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DISTRIBUTION PATTERNS AND CONSERVATION OF EASTERN BRAZILIAN COASTAL FOREST TREE SPECIES

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Mori, Scott A., Brian M. Boom and Ghillean T. Prance (New York Botanical Garden, Bronx, NY 10458). Distribution patterns and conservation of eastern Brazilian coastal forest tree species. Brittonia 33: 233–245. 1981.—The distributions of 127 tree species, each with at least part of their range in the moist coastal forest of eastern Brazil, are analyzed. Of these, 53.5% are endemic to the coastal forest, 11.8% endemic to the coastal forest plus some part of the Planalto of Brazil, 7.8% disjunct with the Amazonian hylaea, and 26% widespread. This high endemism in the coastal forest of eastern Brazil, in view of its rapid destruction, emphasizes the need for increased preservation of the few remaining natural areas. In addition, this study supports the theory that there are at least two centers of endemism in the coastal forests, one centering around Rio de Janeiro and one in southern Bahia/Rio Doce, Espírito Santo. In order to protect the diverse flora of the coastal forests, preservation areas should be established intermittently along their entire length and especially in the centers of endemism.

One of the biological tragedies of this century has been the accelerated destruction of tropical moist forests (Myers, 1980). The decimation of the eastern Brazilian coastal forest is perhaps the most alarming (Mori & Silva, 1979; Sick & Teixeira, 1979; da Vinha et al., 1976). This forest once occupied about one million square kilometers and extended from Rio Grande do Norte to Rio Grande do Sul in a strip ranging from several to 120–160 kilometers wide (Andrade-Lima, 1977; Bigarella et al., 1975; Rizzini, 1979; Smith, 1962). Unfortunately, exploitation of the dye from Pau-brasil (*Caesalpinia echinata* Lam.), various timbers, firewood, charcoal, and forest substitution by sugar, coffee, and cocoa plantations and cattle ranches, have reduced this forest to a small remnant.

Table I summarizes data on forest destruction (Sick & Teixeira, 1979; da Vinha et al., 1976) for four Brazilian states that possess coastal forest. The values for Espírito Santo and São Paulo are for the entire state whereas those for Paraná and Bahia are for coastal forest and part of it, respectively. According to these figures, something between 65.8 and 93% of the original forest has been destroyed. Southeastern Pernambuco/northeastern Alagoas (Andrade-Lima, 1974) and southern Bahia (Mori & Silva, 1979; da Vinha et al., 1976) have relatively large extensions of moist forest remaining. Nevertheless, even here considerable forest has already disappeared and continues to be destroyed. Since the opening of the Brazilian coastal highway in southern Bahia in 1973, forest destruction has continued at an accelerated rate (Mori & Silva, 1979) and the 17.5% of the original forest remaining in 1976 (da Vinha et al., 1976) must surely now be considerably reduced (Mori, pers. obs.).

Until recently, Brazil has been slow to preserve its natural areas. In 1977, only 2,400,000 hectares, or 0.28% of Brazil's territory, were set aside as national parks or biological reserves which placed the country, the world's fifth largest, 68th among the world's nations in areas preserved (Jorge Pádua, 1977). Moreover, only 400,000 hectares were then under actual government ownership (Jorge Pádua, 1977). A more vigorous program by the Brazilian government through its *Instituto Brasileiro de Desenvolvimento Florestal* (IBDF) has considerably, but not sufficiently, increased these figures. Since 1977, the current president, João Figueredo, has declared Cabo Orange, Pacaás Novos, Pico da Neblina, Serra da

TABLE I
FOREST DESTRUCTION IN FOUR OF THE 12 BRAZILIAN STATES THAT POSSESS ATLANTIC COASTAL FOREST[a]

State	State size (km^2)	Source	Original forest cover (km^2)	1930	1948	1965	1968	1976	1979
Espírito Santo	45,597	Sick & Teixeira, 1979	37,799		17,760 (44.3%)		3,650 (9.7%)		
Paraná	199,554	Sick & Teixeira, 1979	94,044	89,444 (95.1%)		32,204 (34.2%)			
São Paulo	247,898	Sick & Teixeira, 1979	210,713						14,750 (7%)
Southern Bahia (Cocoa region)	91,554	da Vinha et al., 1976	33,435					5,852 (17.5%)	

[a] All values are given in square kilometers and the percentage of the original forest cover is included in parentheses.

Capivara, and Jaú as national parks and Atol das Rocas, Rio Trombetas and Lago Piratuba as marine biological reserves. By July 1980, Brazil's national parks and reserves had increased to 7,400,000 hectares (Jorge Pádua, 1980). Brazilian concern for the environment is also reflected in a recent plan for the development of the Brazilian Amazon (Salati et al., 1979) in which much attention is given to the preservation of the flora and fauna.

Unfortunately, National Park and Biological Reserve status does not necessarily mean that undisturbed forest has been preserved or even that preserved virgin areas will remain intact. The Brazilian national parks and biological reserves along the Atlantic coast include little virgin moist forest (Jorge Pádua & Coimbra Filho, 1979). Prime examples are found in Caparaó National Park, where secondary vegetation now prevails, and in the ecologically more advanced forests of Tijuca National Park, where coffee (*Coffea arabica* L.), Jackfruit (*Artocarpus integrifolia* L.) and *Eucalyptus* persist as relics of the plantations that once covered the entire area or are evidence of past reforestation projects (Jorge Pádua & Coimbra Filho, 1979). There are also cases of encroachment on already existing parks and reserves. For example, Monte Pascoal National Park is being utilized by the Pataxós Indians who originally occupied only 210 hectares. Today their population has grown to about 950 and anthropologists estimate that they will need 5500 hectares for their survival during the next 20 years (Jorge Pádua & Coimbra Filho, 1979). In 1977, 5000 hectares in the municipality of Una, Bahia were acquired as a refuge for the golden lion marmoset (*Leontopithecus chrysomelas*) (Jorge Pádua & Coimbra Filho, 1979). Contrary to its purpose, purchase of this property has accelerated forest destruction because the former private landowners were more protective than is the government.

The purpose of this paper is to provide a scientific basis for conservation efforts through the examination of the distribution patterns of trees native to the moist forests of eastern coastal Brazil. This study is part of a special World Wildlife

Fund-US program for eastern Brazil that includes primatological and ornithological investigations in addition to the botanical work. The objective of this program is the preservation of what little remains of this unique and highly endangered ecosystem.

Methods

All *Flora Neotropica* monographs of plant families that contain trees (Cowan, 1967; Cuatrecasas, 1970; Berg, 1972; Prance, 1972a, 1972b, 1972c; Prance & Silva, 1973; Morley, 1976; Johnston & Johnston, 1978; Prance & Mori, 1979; Sleumer, 1980; Gentry, 1980; Pennington, in press) were examined for the distributions of their tree species. Taxa of Chrysobalanaceae, Dichapetalaceae, and Caryocaraceae, described or discovered in eastern Brazil since the publication of the monographs are also included in the calculations. For the purpose of this analysis, infraspecific taxa are ignored. Where a taxon possesses both trees and shrubs, the latter are ignored. The distribution of each tree species that occurs in the coastal forest was transferred to a *Flora Neotropica* base map (Figs. 1–5) from the map in the monograph or elaborated from specimens annotated by the authors of the monographs. An attempt was made to include only those species found in moist forests. For example, such species as *Hancornia speciosa* Gomez and *Anacardium occidentale* L., which grow in *restinga* (shrub land or low forest on sandy soil, located between beach vegetation and the taller moist forest, Mori & Silva, 1979) adjacent to but not in moist forest, were not included in the analysis, even though their distributions appear to fall within the coastal forest strip. Our concept of moist forest includes the wet and mesophytic forest of da Vinha et al. (1976) and Mori and Silva (1979) and wet montane, lower wet montane, and wet forest of Rizzini (1979) along rivers and in isolated patches.

For the purpose of our analysis, the Neotropics were divided into the six regions outlined in Figure 1, where present-day moist forest species are found. Each species of the coastal forest could then be classified as: (a) endemic to the coastal forest, (b) endemic to the coastal forest and part of the Planalto, (c) disjunct between the coastal forest and one of the other areas, or (d) widespread, i.e. found in the coastal forest and more than one of the other regions (Table II, Figs. 2–5).

The non-arborescent families that have been monographed in the *Flora Neotropica* series (Lleras, 1978; Hansen, 1980; Maas, 1972, 1977; Rogers & Appan, 1973; Smith & Downs, 1974, 1977, 1979) were examined in a similar way. In addition, monographs published elsewhere and Mori's collections from the moist forest were consulted.

We assume that our data represent a random sample of moist forest tree families. However, we recognize that these results may change as more collections are made and additional monographs are completed. We are also aware that the taxonomic concepts of the monographers greatly influence the degree of endemism. If all monographers were splitters, endemism would be high, and vice versa. It is our feeling that there has been a tendency towards splitting and, therefore, that the endemism figure reported here may be somewhat high.

Results

Of the 1245 species considered, 127 or 10.2% have at least part of their distribution in the coastal forest. Of these, 68 or 53.5% are endemic (Fig. 2) and an additional 15 species (11.8%) are found only in the coastal forest and the adjacent Planalto of Brazil or neighboring countries (Fig. 3). There are 10 Amazonian

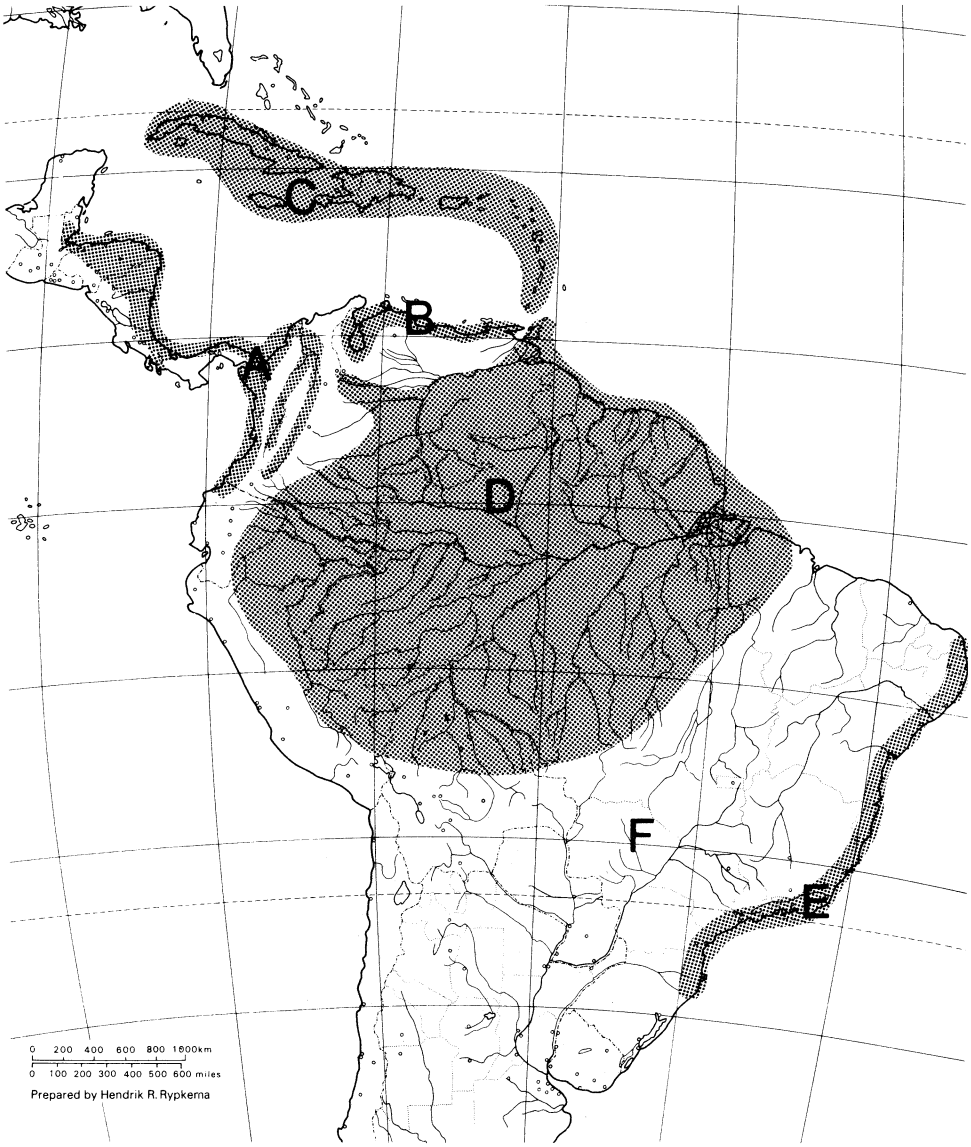

FIG. 1. Present-day areas where moist forest tree species occur in the Neotropics. A. Southern Central America/Northwestern South America. B. Coastal Venezuela. C. Caribbean. D. Amazonia, including the Amazonian and the southern Orinocan River Basins and the Guianas. E. Atlantic coastal forest of Brazil. F. The Planalto of Brazil and similar areas in adjacent countries—within this region *cerrado* and *caatinga* prevail but moist forest species are found where conditions are favorable, such as in gallery forests.

disjuncts (7.8%, Fig. 4) and 33 widespread species (26%, Fig. 5). These data are summarized in Table II.

The non-arborescent families revealed the even higher percentage of endemism of 77.4%. This figure reflects the very high rate of endemism of the largely epiphytic family Bromeliaceae. When the Bromeliaceae are not considered, ende-

TABLE II
DISTRIBUTION OF SELECTED SPECIES OF TREES FOUND IN THE ATLANTIC COASTAL FOREST OF EASTERN BRAZIL

Taxon	Total spp.	Total in coastal forest	Endemic in coastal forest	Endemic in coastal forest and planalto	Amazonian disjuncts	Widespread
Swartzia (Leguminosae)	127	16	5	4	3	4
Brunelliaceae	51	—	—	—	—	—
Moraceae, Olmedieae & Brosimeae	67	9	3	—	1	5
Chrysobalanaceae	363	34	25	3	2	4
Dichapetalaceae	46	4	4	—	—	—
Rhabdodendraceae	3	—	—	—	—	—
Caryocaraceae	24	2	1	—	1	—
Memecyleae (Melastomataceae)	81	8	7	—	—	1
Rhamnus (Rhamnaceae)	21	1	—	—	—	1
Lecythidaceae-I	64	2	—	2	—	—
Flacourtiaceae	233	26	13	5	1	7
Bignoniaceae-I	43	—	—	—	—	—
Meliaceae	122	25	10	1	2	12
Totals:	1245	127	68	15	10	34

mism falls to 37.5%. Data for the non-arborescent families are not presented here because we could not be sure that many of the herbaceous species are actually forest dwellers.

Discussion

The high percentage of endemism of trees in the coastal forest (53.5%, Fig. 2) emphasizes its botanical uniqueness. It has been isolated for long enough, probably since the late Tertiary, from Amazonian moist forests to allow the evolution of new species. Many of these endemics are now endangered because of rapid forest destruction and face imminent extinction unless vigorously protected now. If the trees are eliminated, the plants and animals that depend on them will follow.

Evidence from non-arborescent families also indicates the rich endemism (37.5–77.4%) of the coastal forest. Calderón and Soderstrom (1980) showed that of the 37 neotropical genera of bamboos, 22 are found in eastern Brazil and nine (40.9%) are endemic. In addition, many of the bamboos there represent primitive or unique species (Soderstrom & Calderón, 1974). Kubitzki (1975, 1977) also found in the woody groups he has studied that eastern Brazil is a region of primitive species, and Gentry (1979) adds that coastal Brazil possesses many endemic Bignoniaceae.

Evidence from bird (Haffer, 1974), reptile (Müller, 1973), primate (Kinzey, 1981), and butterfly (Brown, 1979) distributions also supports the hypothesis that the coastal forest of eastern Brazil is a center of endemism for all plant and animal forest species.

Smith (1962) suggests that the greatest diversity of species in the coastal forest is around Rio de Janeiro. He shows how diversity decreases to the south, probably limited by occasional frosts, and to a lesser extent to the north. He admits that more intensive collecting around Rio may distort the evidence for his pro-

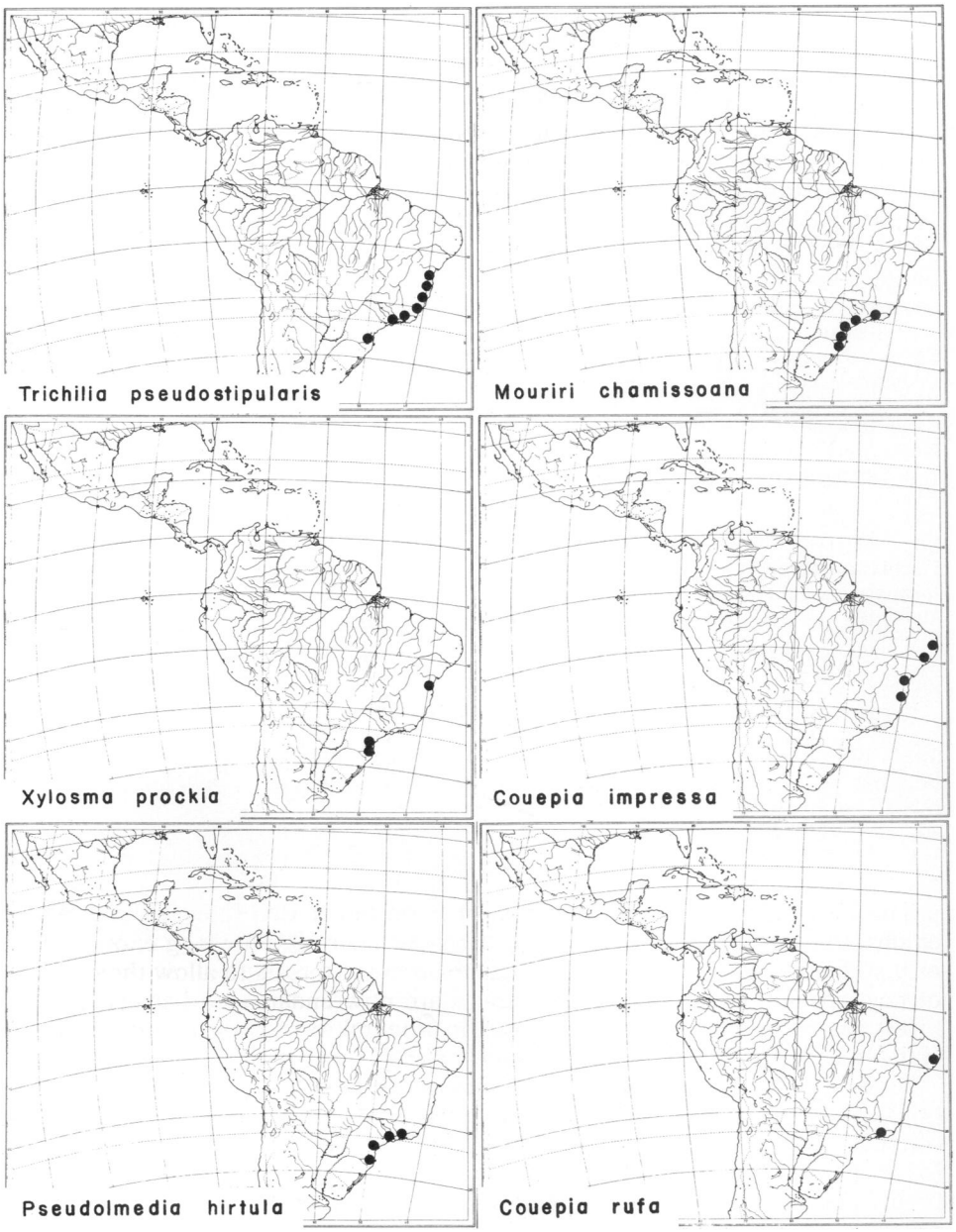

FIG. 2. Selected tree species endemic to the coastal forest of eastern Brazil. All examples from *Flora Neotropica*.

posed center of diversity. Brown (1979) inferred from distributional data of neotropical forest butterflies in the Heliconiini and Ithomiinae (Nymphalidae) four endemic centers in the coastal forest: Pernambuco, Bahia/Rio Doce, Rio de Janeiro/Itabapoana, and Rio de Janeiro/Paranaguá.

Our analysis of the 68 tree species endemic to the coastal forest supports the recognition of Brown's Bahia/Rio Doce and Rio de Janeiro/Itabapoana centers. Twenty-five and 21 species are restricted to these areas, respectively, whereas only two species are restricted to the Pernambuco and four to the Rio de Janeiro/Paranaguá centers. Only 16 of our 68 species occupy more than one of Brown's proposed centers. The presence of so many species in the Bahia/Rio Doce and Rio de Janeiro/Itabapoana centers is influenced by intensive collecting. Thorough collecting does, however, demonstrate that many species are not common to both areas. Furthermore, the active collecting programs pursued in Pernambuco and Santa Catarina should have identified more peculiar species, if these were indeed centers of endemism as hypothesized by Brown (1979).

A comparison of endemism in coastal Brazil with that of other areas in the neotropics is difficult because most others for which endemism values have been calculated are smaller. For example, Dodson and Gentry (1978) found 20% local endemism in the 1.67 square kilometer Río Palenque flora and Croat (1978) found only 7% Panamanian endemics in the 420 square kilometer Barro Colorado Island flora. The estimate of 53.5% endemism given here is comparable to Maguire's calculation (1970) of more than 50% in the flora of the Guayana Highland, which is of about the same extent as the coastal forests of eastern Brazil.

Fifteen species of the 127 studied (11.8%) are shared by the coastal forest and some part of the Planalto of Brazil or adjacent countries (Fig. 3). Most of the Planalto of Brazil is covered by *cerrado* (savanna-like vegetation), but gallery forests provide the conditions needed by moist forest species (Prance, 1981; Smith, 1962). In addition, a present-day forest refuge at the headwaters of the Araguaia River, within the Planalto and surrounded by *cerrado,* has been recognized by Brown (1979) and Prance (1981). Here, many trees of the coastal forests reappear. There are also, in arid northeast Brazil, limited moist forests surrounded by *caatinga* (seasonally dry thorn, shrub vegetation, Mori & Silva, 1979). These patches, called *brejos,* are located on the summits of hills and are thought to represent remnants of the forest that formerly extended uninterruptedly from the Amazon to the coast (Andrade-Lima, 1977, 1981; Bigarella et al., 1975). Finally, some coastal forest trees may have the ecological adaptability to survive in the liana forest (mesophytic forest at ca 1000 m, Mori & Silva, 1979) of the Planalto as well as in the moist forest of the coastal plain. Altitude is often not a barrier to distribution, witness the many Bahian species that grow with equal vigor in *campo rupestre* at 1000 or more meters and in *restinga* near sea level [e.g. *Mandevilla moricandiana* (DC.) Woodson, *Marcetia taxifolia* (St. Hil.) DC., *Bonnetia stricta* (Nees) Mart., *Humiria balsamifera* (Aubl.) St. Hil., *Waltheria cinerascens* St. Hil., *Hirtella glandulosa* Spreng., etc.]. These species are separated by a band of moist forest several hundred kilometers wide as well as by altitude.

Smith (1962) points out that the gallery forests in the Rio Paraguai Basin are so broad that they merge when large rivers lie close together as in the Misiones Territory of Argentina. He adds that at least *Bernardia pulchella* Muell. Arg. and *Dunalia breviflora* (Sendtn.) Sleum. range from there into the coastal forest. *Banara tomentosa* Clos., *Trichilia claussenii* C. DC. and *T. catigua* A. Juss. have similar distributions (Fig. 3).

Disjunction of range between Amazonia and the coastal forests of eastern Brazil (Fig. 4) has been well documented by Andrade-Lima (1953, 1969, 1977, 1981). These two forests were probably continuous in the past and, as aridity increased in the Tertiary, became separated by the xeromorphic *cerrado* and *caatinga* (Bigarella et al., 1975). Our value of 7.8% for Amazonian/eastern Brazilian dis-

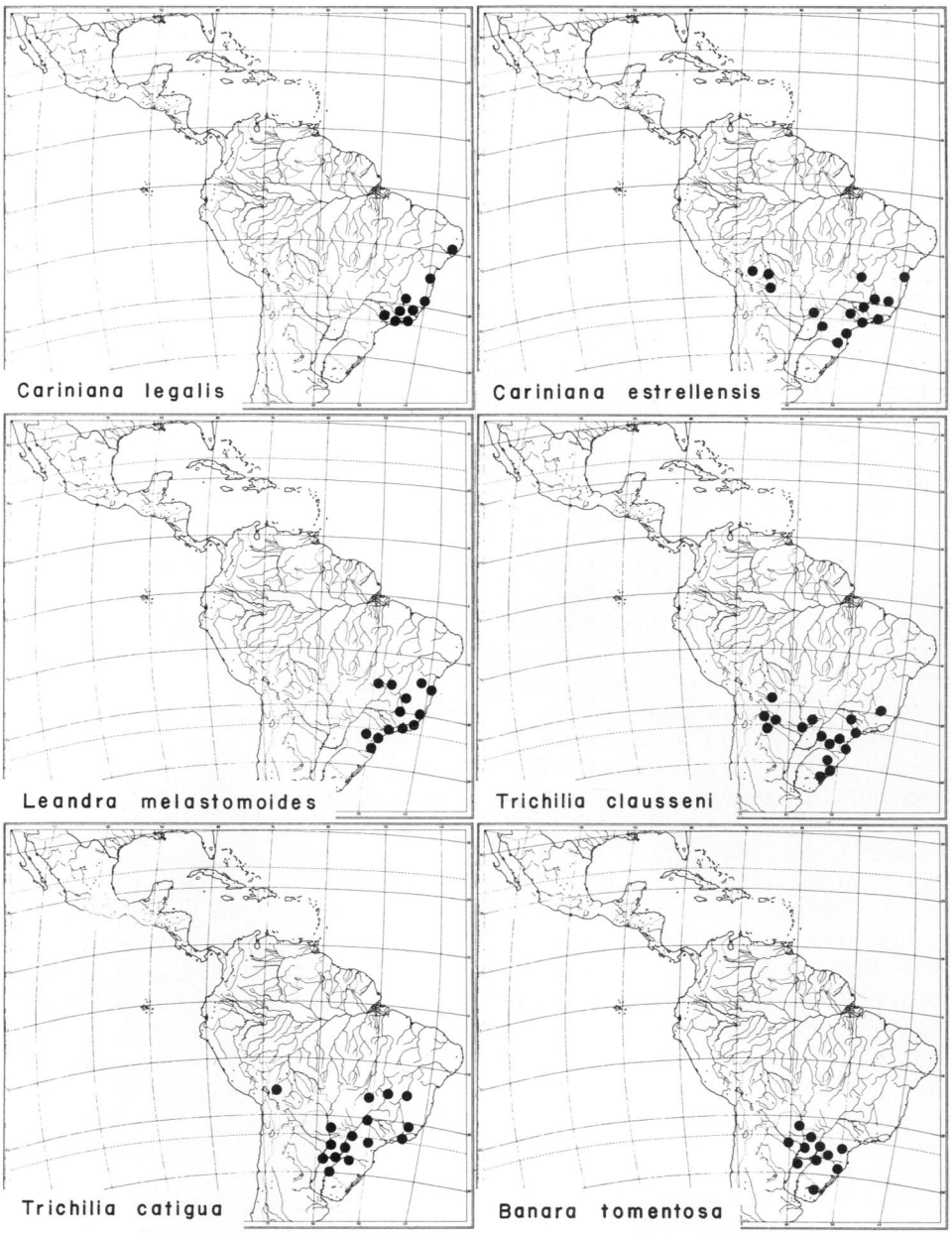

FIG. 3. Selected tree species endemic to the coastal forests of eastern Brazil plus some part of the Planalto of Brazil and similar areas in adjacent countries. All examples except *Leandra melastomoides* from *Flora Neotropica*, information for the latter provided by J. J. Wurdack.

juncts would be considerably increased if the many widespread species that are found both in Amazonia and eastern Brazil entered our calculations.

Widespread species constitute a significant proportion (26%) of the tree flora of eastern Brazil (Fig. 5). Kubitzki (1975), Prance (1979), and Gentry (1979) have

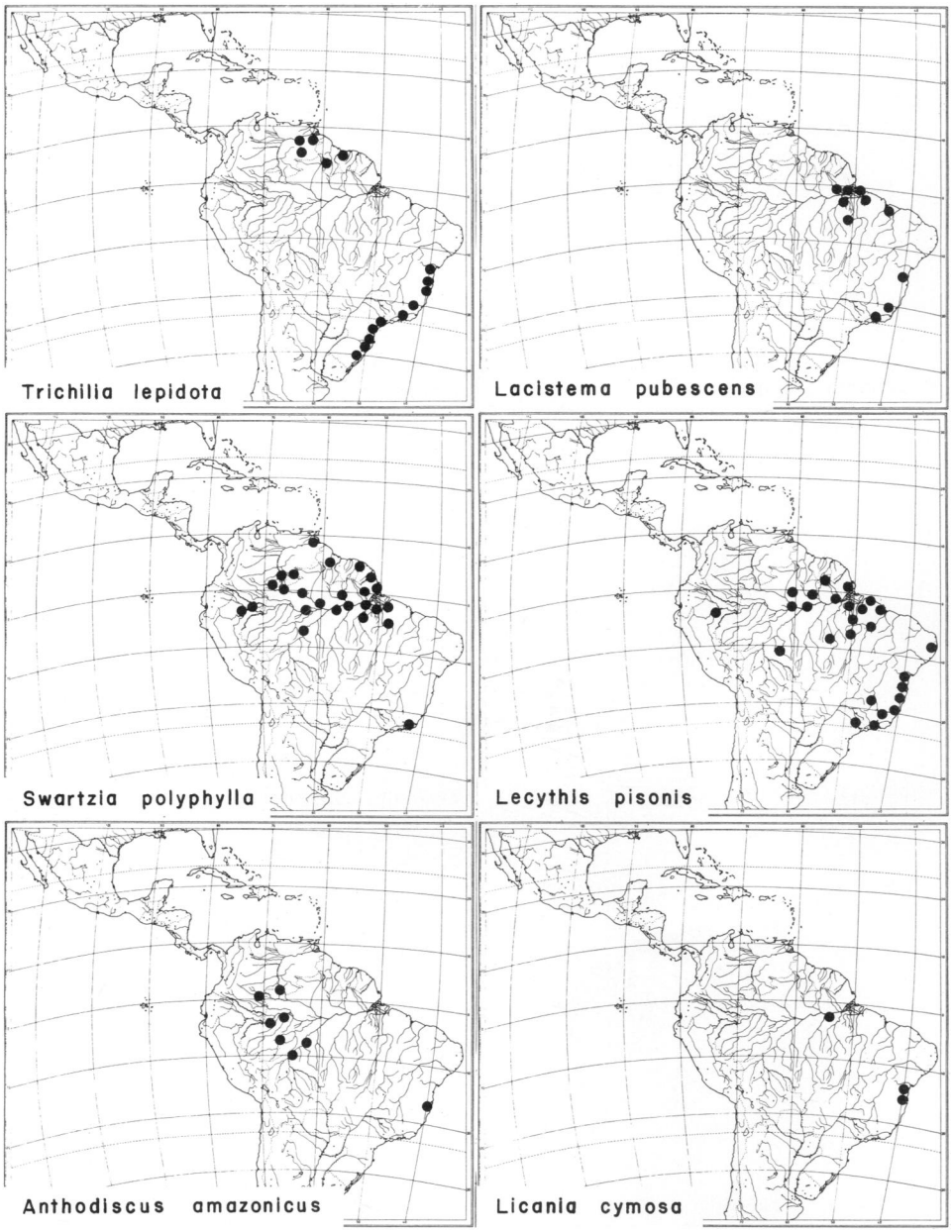

FIG. 4. Selected tree species disjunct between Amazonia and the coastal forests of eastern Brazil. All examples except *Lecythis pisonis* from *Flora Neotropica*.

demonstrated that one or more widespread species is a feature common to most large neotropical genera. This is an important point for monographers for, as Gentry has emphasized (1979), the existence of multiple names for widespread species is a recurrent problem in neotropical plant taxonomy. Even though endemism is high in coastal Brazil, monographers should not assume that all collections from there represent endemic taxa.

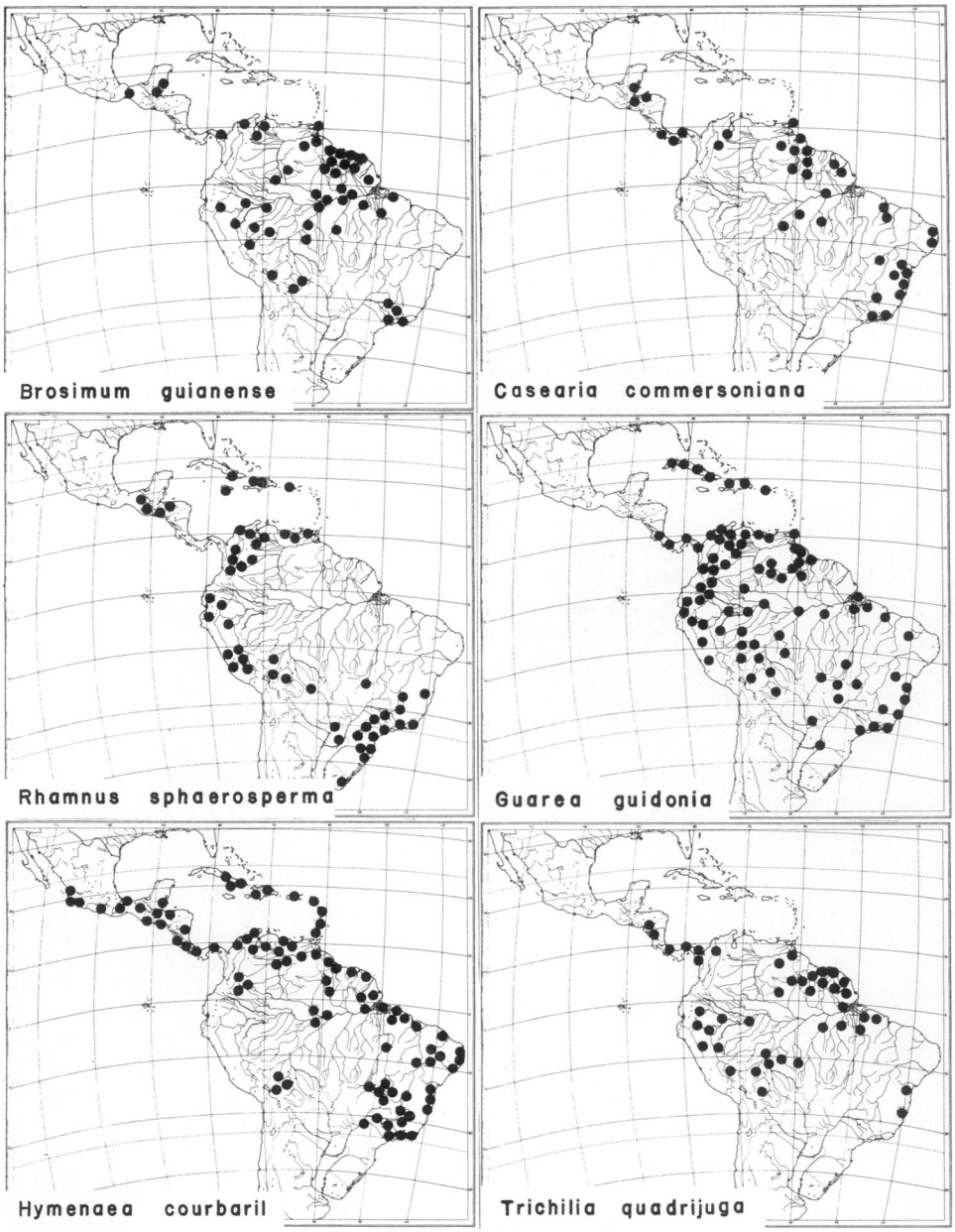

FIG. 5. Selected tree species widespread in the Neotropics. All examples except *Hymenaea courbaril* (Lee & Langenheim, 1975) from *Flora Neotropica*.

One of the species studied, *Rhamnus sphaerosperma* Swartz, is widespread but absent from the Amazon Basin (Fig. 5). It ranges from 400 to 2900 meters (Johnston & Johnston, 1978) and reaches the southern part of the coastal forest by way of the southern half of the Brazilian Planalto. *Chlorophora tinctoria* Gaudich. and *Psychotria carthagenensis* Jacq. have similar distributions (Smith, 1962).

The eastern Brazilian populations of widespread and disjunct species are also candidates for preservation insofar as they incorporate gene pools different from those of populations elsewhere.

Conclusion

This analysis of the distribution of 127 species of Brazilian coastal forest trees indicates a high degree of endemism in the region. Within the coastal forest there are centers of endemism at least around Rio de Janeiro and in the Bahia/Rio Doce area. Because forest destruction is so severe in eastern Brazil, urgent measures are called for to preserve the few forests remaining outside the public domain, as well as to protect from encroachment those already set aside as national parks or biological reserves. Representative forests along the entire length of the coast require conservation, but special attention should be given to the centers of endemism.

Acknowledgments

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BOOK REVIEWS

The Medical Mycology Handbook. Mary C. Campbell and Joyce L. Steward. xvi, 436 pp., illus. John Wiley & Sons, New York. 1980. $25.00.

This spirally bound handbook is intended as an aid in the training of technicians in a medical mycological laboratory and as a resource for information on the subject for all workers in the field. The authors have accomplished the goals admirably. Part I of the manual deals with an understanding of the role of fungi in the medical field. A brief history, some general characteristics of fungous pathogens and opportunistic fungi, taxonomy of the fungi (including some of the recently proposed treatments), and the fungal diseases in various aspects are presented in a concise and readable fashion. Part II outlines the procedures for the technician doing the laboratory work isolating and identifying the isolates from suspected diseases of man. An appendix lists the necessary equipment, reagents, formulae, maintenance of stock cultures, etc. A pertinent bibliography is included at the end of each chapter. A short but valuable glossary has been added, as well as some black-and-white and color plates. Throughout the text good line drawings illustrate the fungi as they appear to the technician using a microscope. The organization and appearance of the book is well done. The manual certainly is one of the best to appear in recent years.—CLARK T. ROGERSON, New York Botanical Garden.

A Catskill Flora and Economic Botany. Karl L. Brooks. **II. Coniferales**. New York State Museum Bull. 441: xi, 166 pp. $2.00. **III. Apetalae**. New York State Museum Bull. 443: x, 374 pp. 1980. $4.00.

These two parts of the *Catskill Flora and Economic Botany* follow part I which dealt with the Pteridophytes (Bull. 438 of 1979). The work represents an amateur botanist's years in the Catskill Mountains in New York and is intended as a source book for those interested in the flora.

The *Flora* is an interesting combination of keys to identification of the taxa and notes and comments on their occurrence. The bulk of each species entry is an extensive review of the historical usages of the plant throughout its range of distribution. These reviews are interesting and comprehensive. Illustrations are reproduced from other sources. Distribution maps for each species comprise an appendix.

This work will be interesting to a broader audience than one expects for a flora. Also, the intensive activity of Mr. Brooks in the Catskills will provide useful information for the flora of the state of New York being undertaken by the New York State Museum.—THOMAS ZANONI, Jardín Botánico Nacional, Santo Domingo, República Dominicana.