CHAPTER 30

SPECIES COUNT OF VASCULAR PLANTS IN ONE HECTARE OF HUMID LOWLAND FOREST IN AMAZONIAN ECUADOR

Henrik Balslev, Renato Valencia, Guillermo Paz y Miño, Henning Christensen and Ingvar Nielsen

INTRODUCTION

Although trees make up the bulk of biomass and species in tropical rain forests, knowledge of the contribution of other life forms to species richness is obviously interesting from a biological point of view. Nevertheless, most plot- and transect based species counts in neotropical rain forests have dealt only with trees, most commonly with trees ≥ 10 cm in diameter at breast height (dbh) (e.g. Pires *et al.*, 1953; Mori *et al.*, 1983; Boom, 1986; Campbell *et al.*, 1986; Balslev *et al.*, 1987; Gentry, 1988; Foster, 1990; Foster and Hubbell, 1990; Faber-Langendoen and Gentry, 1991). Species counts of herbs were published by Poulsen and Balslev (1991), and Gentry (e.g. 1995) provided data on species numbers for trees, vines, and hemi-epiphytes down to 2.5 cm dbh from 150 plots, each 0.1 ha in size, distributed throughout the tropics. Total species counts in plots of neotropical rain forests have been attempted only few times (Whitmore *et al.*, 1985; Gentry and Dodson, 1987; Duivenvoorden, 1994). Here, we present the results of an attempt to count all species of vascular plants in a 1-ha plot of tropical lowland rain forest in Amazonian Ecuador.

STUDY AREA

Our study plot was located on the equatorial line (00° 00', 76° 11') in the eastern lowlands of Ecuador within the Reserva de Producción Faunística Cuyabeno and 1 km north of Laguna Grande. The Cuyabeno area is a mosaic of flat flood plains along rivers and lagoons and hills that are never flooded. The forest on the hills is 30 to 35 m tall, with emergents reaching 40 to 50 m in height. Soils are red and clayey. The climatic conditions are perhumid, with 3555 mm of annual precipitation and no month with less than 100 mm of rain. The period from December through February is the least rainy and 'dry' enough to cause a lowering of the water level of rivers and lagoons, but not so dry as to cause deciduousness of the forest. The 1-ha plot was located in tall forest with an open understory for easy walking. Human influence is limited to hunting and

occasional extraction of wood, food, and medicine by the local inhabitants of the indigenous group of the Sionas.

The density of trees in the study plot was 1561 stems > 5 cm dbh and 693 stems > 10 cm dbh. The basal area was 29.1 m^2 for trees > 5 cm dbh and 25.7 m^2 for trees > 10 cm dbh. The annual mortality rate of forest at the study plot was 1.04% for trees ≥ 10 cm dbh, and the doubling time (i.e. the time needed to double the number of individuals at the existing recruitment rate) was 23 years. Both are low values compared to other neotropical forests, indicating that the forest was in a growing phase, with a net increase in the number of individuals and accumulation of basal area (Korning and Balslev, 1994).

METHODS

The study plot (100 m^2) was divided into 10-m^2 grid squares, marked with plastic tubes and nylon rope. All trees ≥ 5 cm dbh were marked with numbered aluminium plates, their dbh and position in the plot were noted, and voucher specimens were collected of each individual. Trees and shrubs 1 to 5 cm dbh were located individually, their positions were noted, and they were vouchered, but not marked with numbered aluminium plates; this group of plants was censused only in a 70-m^2 (0.49-ha) section, nested in one corner of the 1-ha plot. All lianas and vines in the entire plot were located individually and numbered with aluminium plates, and vouchers were collected. Epiphytes (including hemi-epiphytes) and ground herbs were collected by systematically searching each 10-m^2 grid square. For the epiphytes, vouchers were collected each time a new species was encountered; those growing on the tree trunks were intensively collected, the ones in the canopy less intensively. For the ground herbs, each species was vouchered for each grid square in which it was found. The vouchers were dried, labelled, and identified in the herbaria in Quito, Ecuador, and Aarhus, Denmark. Duplicates were sent to specialists for expert identification.

RESULTS AND DISCUSSION

The numbers of species encountered in each family and category (trees ≥ 10 cm dbh, trees ≥ 5 cm dbh, trees and shrubs 1 to 5 cm dbh, lianas and vines, ground herbs, and epiphytes) are shown in Table 30.1. The relative contribution of each life form to the total species richness is presented in Table 30.2 and compared to other neotropical forests.

We encountered 88 families of angiosperms and several families of pteridophytes. Pteridophytes are not divided into families in Table 30.1; they are treated as one category. The legumes are all treated as one family, Fabaceae s.l., while Moraceae and Cecropiaceae are treated as two families, as are Zingiberaceae and Costaceae. This number of families corresponded to the number found in the 90-km^2 Reserva Ducke in central Amazonian Brazil (Prance,

Table 30.1 Numbers of species encountered in a 1-ha plot (0.49-ha for trees and shrubs 1 to 5 cm dbh) in terra firme rain forest in the Cuyabeno area, Amazonian Ecuador. Legumes are treated as one family (Fabaceae s.l., including Mimosaceae and Caesalpiniaceae). All ferns and fern allies are lumped into one group – pteridophytes. The total number of species for each family takes into account that the same species may be found in more than one life form category

Family	*Trees ≥ 10 cm dbh*	*Trees ≥ 5 cm dbh*	*Trees & shrubs 1–5 cm dbh* (0.49-ha)	*Lianas & vines*	*Ground herbs*	*Epiphytes*	*Total*
Araceae	–	–	–	2	28	68	71
Fabaceae, s. l.	33	47	48	12	–	–	59
Lauraceae	29	38	27	–	–	–	48
Pteridophytes	–	–	1	1	25	27	44
Sapotaceae	25	34	29	–	–	–	44
Rubiaceae	7	15	32	1	4	1	39
Myrtaceae	10	18	27	–	–	–	34
Moraceae	21	26	20	–	–	–	33
Annonaceae	9	26	23	1	–	–	32
Burseraceae	20	24	16	–	–	–	29
Euphorbiaceae	13	18	11	–	–	–	25
Meliaceae	9	15	19	–	–	–	24
Arecaceae	6	6	15	1	–	2	22
Melastomataceae	4	9	13	2	–	8	22
Myristicaceae	12	16	13	–	–	–	22
Bromeliaceae	–	–	–	–	3	22	22
Chrysobalanaceae	14	20	14	–	–	–	20
Gesneriaceae	–	–	–	–	2	12	14
Bignoniaceae	–	1	4	10	–	–	14
Clusiaceae	7	9	9	1	–	2	14
Flacourtiaceae	6	10	6	–	–	–	13
Cecropiaceae	10	10	7	1	–	–	13
Sapindaceae	3	6	8	9	–	–	11
Apocynaceae	3	8	3	–	–	–	9
Hippocrateaceae	1	3	9	3	–	–	9
Marantaceae	–	–	–	–	9	–	9
Piperaceae	–	2	6	1	–	3	9
Sterculiaceae	3	8	5	–	–	–	8
Bombacaceae	6	7	5	–	–	–	8
Poaceae	–	–	–	–	8	–	8
Orchidaceae	–	–	–	–	1	7	8
Icacinaceae	1	3	5	2	–	–	7
Elaeocarpaceae	5	5	7	–	–	–	7
Lecythidaceae	7	7	7	–	–	–	7
Menispermaceae	–	–	–	7	–	–	7
Cyclanthaceae	–	–	–	–	1	7	7
Olacaceae	3	5	6	1	–	–	6
Nyctaginaceae	4	6	5	–	–	–	6
Simaroubaceae	1	4	5	–	–	–	6
Tiliaceae	5	6	2	–	–	–	6
Monimiaceae	3	6	3	–	–	–	6
Combretaceae	3	3	2	2	–	–	5

Continued

Table 30.1 Continued

Family	*Trees ≥ 10 cm dbh*	*Trees ≥ 5 cm dbh*	*Trees & shrubs 1–5 cm dbh* (0.49-ha)	*Lianas & vines*	*Ground herbs*	*Epiphytes*	*Total*
Sabiaceae	3	5	2	–	–	–	5
Violaceae	1	3	5	–	–	–	5
Dichapetalaceae	–	2	3	1	–	–	5
Celastraceae	–	1	–	4	–	–	5
Vochysiaceae	3	3	4	–	–	–	4
Polygonaceae	4	4	2	–	–	–	4
Quiinaceae	2	4	3	–	–	–	4
Loganiaceae	–	2	4	1	–	–	4
Boraginaceae	–	3	4	–	–	–	4
Connaraceae	–	–	1	4	–	–	4
Passifloraceae	–	–	–	3	–	–	4
Cyperaceae	–	–	–	1	4	–	4
Erythroxylaceae	1	3	1	–	–	–	3
Anacardiaceae	1	3	2	–	–	–	3
Smilacaceae	–	–	–	3	–	–	3
Dilleniaceae	–	–	–	3	–	–	3
Zingiberaceae	–	–	–	–	3	–	3
Heliconiaceae	–	–	–	–	3	–	3
Costaceae	–	–	–	–	3	–	3
Verbenaceae	1	1	2	1	–	–	2
Ulmaceae	1	2	1	–	–	–	2
Rutaceae	1	2	–	–	–	–	2
Ebenaceae	2	2	–	–	–	–	2
Capparidaceae	–	1	2	–	–	–	2
Malphigiaceae	–	–	–	2	–	–	2
Phytolaccaceae	–	–	–	2	–	–	2
Cucurbitaceae	–	–	–	2	–	–	2
Vitaceae	–	–	–	2	–	–	2
Dioscoreaceae	–	–	–	2	–	–	2
Cactaceae	–	–	–	–	–	2	2
Araliaceae	1	1	1	–	–	–	1
Rosaceae	1	1	–	–	–	–	1
Myrsinaceae	–	1	1	–	–	–	1
Solanaceae	–	–	1	–	–	–	1
Theophrastaceae	–	–	1	–	–	–	1
Acanthaceae	–	–	1	–	–	–	1
Lacistemaceae	–	–	1	–	–	–	1
Ochnaceae	–	–	1	–	–	–	1
Aristolochiaceae	–	–	–	1	–	–	1
Asclepiadaceae	–	–	–	1	–	–	1
Asteraceae	–	–	–	1	–	–	1
Lythraceae	–	–	–	1	–	–	1
Marcgraviaceae	–	–	–	1	–	–	1
Mendonciaceae	–	–	–	1	–	–	1
Gentianaceae	–	–	–	–	1	–	1
Commelinaceae	–	–	–	–	1	–	1
Begoniaceae	–	–	–	–	–	1	1
Indeterminate	2	8	8	5	–	10	23
Total	307	473	464	99	96	172	942

Table 30.2 Relative contribution of different life-forms to total species richness in some neotropical rain forests (sources: Manu (Foster 1990), Barro Colorado Island (Foster and Hubbel 1990), La Selva (Hammel 1990), Río Palenque (Gentry and Dodson 1987), Río Puerto Viejo (Whitmore *et al.* 1985), and Cuyabeno (present study))

		% of species					
Site	*Area* (ha)	*Trees*	*Shrubs*	*Lianas and vines*	*Ground herbs*	*Epiphytes*	*Total # of species*
Manu floodplain (Amazonian Peru)	2000	27	29	19	13	12	1215
Barro Colorado Island (Canal Zone, Panama)	1500	24	18	17	22	19	966
La Selva (lowland Costa Rica)	1500	22	19	9	25	25	1740
Río Palenque (coastal plain, Ecuador)	1700	15	10	16	36	22	1033
Río Palenque (coastal plain, Ecuador)	0.1	32	10	9	13	35	365
Río Puerto Viejo (lowland Costa Rica)	0.1	43	6	15	7	27	233
Cuyabeno (Amazonian Ecuador)	1.0	50	11	11	10	18	942

1990), but was less than the 100 families encountered in 10 0.1-ha plots in the Caquetá area of Amazonian Colombia (Duivenvoorden, 1994).

The number of species/family ranged from 1 to 71 species. If the three life-form categories (trees ≥ 10 cm dbh, ≥ 5 cm dbh, and 1 to 5 cm dbh) are combined in one category, there is a clear tendency for the species-rich families (> 20 species) to be confined to one or two categories. The Araceae, Pteridophytes, Bromeliaceae, and Gesneriaceae were either ground herbs or epiphytes. The Lauraceae, Sapotaceae, Moraceae, Myrtaceae, Burseraceae, Myristicaceae, Meliaceae, Chrysobalanaceae, and Euphorbiaceae were all trees or shrubs. Fabaceae and Bignoniaceae included trees and lianas. Rubiaceae and Melastomataceae included all, or all but one, of the life-form categories, even though most of their species were in the trees and shrubs category.

Trees ≥ 10 cm dbh

This is the most commonly studied group of plants in species counts in plots of tropical rain forests. Our count at Cuyabeno of 307 species in 1 ha appears to be the highest count so far reported for either neotropical or Asian forests (Valencia *et al.*, 1994). From Yanamomo in the Iquitos area of neighbouring Peru, Gentry (1988) reported 300 species ≥ 10 cm dbh, including 17 lianas, in a 1-ha plot. Several other counts report numbers varying from 150 to 250 species of trees ≥ 10 cm dbh in 1 ha. Since many of the species are represented by few or even a single individual, these species counts are highly influenced by the density of the forests. Densities may vary from about 400 to 850 trees ≥ 10 cm dbh/ha. Therefore, if counted as species/individuals, the Yanomomo plot would be richer, with an average of 2.0 individuals/species, than the Cuyabeno plot, with an average of 2.2 individuals/species.

Trees ≥ 5 cm dbh

In this size class, we encountered 473 species, indicating that small trees were extremely important to the overall species richness of this tropical rain forest. Added species, relative to the ≥ 10 cm dbh class, were encountered in most of the species-rich tree families such as Fabaceae, Rubiaceae, Lauraceae, Sapotaceae, Annonaceae, Myrtaceae, and Chrysobalanaceae.

Trees and shrubs 1 to 5 cm dbh

In this category we found 464 species. Only 55% of these species were shared with the ≥ 5 cm dbh size class, meaning that 209 species were found only among the trees and shrubs with 1 to 5 cm dbh. These species, however, were mostly found in the families rich in species of larger trees. Because trees with stems > 5 cm dbh must grow through the 1 to 5 cm dbh size class, we should expect to find all 473 species > 5 cm dbh in the 1 to 5 cm dbh class, in addition to the 209

species that did not reach > 5 cm dbh. This suggests that small and slender treelets are by far the most species-rich growth form at Cuyabeno. That result agrees with comparable data from the Caquetá area, where trees ≤ 2.5 cm dbh accounted for 24% to 47% of the species (Duivenvoorden, 1994). The exceptionally high number of slender trees and shrubs may be partly caused by the fact that the forest at the study plot is in a building phase.

Lianas and vines

Lianas and vines were encountered in 37 families and numbered 99 species (Paz y Miño, Balslev, and Valencia *et al.*, 1991; Paz y Miño, Balslev, Valencia, and Mena, 1991). A few families (Fabaceae, Bignoniaceae, Sapindaceae, and Menispermaceae) accounted for the major portion of the liana species (38 of the 99 species), whereas the remaining 33 families had four or fewer liana species. In Bignoniaceae and Menispermaceae, all or nearly all species were lianas; in Fabaceae and Sapindaceae, lianas were a secondary life form relative to trees and shrubs. The 99 species of lianas and vines accounted for 10% of the species at Cuyabeno. This is more than the 0% to 7% reported for the Caquetá area (Duivenvoorden, 1994), but far less than the average of 20% climbers reported for neotropical forests by Gentry (1982).

Ground herbs

The ground herbs were distributed among 15 families and numbered 96 species (Poulsen and Balslev, 1991). The ground herbs thus accounted for 10% of the species richness at Cuyabeno. Araceae and pteridophytes accounted for more than half of the ground herb species. Among the 28 terrestrial species of Araceae, only three were obligate terrestrials, while the remaining 25 were facultative terrestrials that were also found among the epiphytes. Among the pteridophytes, 15 were obligate terrestrial, while 10 were also among the epiphytes.

It is interesting to note that Poaceae ranked fourth in terms of species richness among ground herbs. This family is normally not thought of as a 'rain forest family'.

A special sub-category was the saprophytes, represented by a single species, *Voyria flavescens* (Gentianaceae), among the ground herbs in our plot.

Epiphytes and hemi-epiphytes

The epiphytes were represented in 13 families and included 172 species, mostly belonging to the Araceae (68 species), the pteridophytes (27 species), and the Bromeliaceae (22 species). The low count for Orchidaceae (7 species) was probably caused by difficulties in distinguishing sterile specimens and also because this family is mostly found in the canopy, which was only partly searched in this census. Epiphytes and hemi-epiphytes accounted for 18% of the species

in Cuyabeno. Much lower numbers (5%) were reported for the Caquetá area (Duivenvoorden, 1994), but higher numbers – 35% and 25%, respectively – were found in western Ecuador (Gentry and Dodson, 1987) and Costa Rica (Hammel, 1990).

Total species numbers

The total species number of 942 in a 1-ha plot is remarkable in itself. It is close to the approximate 1000 species found in Denmark (43 000 km^2) in the north temperate zone at 55° north latitude and the 830 species so far reported for the 90-km^2 Reserva Ducke in central Brazil. Other plot-based total species counts for vascular plants include a 0.01-ha plot in Costa Rica, which had 233 species (Whitmore *et al.*, 1985), and 10 0.1-ha plots in the Caquetá area of Amazonian Colombia, which had a total of 1223 species with a variation of 40 to 313 species in each 0.1-ha plot. The Caquetá sample, however, included a number of forest types on rich and poor soils that were or were not subjected to flooding.

CONCLUSION

Our data support the contention that the western Amazon, close to the Andean foothills, houses the most species-rich rain forest. The tree growth form is the most important contributor to this species richness, with about one-half of the species, and among the trees, the small, slender treelets contribute the larger part of the species richness. Other growth forms such as lianas, vines, and ground herbs each contributed about one-tenth of the species, whereas epiphytes and hemi-epiphytes contributed close to one-fifth of the species. The plant families found to dominate these species-rich rain forests are the same in Cuyabeno as elsewhere in the neotropical region. Some 15 families of the total of 88 accounted for about two-thirds of the total species richness. Most of these species-rich families were typical tree families (Fabaceae, Lauraceae, Sapotaceae, Moraceae, etc.). Species-rich herbaceous groups included the Araceae, Bromeliaceae, and pteridophytes. Future studies on rain forests should include life forms other than trees to account for about half of the species richness. Tree studies will, however, still provide the best indicator of overall species richness.

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