J. S. (2002). A morphological analysis of the *Compsoneura sprucei* complex (Myristicaceae), with a new combination for the Central American species *Compsoneura mexicana*. *Systematic Botany*, **27**, 662–673.
Jiménez, Q. (2007a). Meliaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 575–614.
Jiménez, Q. (2007b). Menipsermaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 616–628.
Jiménez, Q. (2007c). Myristicaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 684–691.
Jiménez, Q. (2007d). Olacaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 814–823.
Jiménez, Q. (2014). Rutaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 7*, pp. 780–814.
Jiménez, Q. (2015a). Tetrameristaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 391–392.
Jiménez, Q. (2015b). Theaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 393–406.
Judd, W. S., Ionta, G. M. & Majure, L. C. (2018a). Taxonomic studies in the Miconieae (Melastomataceae). XIV. Species of *Miconia* section *Sagraea* that occur in the Greater Antilles and additionally in the Lesser Antilles and/or continental regions. *Journal of the*

290 *Botanical Research Institute of Texas*, **1**2, 531–547.
291 Judd, W. S., Ionta, G. M., Majure, L. C. & Michelangeli, F. A. (2018b). Taxonomic and
292 nomenclatural notes on *Miconia crenata* and related species (Melastomataceae: Miconieae)
293 in the Greater Antilles. *Journal of the Botanical Research Institute of Texas*, **1**2, 521–529.
294 Junikka, L., Maas, P., Maas-van de Kamer, H. & Westra, L. (2016). Revision of *Oxandra*
295 (Annonaceae). *Blumea-Biodiversity, Evolution and Biogeography of Plants*, **6**1, 215–266.
296 Kallunki, J. A. (2009). Validation of *Neoraputia* (Galipeae, Rutaceae) and description of two
297 new species from Eastern Brazil. *Brittonia*, **6**1, 28–34.
298 Kallunki, J. A. & Pirani, J. R. (1998). Synopses of *Angostura* Roem. & Schult. and
299 *Conchocarpus* J. C. Mikan (Rutaceae). *Kew Bulletin*, **5**3, 257–334.
300 Kelly, L. M. & Almeda, F. (2012). 199. Symplocaceae. *Flora Mesoamericana*, *Volume 4*, pp.
301 620–626.
302 Kelly, L. M., Almeda, F. & Fritsch, P. W. (2016). A taxonomic revision of Mexican and
303 Central American *Symplocos* (Symplocaceae). *Phytotaxa*, **2**64.
304 King, R. M. & Robinson, H. (1977). Studies in Eupatorieae (Asteraceae). CLXVII. Four new
305 species of *Bartlettina*. *Phytologia*, **3**8, 106–117.
306 Knapp, S. & Pena-Chocarro, M. (2015). 116. Resedaceae. *Flora Mesoamericana*, *Volume 2*,
307 pp. 240–242.
308 Knapp S, Stafford M, Sousa Pena M, Martinez M (2005). A preliminary names list for the
309 Solanaceae of Mesoamerica. *Monographs in systematic botany from the Missouri Botanical*
310 *Garden*, **1**04, 71–116.
311 Kriebel, R. (2010). Gesneriaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H.
312 Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 844–933.
313 Kriebel, R. (2016). A Monograph of *Conostegia* (Melastomataceae, Miconieae). *PhytoKeys*,
314 **6**7, 1–326.
315 Kriebel, R. & Almeda, F. (2012). Five new species of *Miconia* (Melastomataceae: Miconieae)
316 from Costa Rica and Panama. *Harvard Papers in Botany*, **1**7, 53–64.
317 Kriebel, R. & Almeda, F. (2013). Two new species of *Miconia* (Melastomataceae: Miconieae)
318 from the cloud forests of Panama. *Phytotaxa*, **1**34, 27–41.
319 Kriebel, R. & Almeda, F. (2015). Symplocaceae. *Manual de plantas de Costa Rica* (ed. B.E.
320 Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 380–388.
321 Landrum, L., Barrie, F. R., Kawasaki, M. L. & Holst, B. K. (2009). 177. Myrtaceae. *Flora*
322 *Mesoamericana*, *Volume 4*, pp. X–X.
323 Lombardi, J. A. & Barrie, F. (2015). 110. Celastraceae. *Flora Mesoamericana*, *Volume 2*, pp.
324 211–233.
325 Lorence, D. H. & Taylor, C. M. (2009). 207. Rubiaceae. *Flora Mesoamericana*, *Volume 4*, pp.
326 1–288.
327 Lott, E. J. & García-Mendoza, A. (1994). Agavaceae. *Flora Mesoamericana*, *Volume 6*, pp.
328 6–35.
329 Lourenco, A., Parra-O., C., Sánchez-Chávez, E. & Lucas, E. (2018). New combinations and
330 names for continental American *Calyptranthes* (Myrtaceae: *Myrcia* s.l.). *Phytotaxa*, **3**73.
331 Luteyn, J. L., Clemants, S. E., Diggs, G. M., Dorr, L. J., Judd, W. S., Sórensen, P. D., Stevens,
332 P. F. & Wallace, G. D. (1995). Ericaceae, Part II. The Superior-Ovaried Genera
333 (Monotropoideae, Pyroloideae, Rhododendroideae, and Vaccinioideae P.P.). *Flora*
334 *Neotropica*, **6**6, i–560.
335 Luteyn, J. L. & Wilbur, R. L. (2005). Family 172 Ericaceae. *Flora Costaricensis*, pp. 1–107.
336 Field Museum of Natural History.
337 Luteyn, J. L. & Wilbur, R. L. (2009). 191. Ericaceae. *Flora Mesoamericana*, *Volume 4*, pp.

411–463.
Maas, P. J., Westra, L. Y. & Vermeer, M. (2007). Revision of the neotropical genera *Bocageopsis*, *Onychopetalum*, and *Unonopsis* (Annonaceae). *Blumea-Biodiversity, Evolution and Biogeography of Plants*, **5**2, 413–554.
Maas, P. J. M., Westra, L. Y. T., Brown, K. S., Maas, P. J. M., ter Welle, B. J. H., Webber, A. C., Thomas, A. L., Waha, M., van der Heijden, E., Bouman, F., Cavé, A., Leboeuf, M., Laprévote, O., Koek-Noorman, J., Morawetz, W. & Hemmer, W. (1992). *Rollinia*. *Flora Neotropica*, **5**7, 1–188.
Maas, P. J. M., Westra, L. Y. T. & Chatrou, L. W. (2003). *Duguetia* (Annonaceae). *Flora Neotropica*, **8**8, 1–274.
Maas, P. J. M., Westra, L. Y. T., Chatrou, L. W., Verspagen, N., Rainer, H., Zamora, N. A. & Erkens, R. H. J. (2019). Twelve new and exciting Annonaceae from the Neotropics. *Phytokeys*, **1**26, 25–69.
Maas, P. J. M., Westra, L. Y. T., Guerrero, S. A., Lobão, A. Q., Scharf, U., Zamora, N. A. & Erkens, R. H. J. (2015). Confronting a morphological nightmare: revision of the Neotropical genus *Guatteria* (Annonaceae). *Blumea-Biodiversity, Evolution and Biogeography of Plants*, **6**0, 1–219.
Machado, C. A., Robbins, N., Gilbert, M. T. P. & Herre, E. A. (2005). Critical review of host specificity and its coevolutionary implications in the fig/fig-wasp mutualism. *Proceedings of the National Academy of Sciences*, **1**02, 6558–6565.
Maguire, B. (1978). Notes on the Clusiaceae - Chiefly of Panama. III. *Phytologia*, **3**9, 65–77.
Marinho, L. C., Cai, L., Duan, X., Ruhfel, B. R., Fiaschi, P., Amorim, A. M., van den Berg, C. & Davis, C. C. (2019). Plastomes resolve generic limits within tribe Clusieae (Clusiaceae) and reveal the new genus *Arawakia*. *Molecular Phylogenetics and Evolution*, **1**34, 142–151.
Martén-Rodríguez, S. (2014). Picramniaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 7*, pp. 1–5.
McPherson, G. (2011). Notes on *Tetrorchidium* (Euphorbiaceae) in Panama. *Novon*, **2**8, 468–471.
Merello, M. (2013a). Podocarpaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 2*, pp. 11–13.
Merello, M. (2013b). Zamiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 2*, pp. 14–16.
Michelangeli, F. A., Almeda, F., Alvear, M., Bécquer, E. R., Burke, J., Caddah, M. K., Goldenberg, R., Ionta, G. M., Judd, W. S., Majure, L. C., Meirelles, J., Nicolas, A. N., Ocampo, G., Penneys, D. S., Skean Jr., J. D. & Ulloa Ulloa, C. (2016). (2462) Proposal to conserve *Miconia*, nom. cons. against the additional names *Maieta* and *Tococa* (Melastomataceae: Miconieae). *Taxon*, **6**5, 892–893.
Miller, J. (2012a). 210. Cordiaceae. *Flora Mesoamericana*, *Volume 4*, pp. 294–304.
Miller, J. (2012b). 211. Ehretiaceae. *Flora Mesoamericana*, *Volume 4*, pp. 305–309.
Miller, J. (2012c). 213. Heliotropiaceae. *Flora Mesoamericana*, *Volume 4*, pp. 310–317.
Mitchell, J. D. & Daly, D. C. (2015). A revision of *Spondias* L. (Anacardiaceae) in the Neotropics. *PhytoKeys*, pp. 1–92.
Monro, A. K. (2012). Eight new species of *Cestrum* (Solanaceae) from Mesoamerica. *PhytoKeys*, pp. 49–82.
Monro, A. K. (2015). 104. Urticaceae. *Flora Mesoamericana*, *Volume 2*, pp. 116–174.
Morales, J. F. (2003). Poaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 3*, pp. 598–821.
Morales, J. F. (2007a). Juglandaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel,

M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 41–44.
Morales, J. F. (2007b). Loranthaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 218–236.
Morales, J. F. (2007c). Myricaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 682–684.
Morales, J. F. (2007d). Myrsinaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 692–728.
Morales, J. F. (2007e). Ochnaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 805–813.
Morales, J. F. (2007f). Phytolaccacaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 894–902.
Morales, J. F. (2009). 204. Apocynaceae. *Flora Mesoamericana*, *Volume 4*, pp. 741–757.
Morales, J. F. (2010a). Connaraceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 65–71.
Morales, J. F. (2010b). Cunoniaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 182–187.
Morales, J. F. (2010c). Fagaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 776–781.
Morales, J. F. (2010d). Grossulariaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 931–934.
Morales, J. F. (2010e). Sinopsis del género *Weinmannia* (Cunoniaceae) en México y Centroamérica. *Anales del Jardín Botánico de Madrid*, **1**67, 137–155.
Morales, J. F. (2014a). Polygalaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 7*, pp. 342–357.
Morales, J. F. (2014b). Proteaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 7*, pp. 394–400.
Morales, J. F. (2014c). Quiinaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 7*, pp. 401–403.
Morales, J. F. (2015a). 109. Lepidobotryaceae. *Flora Mesoamericana*, *Volume 2*, pp. 210–211.
Morales, J. F. (2015b). Sabiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 1–10.
Morales, J. F. (2015c). Sapindaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 1–10.
Morales, J. F. (2015d). Sapotaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 96–140.
Morales, J. F. (2015e). Schlegeliaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 143–148.
Morales, J. F. (2015f). Siparunaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 1–10.
Morales, J. F. (2015g). Staphyleaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 339–340.
Morales, J. F. (2015h). Vochysiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 625–630.
Morales, J. F. & Grayum, M. H. (2009). *Mollindeia maxima* (Monimiaceae), un nuevo nombre para *Mollinedia macrophylla*. *Darwiniana*, **4**7, 229–230.
Morales, J. F. & Méndez G., M. (2005). Estudios en las Apocynaceae Neotropicales XXII: Nuevos realineamientos taxonómicos en el género *Stemmadenia* (Apocynaceae, Rauvolfioideae, Tabernaemontaneae). *Candollea*, **6**0, 345–371.

Morales, J. F. & Zamora, N. A. (2017). A synopsis of *Aspidosperma* (Apocynaceae) in Mexico and Central America with a taxonomic clarification of *Aspidosperma cruentum* and a new cryptic species. *Phytoneuron*, **6**8, 1–13.
Moran, R. C. (1995). 17. Cyatheaceae. *Flora Mesoamericana*, *Volume 4*, pp. 1–88.
Moreira, P. A., Lins, J., Dequigiovanni, G., Veasey, E. A. & Clement, C. R. (2015). The Domestication of Annatto (*Bixa orellana*) from *Bixa urucurana* in Amazonia. *Economic Botany*, **6**9, 127–135.
Mori, S. A., Kiernan, E. A., Smith, N. P., Huang, Y., Kelley, L., Prance, G. T. & Thiers, B. (2016). Observations on the phytogeography of the Lecythidaceae clade (Brazil nut family). *Phytoneuron*, **3**0, 1–85.
Mori, S. A. & Prance, G. T. (1990). Lecythidaceae - II. The zygomorphic-flowered New World genera (*Couroupita*, *Corythophora*, *Bertholletia*, *Couratari*, *Eschweilera*, & *Lecythis*). *Flora Neotropica*, **2**1, 1–375.
Mori, S. A. & Prance, G. T. (2009). 179. Lecythidaceae. *Flora Mesoamericana*, *Volume 4*, pp. 151–163.
Murray, N. A. (1993). Revision of *Cymbopetalum* and *Porcelia* (Annonaceae). *Systematic Botany Monographs*, **4**0, 1–121.
Nee, M. (2015a). 102. Ulmaceae. *Flora Mesoamericana*, *Volume 2*, pp. 88–89.
Nee, M. (2015b). 105. Cannabaceae. *Flora Mesoamericana*, *Volume 2*, pp. 174–177.
Nishida, S. (1999). Revision of *Beilschmiedia* (Lauraceae) in the Neotropics. *Annals of the Missouri Botanical Garden*, **8**6, 657–701.
Nixon, K. C. & Barrie, F. R. (2017). Three Previously Undescribed Species of *Quercus* (Fagaceae) from Mesoamerica and the Designation of a Lectotype for *Q. acutifolia*. *Novon*, **2**5, 444 – 450.
Pastore, J. F. B., Cardoso, D. B. O. S. & Aymard C., G. A. (2010). A Synopsis, New Combinations, and Synonyms in *Acanthocladus* (Polygalaceae). *Novon: A Journal for Botanical Nomenclature*, **2**0, 317–324.
Penneys, D. S. & Judd, W. S. (2013). A revised circumscription for the Blakeeae (Melastomataceae) with associated nomenclatural adjustments. *PhytoKeys*, pp. 17–32.
Penneys, D. S., Michelangeli, F., Judd, W. & Almeda, F. (2010). Henrietteeae (Melastomataceae): a new neotropical berry-fruited tribe. *Systematic Botany*, **3**5, 783–800.
Pennington, T. & Clarkson, J. (2013). A revision of *Guarea* (Meliaceae). *Edinburgh Journal of Botany*, **7**0, 179–.
Pennington, T. D. (1997). *The genus Inga: botany.*. Royal Botanic Gardens.
Pennington, T. D. (2016). Systematic treatment of American *Trichilia* (Meliaceae). *Phytotaxa*, **2**59, 18–162.
Penninton, T. D., Monro, A. K., Wood, S. P. T. & Knapp, S. (2009). 206. Sapotaceae. *Flora Mesoamericana*, *Volume 4*, pp. 571–610.
Pérez-Zabala, J. A. (2007). Studies on the genus *Prunus* (Rosaceae) in the Neotropics: taxonomic and nomenclature changes for Colombia. *Anales del Jardín Botánico de Madrid*, **6**4, 177–190.
Persson, C. & Delprete, P. G. (2017). The *Alibertia* group (Gardenieae-Rubiaceae). *Flora Neotropica*, **1**19, 1–241.
Piedrahíta, A. I., II, P. P. L. & De Gracia Cruz, J. E. (2015). A new species of *Dendropanax* (Araliaceae) of restricted range from the Caribbean slope of Panama. *Novon: A Journal for Botanical Nomenclature*, **2**4, 165–169.
Pirie, M. D. (2005). New species of *Cremastosperma* (Annonaceae) from Colombia, Ecuador, and Panama. *Blumea-Biodiversity, Evolution and Biogeography of Plants*, **5**0, 41–60.

Plowman, T. & Barrie, F. R. (2010). Erythroxylaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 284–289.
Plowman, T. & Hensold, N. (2004). Names, types, and distribution of Neotropical species of *Erythroxylum* (Erythroxylaceae). *Brittonia*, **5**6, 1–53.
Pool, A. (2015). 101. Rhamnaceae. *Flora Mesoamericana*, *Volume 2*, pp. 55–88.
Pool, A., Knapp, S. & Rueda, R. (2012). 216. Lamiaceae. *Flora Mesoamericana*, *Volume 4*, pp. 353–453.
Porter, D. M. (1970). Family 91. Burseraceae. *Flora of Panama, Part VI*, *Volume 57*, pp. 5–27. Missouri Botanical Garden Press.
Prance, G. T. (1979). Chrysobalanaceae. *Flora of Ecuador*, **1**0, 1–24.
Prance, G. T., Rodríguez, A. & Kriebel, R. (2010). Dichapetalaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 190–202.
Pruski, J. F. & Robinson, H. (2018). Asteraceae. *Flora Mesoamericana*, *Volume 5*, pp. xx–xx.
Radosavljevic, A. (2019). The rise of *Cynometra* (Leguminosae) and the fall of *Maniltoa*: a generic re-circumscription and the addition of 4 new species. *PhytoKeys*, **1**27, 1–37.
Rainer, H. (2006). Monographic studies in the genus *Annona* L.(Annonaceae): Inclusion of the genus *Rollinia* A. St.-Hil. *Annalen des Naturhistorischen Museums in Wien. Serie B f ur Botanik und Zoologie*, pp. 191–205.
Renner, S. S. & Hausner, G. (2005). Siparunaceae. *Flora Neotropica*, **9**5, 1–247.
Reynel, C. (2017). *Zanthoxylum* (Rutaceae). *Flora Neotropica*, **1**17, 1–263.
Ricketson, J. (2012). 209. Hydrophyllaceae. *Flora Mesoamericana*, *Volume 4*, pp. 291–294.
Ricketson, J. M. & Pipoly, J. J. (1997). Nomenclatural notes and a synopsis of Mesoamerican *Stylogyne* (Myrsinaceae). *SIDA, Contributions to Botany*, **1**7, 591–597.
Ricketson, J. M. & Pipoly, J. J. (2003). A new species of *Stylogyne* (Myrsinaceae) from Darién, Panama. *SIDA*, **2**0, 919–922.
Ricketson, J. M. & Pipoly, J. J. (2009). 193. Myrsinaceae. *Flora Mesoamericana*, *Volume 4*, pp. 468–568.
Robson, N. K. B. (1978). Flora of Panama. Part VI. Family 123A. Hypericaceae. *Annals of the MIssouri Botanical Garden*, **6**5, 9–26.
Robyns, A. (1964). Family 116. Bombacaceae. *Flora of Panama, Part VI*, *Volume 51*, pp. 37–68. Missouri Botanical Garden Press.
Robyns, A. (1967a). Family 127. Violaceae. *Flora of Panama, Part VI* (eds. R. E. Woodson & R. W. Schery), *Volume 54*, pp. 65–84. Missouri Botanical Garden Press.
Robyns, A. (1967b). Family 95. Vochysiaceae. *Flora of Panama, Part VI* (eds. R. E. Woodson & R. W. Schery), *Volume 54*, pp. 1–7. Missouri Botanical Garden Press.
Rodríguez, A. (2007). Muntingiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 679–681.
Rodríguez, A. (2015a). Sterculiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 341–369.
Rodríguez, A. (2015b). Tiliaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 418–445.
Rodríguez, A. & Estrada, A. (2007). Passifloraceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 862–892.
Rodríguez, S. M. (2015c). Simaroubaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 193–198.
Rohde, R., Rudolph, B., Ruthe, K., Lorea-Hernández, F. G., Rodrigues de Moraes, P. L., Li, J. & Rohwer, J. G. (2017). Neither *Phoebe* nor *Cinnamomum* - the tetrasporangiate species of

Aiouea (Lauraceae). *Taxon*, **6**6, 1085–1111.
Rohwer, J. G. (1993). Lauraceae: *Nectandra*. *Flora Neotropica*, **6**0, 1–332.
Rojas-Alvarado, A. F. (2005). Nuevos taxa de helechos arborescentes (Filicales: Cyatheaceae) en Costa Rica. *Lankesteriana*, **5**, 191–200.
Rojas-Alvarado, A. F. (2007). Novedades en *Cyathea* (Filicales: Cyatheaceae) para Costa Rica y Panamá. *Métodos en Ecología y Sistemática*, **2**, 1–13.
Rueda, R. (2012). 217. Verbenaceae. *Flora Mesoamericana*, *Volume 4*, pp. 453–473.
Sánchez, J. (2010). Gentianaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 821–840.
Santamaría-Aguilar, D. A., Aguilar-Fernández, R. & Lagomarsino, L. P. (2019). A taxonomic synopsis of *Virola* (Myristicaceae) in Mesoamerica, including six new species. *PhytoKeys*, **1**34, 1–82.
Santamaría-Aguilar, D. A., Zamora-Villalobos, N. A. & Aguilar-Fernández, R. (2015). Sinopsis del género *Laetia* (Salicaceae) en Mesoamérica y la descripción de una nueva especie. *Phytoneuron*.
Schatz, G. & Maas, P. (2010). Synoptic revision of *Stenanona* (Annonaceae). *Blumea-Biodiversity, Evolution and Biogeography of Plants*, **5**5, 205–223.
Schatz, G., Maas, P., van de Kamer, H. M., Westra, L. & Wieringa, J. J. (2017). Revision of the Neotropical genus *Sapranthus* (Annonaceae). *Blumea-Biodiversity, Evolution and Biogeography of Plants*, **6**3, 54–66.
Schatz, G. E., Maas, P. J. M., van de Kamer, H. M. & Westra, L. Y. T. (2018). Revision of the Neotropical genus *Desmopsis* (Annonaceae). *Blumea-Biodiversity, Evolution and Biogeography of Plants*, **6**3, 67–86.
Schatz, G. E., Ramos A., C. A., Ortiz, O. O. & McPherson, G. (2015). A New, Restricted Range Species of *Annona* (Annonaceae) Endemic to the Caribbean Slope of Panama. *Novon: A Journal for Botanical Nomenclature*, **2**4, 203–208.
Schneider, J. V. & Zizka, G. (2016). Quiinaceae. *Flora Neotropica*, **1**15, 1–162.
Secco, R. d. S. (2005). Alchorneae (Euphorbiaceae). *Flora Neotropica Monograph*, **9**3, 1–194.
Simões, A. O., Endress, M. E. & Conti, E. (2010). Systematics and character evolution of Tabernaemontaneae (Apocynaceae, Rauvolfioideae) based on molecular and morphological evidence. *Taxon*, **5**9, 772–790.
Skog, L. E. (1978). New Panamanian species of Gesneriaceae. *Brittonia*, **3**0, 319–326.
Smith, D. A. (2010). Elaeocarpaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 222–236.
Sothers, C. A., Prance, G. T. & Chase, M. W. (2016). Towards a monophyletic *Licania*: a new generic classification of the polyphyletic Neotropical genus *Licania* (Chrysobalanaceae). *Kew Bulletin*, **7**1, 58–.
Soto, A. (2007). Papaveraceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 860–862.
Soto, A. (2014). Polygonaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 7*, pp. 358–383.
Sousa, S. (1993). The genus *Ing*a (Leguminosae: Mimosoideae) from southern Mexico and Central America: a preliminary study for the Flora Mesoamericana. *Annals of the Missouri Botanical Garden (USA)*, pp. –.
Spellman, D. L. (1975). Family 163. Asclepiadaceae. *Flora of Panama, Part VIII*, *Volume 62*, pp. 103–156. Missouri Botanical Garden Press.
Stace, C. A. (2009). 182. Combretaceae. *Flora Mesoamericana*, *Volume 4*, pp. 339–345.
Stafford, M. J. (2015). 122. Zygophyllaceae. *Flora Mesoamericana*, *Volume 2*, pp. 301–303.

Standley, P. C. (1940). Studies of American Plants - IX. *Botanical Series Field Museum of Natural History*, **2**2, 1–62.
Ståhl, B. (2009). 192. Theophrastaceae. *Flora Mesoamericana*, *Volume 4*, pp. 463–467.
Struwe, L. & Albert, V. A. (2004). A Monograph of Neotropical *Potalia* Aublet (Gentianaceae: Potalieae). *Systematic Botany*, **2**9, 670–701.
Taylor, C. M. (1985). A revision of the Central American species of *Monnina* (Polygalaceae). *Rhodora*, **8**7, 159–188.
Taylor, C. M. (1992). Revision of *Cosmibuena* (Rubiaceae). *Annals of the Missouri Botanical Garden*, **7**9, 886–900.
Taylor, C. M. (2014). Rubiaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 7*, pp. 469–769.
Taylor, C. M. (2015a). Rubiacearum Americanarum Magna Hama Pars XXXIV: The New Group *Palicourea* sect. *Tricephalium* with eight new species and a new subspecies (Palicoureeae). *Novon: A Journal for Botanical Nomenclature*, **2**4, 55–95.
Taylor, C. M. (2015b). Rubiacearum Americanarum Magna Hama XXXIII: The new group *Palicourea* sect. *Didymocarpae* with four new species and two new subspecies (Palicoureeae). *Novon*, **2**3, 452–478.
Taylor, C. M. (2017a). Another Taxonomic Review of the Neotropical Genus *Joosia* (Rubiaceae, Cinchoneae). *Novon: A Journal for Botanical Nomenclature*, **2**5, 214–237.
Taylor, C. M. (2017b). Rubiacearum Americanarum Magna Hama Pars XXXVII: The new group *Palicourea* sect. *Chocoanae* of the Chocó Biogeographic Region, with two new species (Palicoureeae). *Novon: A Journal for Botanical Nomenclature*, **2**5, 322–342.
Taylor, C. M., Hammel, B. & Gereau, R. E. (2011a). Rubiacearum Americanarum Magna Hama Pars XXVII: Six new species and a new taxonomic view of *Posoqueria*. *Novon*, **2**1, 118–132.
Taylor, C. M. & Hollowell, V. C. (2016). Rubiacearum Americanarum Magna Hama Pars XXXV: The New group *Palicourea* sect. *Nonatelia*, with five new species (Palicoureeae). *Novon: A Journal for Botanical Nomenclature*, **2**5, 69–110.
Taylor, C. M., Lorence, D. H. & Gereau, R. E. (2010). Rubiacearum Americanarum Magna Hama Pars XXV: The nocturnally flowering *Psychotria* domingensis-*Coussarea hondensis* group plus three other Mesoamerican *Psychotria* species transfer to *Palicourea*. *Novon: A Journal for Botanical Nomenclature*, **2**0, 481–492.
Taylor, C. M., Sánchez-González, J., Hammel, B., Lorence, D. H., Persson, C., Delprete, P. G. & Gereau, R. E. (2011b). Rubiacearum Americanarum Magna Hama Pars XXVIII: New taxa, new combinations, new names, and lectotypification for several species found in Mexico and Central America. *Novon: A Journal for Botanical Nomenclature*, **2**1, 133–148.
Thomas, W. W. (2011). *Nothotalisia*, a new genus of Picramniaceae from tropical America. *Brittonia*, **6**3, 51–61.
Todzia, C. (1989). A new species of *Hybanthus* (Violaceae) from Panama. *Annals of the Missouri Botanic Garden*, **7**6, 360–362.
Torke, B. M. & Schaal, B. A. (2008). Molecular phylogenetics of the species-rich Neotropical genus *Swartzia* (Leguminosae, Papilionoideae) and related genera of the Swartzioid clade. *American Journal of Botany*, **9**5, 215–228.
Torke, B. M. & Zamora, N. A. (2010). Notes on *Swartzia* (Leguminosae) in Central America preliminary to the Flora Mesoamericana, with descriptions of two new species from Costa Rica. *Brittonia*, **6**2, 222–232.
Trofimov, D., Rudolph, B. & Rohwer, J. G. (2016). Phylogenetic study of the genus *Nectandra* (Lauraceae), and reinstatement of *Damburneya*. *Taxon*, **6**5, 980–996.

van der Werff, H. (1993). A revision of the genus *Pleurothyrium* (Lauraceae). *Annals of the Missouri Botanical Garden*, **8**0, 39–118.
van der Werff, H. (2002). A synopsis of *Ocotea* (Lauraceae) in Central America and Southern Mexico. *Annals of the Missouri Botanical Garden*, **8**9, 429–451.
van der Werff, H. (2009). Eight new species of Lauraceae from Ecuador, Peru, and Panama. *Novon: A Journal for Botanical Nomenclature*, **1**9, 534–548.
van der Werff, H. & Zamora V., N. A. (2010). Note on *Tachigali* (Leguminosae) in Central America with the description of a new species. *Harvard Papers in Botany*, **1**5, 149–153.
Vickery, A. R. (2009). 190. Clethraceae. *Flora Mesoamericana*, *Volume 4*, pp. 408–411.
Wahlert, G. A. & Ballard, H. E. (2009). A new zygomorphic-flowered *Rinorea* (Violaceae) from the Neotropics. *Novon: A Journal for Botanical Nomenclature*, **1**9, 416 – 420 – 5.
Wahlert, G. A., Marcussen, T., de Paula-Souza, J., Feng, M. & Ballard Jr, H. E. (2014). A phylogeny of the Violaceae (Malpighiales) inferred from plastid DNA sequences: implications for generic diversity and intrafamilial classification. *Systematic Botany*, **3**9, 239–252.
Webster, G. L. & Huft, M. J. (1988). Revised synopsis of Panamanian Euphorbiaceae. *Annals of the Missouri Botanical Garden*, pp. 1087–1144.
Whitefoord, C. (1992). Eight new species of *Ouratea* (Ochnaceae) from Mesoamerica. *Novon*, **2**, 274–281.
Whitefoord, C. & Knapp, S. (2012). 197. Ebenaceae. *Flora Mesoamericana*, *Volume 4*, pp. 611–616.
Wilbur, R. L. (2009). 202. Gentianaceae. *Flora Mesoamericana*, *Volume 4*, p. 640.
Wunderlin, R. P. (1983). Revision of the arborescent *Bauhinia*s (Fabaceae: Caesalpinioideae: Cercideae) native to Middle America. *Annals of the Missouri Botanical Garden*, **7**0, 95–127.
Wurdack, K. J., Hoffmann, P., Samuel, R., Bruijn, A., Bank, M. & Chase, M. W. (2004). Molecular phylogenetic analysis of Phyllanthaceae (Phyllanthoideae pro parte, Euphorbiaceae sensu lato) using plastid RBCL DNA sequences. *Am. J. Bot.*, **9**1, 1882–1900.
Zamora, N. (2007). Humiriaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 6*, pp. 11–16.
Zamora, N. (2010). Fabaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 5*, pp. 395–775.
Zamora, N. (2015). Styracaceae. *Manual de plantas de Costa Rica* (ed. B.E. Hammel, M.H. Grayum, C. Herrera, and N. Zamora), *Volume 8*, pp. 373–377.
Zamora, N. (2017). *Trees of Costa Rica*. Editorial Tecnológica de Costa Rica.