

On the vegetation of a seasonal *mixedwater* inundation forest near Manaus, Brazilian Amazonia

by

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Abstract

The species composition of an area of 0.5 hectare of seasonal inundation forest located between the blackwater Negro River and the whitewater Solimões River at Lago Janauari near Manaus, Brazil, was studied. Sixty-six arboreal species representing 55 genera and 31 families were recorded. Total basal area was 15 m² and bole volume was 125 m³. The most abundant species were *Pouteria* sp. (Sapotaceae) and *Pterocarpus amazonum* (Fabaceae). The highest basal area per species was 2.15 m² for *Calophyllum brasiliense* (Clusiaceae). The vegetation in the study area represented an ecotone with characteristic tree species of the seasonal inundated forests in the whitewater (várzea) or/and blackwater (igapó) region of Central Amazonia. Following the terminology of Amazonian forest types subject to inundation (PRANCE 1979) it is therefore named "seasonal várzea & igapó" or "mixedwater" inundation forest.

Keywords: Inundation forest, *igapó*, *várzea*, floodplains, ecotone, Amazon, Neotropics.

Introduction

In Central Amazonia, there are seasonal changes in the water level of the Rio Solimões-Amazonas and the Rio Negro averaging about 10 m. Forests beside the rivers are flooded to a depth of several meters for five to seven months each year. These natural events have occurred for at least 2.4 million years (IRION et al. 1997). The pronounced seasonal periodicity of the "monomodal floodpulse" (JUNK et al. 1989) has brought about long-term adaptations and the evolution of endemic species of plant and animals (cf. JUNK 1997). They represent organisms characteristic either of "seasonal *igapó*", (forest annually flooded by black- and/or clearwater rivers) or of "seasonal *várzea*" (forest flooded by whitewater rivers), definitions according to PRANCE 1979, 1980; cf. ADIS 1997; IRMLER 1977; WORBES 1997.

In the region of Manaus, where the large blackwater Rio Negro and the large whitewater Rio Solimões come together, the inundation forest is influenced by both types of water. In this study, we investigated whether the vegetation is representative of both floristic components, i.e. from *igapó* and *várzea*, and whether it can be considered an ecotone, as was previously suggested for the terrestrial invertebrate fauna by ADIS (1992).

Materials and methods

The study area was at Lago Janauari (03°20'S, 60°17'W), situated on a spit between the Rio Negro and the Rio Solimões about 10 km from Manaus, across the river (cf. Map). The region was influenced by blackwater of the Rio Negro during low water level and by whitewater of the Rio Solimões during the high water period. The study area in this "*mixedwater*" inundation forest (cf. PRANCE 1979) was flat and had no direct connection with non-flooded upland areas, which were several km distant (comp. Fig. 18 in IRMLER 1975). The soil consisted of clay, predominantly montmorillonite, which represented alluvial deposits of the Rio Solimões. A scanty litter layer was formed during the non-inundation period (August-September-April/March). It was mostly carried out of the forest by the current of the annual floodwaters and/or partially covered by sediments during inundation. Further information on the study area is given by ADIS (1992), IRMLER (1975, 1976) and MORAIS (1995).

The study site was located close to sampling station 6 of IRMLER (1975), bordering a rivulet cutting through the *mixedwater* inundation forest. It is part of the Ecological Park of SELVATUR, Manaus, and represents a study area of the Projeto INPA/Max-Planck on investigations of the terrestrial invertebrate fauna (cf. ADIS 1992, 1997; MORAIS 1995; MORAIS et al. 1997a, b). The study area was situated about 26.3 m above sea-level and annually inundated for 17.7 ± 4.8 weeks ((March)/April/(May)-(July)/August/(-September; average duration calculated for 1987-96 based on water-gauge readings in the harbour of Manaus).

The floristic inventory of woody plants was carried out on 0.5 hectare during the low-water period in October 1987 by the first author and tree spotters of INPA. A rectangular area of 100 x 50 m along the rivulet was subdivided into 10 plots, each 10 m in width and extending 50 m from the forest edge into the forest. The height of trees was estimated using a pole of known length. The lower dbh-limit was established at 10 cm. Some species were identified in the field, the others were checked in the INPA herbarium where voucher specimens have been deposited. In addition, some large trees frequent in the study area and forming the top canopy (cf. ERWIN 1983) were identified. Family Importance Values (FIV; MORI et al. 1983) and relative Species Importance Values (SIV; equal to the sum of relative abundance, relative frequency and relative basal area) of all living woody plants on the study site were computed.

Results and discussion

Floristic composition

Thirty-one plant families were recorded on the study site (Table 1). Leguminosae *sensu lato* was richest in species: eighteen species belonged to the Fabaceae, seventeen to the Mimosaceae, and ten species to the Caesalpiniaceae. The family Euphorbiaceae, with seven species, ranked highest for Family Importance Value (FIV) equal to 35 (cf. MORI et al. 1983). It was followed (in decreasing order of FIV; see Table 1) by the Sapotaceae, Clusiaceae, Mimosaceae, Fabaceae and Moraceae. Caesalpiniaceae, Lecythidaceae, Myristicaceae and Lauraceae ranked intermediate, with a FIV from 19 to 11. The remaining 21 families had a low FIV which varied between 9 and 2.

In total, 66 woody plant species representing 55 genera were recorded on the study site (Tables 1, 2). The total number of living trees was 198 (a calculated 396 per ha). *Pouteria* sp. ranked highest according to its Species Importance Value (SIV) equal to 17.5. This species (14 trees) and *Pterocarpus amazonum* (13 trees) were both very frequent and very abundant (Table 2). *Calophyllum brasiliense* had the highest basal area (2.15 m²). Together, these three species represented one-sixth of the total SIV. Twenty-eight species in Table 2 were only represented by a single species. Woody climbers (lianas) were represented by two species. Palms (Arecaceae) were not recorded on the study site but were present in the study area (*Astrocaryum jauari*; cf. Table 4).

Forest structure

The maximum diameters at breast height (dbh \geq 10 cm) recorded were 121.0 and 112.7 cm for trees of *Calophyllum brasiliense* in plots 6 and 3 (cf. bole volume Table 3). Other species represented by large trees were *Sloanea* sp. (plot 3: 97.1 cm), *Pterocarpus amazonum* (plot 5: 76.4 cm), *Piranhea trifoliata* (plot 9: 76.4 cm) and *Hura crepitans* (plot 6: 73.2 cm). The distribution of the dbh size classes was in a typical J-shaped curve (Fig. 1), as has been shown for various other tropical forests (CAMPBELL et al. 1986; LAMPRECHT 1972).

Basal area varied between 0.4 and 3.0 m² per plot (Table 3). The calculated mean for the ten plots investigated was 1.4 ± 1.0 m². The estimated value of the study site was 29 m² per ha. The basal area of Amazonian forests rarely surpasses 40 m² per ha (PIRES 1984). KLINGE et al. (1995) reported 45 m² for a seasonal *várzea* forest. The highest basal area per species (Table 2) was 2.15 m² for *Calophyllum brasiliense* (Clusiaceae).

The maximum height of trees was 26 m, attained by *Calophyllum brasiliense* (one tree each in plots 3 & 6), and *Sloanea* sp. (one tree in plot 3). Single individuals of *Buchenavia macrophylla*, *Pterocarpus amazonum* and *Virola surinamensis* reached heights of between 23 and 25 m. The majority of the species forming the main canopy was intermediate in height (Fig. 2: top). Thirty-six species composed the lower canopy (5-9.9 m). Tree crown layers are indicated by the peak of the frequency curve: in 3-8 m, 12-16 m and 20-22 m height (Fig. 2: bottom). Height and dbh data for species represented by at least 13 individuals are depicted in Figure 3. The space from ground level to 3 m above ground was free of tree crowns, except for a few young trees, e.g. of *Micropholis* sp. and *Swartzia* sp.

Vegetation type

According to the floristic categories of Amazonian forest types subject to inundation (PRANCE 1979, 1980), the vegetation in the study area contains tree species characteristic of both the seasonal *várzea*, and the seasonal *igapó*, and also trees which occur in both types of inundation forest (Table 4). Therefore the forest investigated is a mixture of seasonal *várzea* & *igapó* and is better termed a "mixedwater" inundation forest because of the influence of both whitewater and black/clear waters. One of the reasons is the dispersal of diaspores by water and fish (hydrochory, ichthyochory) during the high water period (cf. KUBITZKI & ZIBURSKI 1984). The mixedwater inundation forest should therefore be considered an ecotone with respect to both flora and terrestrial invertebrate fauna (cf. ADIS 1992; MORAIS 1995; MORAIS et al. 1997a, b). Another example of this occurs in the Anavilhanas Archipelago in the Rio Negro, where the large whitewater river Rio Branco influences the *igapó* vegetation of the Rio Negro (cf. RODRIGUES 1961). Further floristic and faunistic inventories of this area are currently in progress.

Resumo

Estudou-se a composição de espécies numa área de 0,5 hectare de uma floresta inundável sazonal, situada no Lago Janauari perto de Manaus, Brasil, entre o Rio Negro, de água preta, e o Rio Solimões, de água branca. Registrou-se 66 espécies arbóreas, representando 55 gêneros e 31 famílias. A área basal total foi de 15 m² e o volume do fuste 125 m³. As espécies mais abundantes foram *Pouteria* sp. (Sapotaceae) e *Pterocarpus amazonum* (Fabaceae). A maior área basal por espécie foi de 2,15 m² para *Calophyllum brasiliense* (Clusiaceae). A vegetação na área de estudo representou um ecótono com espécies de árvores características para a floresta sazonal na região da água branca (*várzea*) ou/e da água preta (*igapó*) da Amazônia Central. Seguindo a terminologia para os tipos de florestas amazônicas sujeitas à inundação (PRANCE 1979) denomina-se, desta forma, "*várzea* & *igapó* sazonal" ou floresta inundável de "água mista".

Acknowledgments

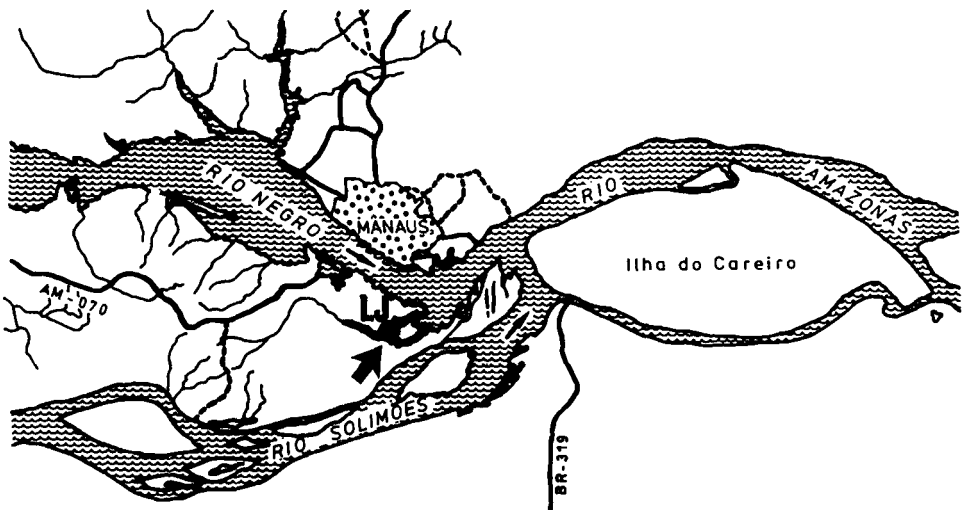
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Map 1:

Location of the mixedwater inundation forest at Lago Januári (03°2'S, 60°17'W).

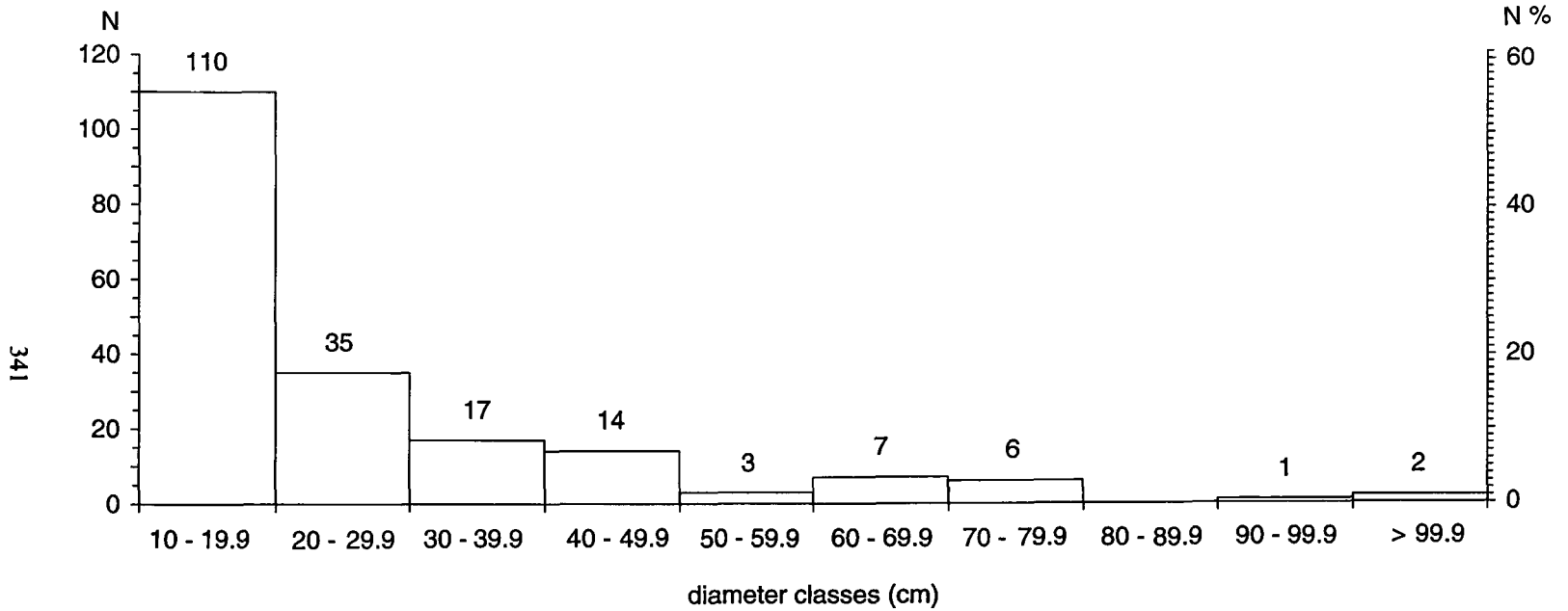


Fig. 1:
Diameter classes (cm) of 198 trees (dbh \geq 10 cm) sampled on 0.5 ha of a seasonal *mixedwater* inundation forest at Lago Janauari near Manaus.

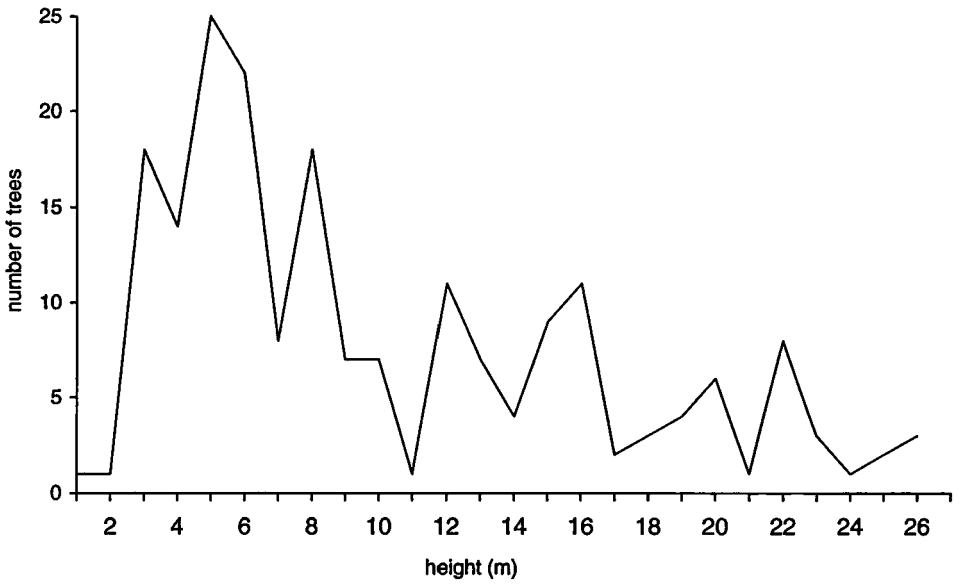
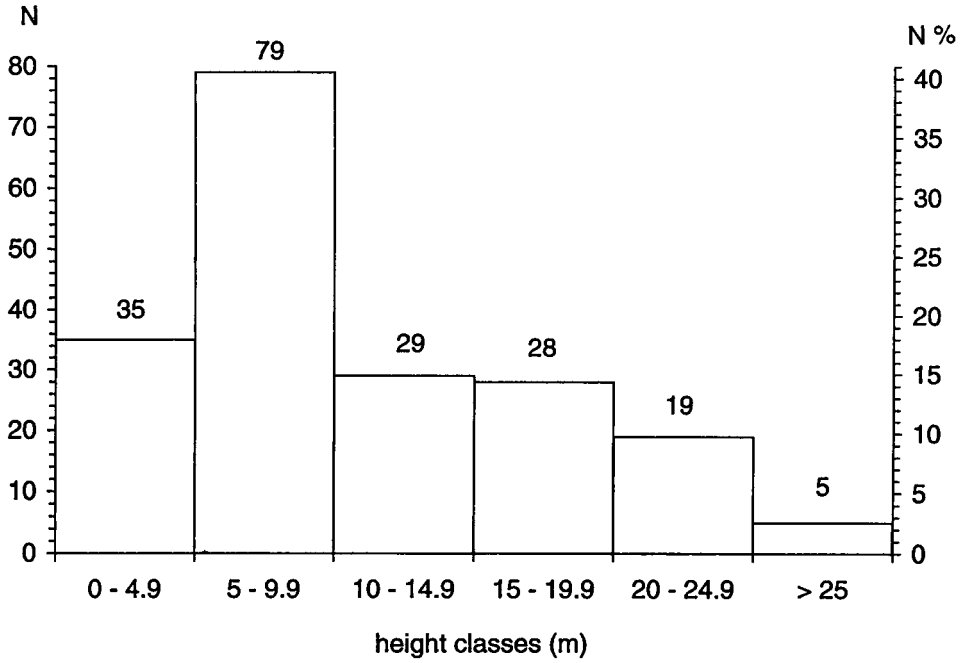


Fig. 2: Dbh-class distribution of 198 trees (dbh \geq 10 cm; top) and frequency of tree height (bottom) sampled on 0.5 ha of a seasonal *mixedwater* inundation forest at Lago Janauari near Manaus.

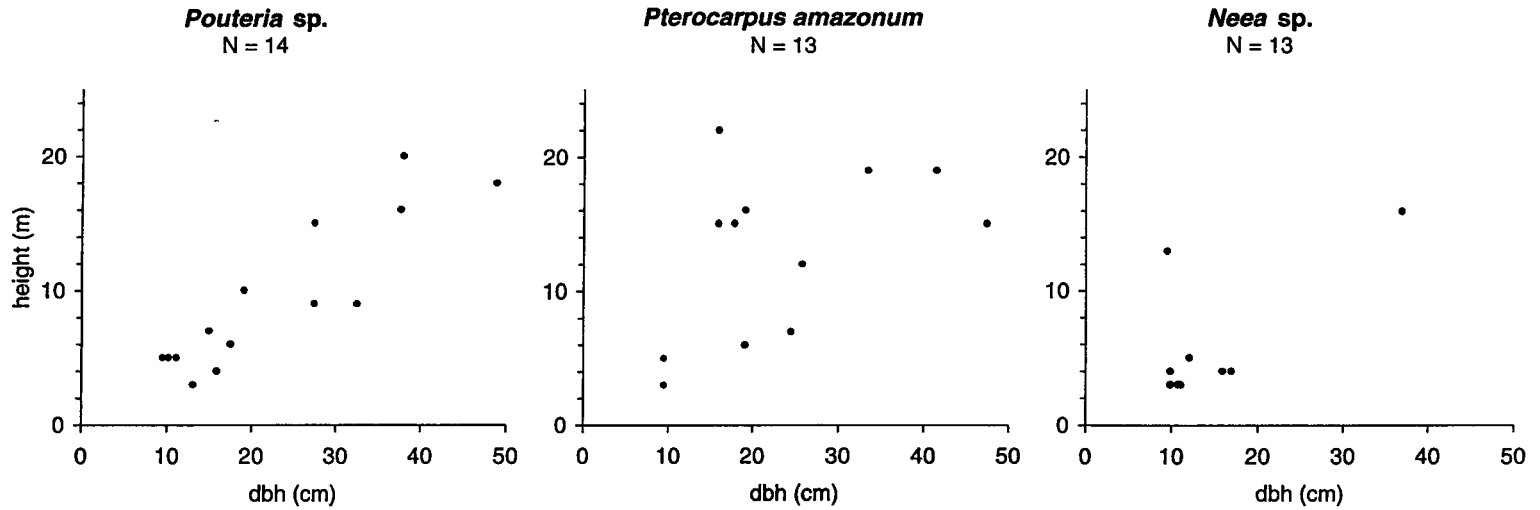


Fig. 3:
Height plotted against dbh (≥ 10 cm) of three frequent tree species in the seasonal *mixedwater* inundation forest at Lago Janauari near Manaus.

Table 1: Plant families in 0.5 ha of the seasonal *mixedwater* inundation forest at Lago Janauari near Manaus. FIV = Family Importance Value.

Plant family	Number of genera	Number of species	Number of trees	Relative basal area	Relative tree density	FIV
1 Euphorbiaceae	7	7	23	12.97	11.62	35.19
2 Sapotaceae	4	4	24	7.61	12.12	25.79
3 Clusiaceae	3	3	9	16.29	4.55	25.38
4 Mimosaceae	4	5	17	7.46	8.59	23.62
5 Fabaceae	3	4	18	8.14	9.09	23.29
6 Moraceae	2	4	10	9.32	5.05	20.44
7 Caesalpinaceae	3	3	10	9.57	5.05	19.16
8 Lecythidaceae	2	4	10	2.59	5.05	13.70
9 Myristicaceae	1	2	9	3.88	4.55	11.45
10 Lauraceae	2	3	9	1.79	4.55	10.89
11 Anonaceae	2	3	7	0.67	3.54	8.75
12 Nyctaginaceae	1	1	9	1.40	4.55	7.46
13 Meliaceae	1	1	7	2.37	3.54	7.42
14 Chrysobalanaceae	1	1	2	4.63	1.01	7.16
15 Olacaceae	2	2	2	2.29	1.01	6.33
16 Elaeocarpaceae	1	2	2	3.22	1.01	5.75
17 Combretaceae	2	1	2	1.15	1.01	5.19
18 Rubiaceae	1	2	3	0.41	1.52	4.95
19 Cecropiaceae	1	1	5	0.87	2.53	4.91
20 Apocynaceae	2	2	2	0.37	1.01	4.41
21 Violaceae	1	1	3	1.19	1.52	4.22
22 Myrtaceae	1	1	4	0.47	2.02	4.01
23 Polygonaceae	1	1	2	0.45	1.01	2.98
24 Sterculiaceae	1	1	2	0.24	1.01	2.76
25 Erythroxylaceae	1	1	1	0.13	0.51	2.15
26 Ochnaceae	1	1	1	0.12	0.51	2.14
27 Rutaceae	1	1	1	0.11	0.51	2.13
28 Bombacaceae	1	1	1	0.09	0.51	2.11
29 Hippocrateaceae	1	1	1	0.09	0.51	2.11
30 Ebenaceae	1	1	1	0.08	0.51	2.10
31 Flacourtiaceae	1	1	1	0.05	0.51	2.07
Total	55	66	198	100.00	100.00	300.00

Table 2: Species composition in 0.5 ha of the seasonal *mixedwater* inundation forest at Lago Januári near Manaus. SIV = Species Importance Value.

	Plant species	Family	Number of trees	Basal area (m ²)	SIV
1	<i>Pouteria</i> sp.	Sapotaceae	14	0.73	17.53
2	<i>Calophyllum brasiliense</i> Camb.	Clusiaceae	2	2.15	17.19
3	<i>Pterocarpus amazonum</i> (Mart.ex Bth.) Amsh.	Fabaceae	13	0.76	15.89
4	<i>Pseudolmedia</i> sp.	Moraceae	4	1.24	12.63
5	<i>Hura crepitans</i> L.	Euphorbiaceae	7	0.91	12.53
6	<i>Lecointea amazonica</i> Ducke	Caesalpinaceae	6	0.60	10.53
7	<i>Neea</i> sp.	Nyctaginaceae	9	0.20	9.32
8	<i>Eschweilera</i> sp.	Lecythidaceae	7	0.31	9.09
9	<i>Hevea spruceana</i> Muell. Arg.	Euphorbiaceae	7	0.29	8.95
10	<i>Trichilia</i> sp.	Meliaceae	7	0.34	8.60
11	<i>Virola surinamensis</i> (Rol.) Warb	Myristicaceae	4	0.50	7.49
12	<i>Pithecellobium</i> sp.	Mimosaceae	6	0.22	7.25
13	<i>Rheedia</i> sp.	Clusiaceae	6	0.20	7.10
14	<i>Parinari excelsa</i> Sab.	Chrysobalanaceae	2	0.67	6.98
15	indet.	Lauraceae	6	0.23	6.63
16	<i>Unonopsis</i> sp.	Annonaceae	5	0.07	6.37
17	* <i>Acacia</i> sp.	Mimosaceae	2	0.54	6.11
18	<i>Sloanea</i> sp.	Elaeocarpaceae	2	0.47	5.58
19	<i>Cecropia</i> sp.	Cecropiaceae	5	0.13	5.42
20	<i>Micropholis</i> sp.	Sapotaceae	4	0.19	5.38
21	<i>Campislandra</i> sp.	Caesalpinaceae	2	0.42	5.27
22	<i>Eugenia</i> sp.	Myrtaceae	4	0.07	5.19
23	<i>Sorocea</i> sp.	Moraceae	4	0.04	5.00
24	<i>Virola elongata</i> (Bth.) Warb.	Myristicaceae	5	0.06	4.98
25	<i>Labatia</i> sp.	Sapotaceae	4	0.13	4.95
26	<i>Swartzia</i> sp.	Caesalpinaceae	2	0.36	4.87
27	<i>Vatairea</i> sp.	Fabaceae	3	0.19	4.83
28	<i>Leonia</i> sp.	Violaceae	3	0.17	4.73
29	<i>Mabea</i> sp.	Euphorbiaceae	4	0.05	4.41
30	<i>Piranhea trifoliata</i> Baill.	Euphorbiaceae	1	0.46	4.35
31	<i>Helicteria</i> sp.	Olcaceae	1	0.32	3.38
32	<i>Inga</i> sp. 2	Mimosaceae	3	0.17	3.37
33	<i>Inga</i> sp. 1	Mimosaceae	4	0.08	3.25
34	<i>Cocoloba</i> sp.	Polygonaceae	2	0.07	2.81
35	<i>Inga</i> sp.	Mimosaceae	2	0.06	2.81
36	indet	Rubiaceae	2	0.05	2.70
37	<i>Neoxythece elegans</i> (A.DC.) Aubr.	Sapotaceae	2	0.05	2.67
38	* Indet.	Sterculiaceae	2	0.03	2.60
39	<i>Nectandra</i> sp.	Lauraceae	2	0.02	2.48
40	<i>Buchenavia macrophylla</i> Elchl.	Combretaceae	1	0.16	2.26
41	<i>Vatairea guianensis</i> Aubl.	Fabaceae	1	0.14	2.17
42	<i>Alchornea</i> sp.	Euphorbiaceae	1	0.11	1.97
43	<i>Drypetes</i> sp.	Euphorbiaceae	2	0.02	1.81
44	<i>Etaballia</i> sp.	Fabaceae	1	0.08	1.76
45	<i>Pseudolmedia</i> cf. <i>laevigata</i> Trec.	Moraceae	1	0.06	1.58
46	<i>Aspidosperma</i> sp.	Apocynaceae	1	0.04	1.47
47	<i>Gustavia hexapetala</i> (Aubl.) Smilh	Lecythidaceae	1	0.03	1.41
48	<i>Sapulum</i> sp.	Euphorbiaceae	1	0.03	1.36
49	<i>Xytopia</i> sp.	Annonaceae	1	0.02	1.31
50	<i>Erythroxylum</i> sp	Erythroxylaceae	1	0.02	1.31
51	<i>Durioia</i> sp.	Ochnaceae	1	0.02	1.30
52	<i>Zanthoxylum compactum</i> (Huber ex Albuquerque) Wat.	Rutaceae	1	0.02	1.29
53	<i>Eschweilera albiflora</i> (A. DC.) Miers	Lecythidaceae	1	0.01	1.28
54	<i>Endlicheria</i> sp.	Lauraceae	1	0.01	1.28
55	<i>Ceiba pentandra</i> Gaert.	Bombacaceae	1	0.01	1.27
56	<i>Salacia</i> sp.	Hippocrateaceae	1	0.01	1.27
57	<i>Minuartia</i> sp.	Olcaceae	1	0.01	1.27
58	<i>Himatanthus</i> sp.	Apocynaceae	1	0.01	1.26
59	<i>Diospyros</i> sp.	Ebenaceae	1	0.01	1.26
60	<i>Gustavia augusta</i> L.	Lecythidaceae	1	0.01	1.26
61	indet.	Annonaceae	1	0.01	1.25
62	* <i>Thiloa paraguariensis</i> Eichler	Combretaceae	1	0.01	1.25
63	<i>Sickingia tinctoria</i> (H.B.K.) K.Sch.	Rubiaceae	1	0.01	1.25
64	<i>Caraipa</i> sp.	Clusiaceae	1	0.01	1.24
65	<i>Casearia aculeata</i> Jacq.	Flacourtiaceae	1	0.01	1.23
66	indet.	Moraceae	1	0.01	1.22
Total			198	14.48	300

*= Lianas

Table 3: Number of plant species, their basal area, and bole volume sampled in ten single plots (50 x 10 m) representing 0.5 ha of a *mixedwater* inundation forest at Lago Janauari near Manaus.

Plot	Plant species	Basal area (m ²)	Bole volume (m ³)
1	22	0.81	6.16
2	20	0.61	3.08
3	25	2.12	29.54
4	19	0.99	6.51
5	13	0.35	5.81
6	23	3.00	25.42
7	19	1.24	8.50
8	17	1.33	11.03
9	27	2.95	22.13
10	13	1.08	5.58
Total	198	14.48	123.76
Mean ± s.d.	20 ± 5	1.4 ± 1.0	12.4 ± 9.6

Table 4: Tree species of the *mixedwater* inundation forest at Lago Janauari near Manaus, representing the characteristic vegetation of seasonal várzea or/and seasonal igapó. (Assignment according to KEEL & PRANCE 1979; KLINGE et al. 1976; KUBITZKI & ZIBURSKI 1994; MOREIRA 1970; PRANCE 1979, 1980; REVILLA 1981; RODRIGUES 1960; TAKEUCHI 1962; WORBES 1983, 1986, 1997; WORBES et al. 1992). * = recorded on the study site of 0.5 ha.

várzea	igapó	várzea & igapó
* <i>Buchenavia macrophylla</i> Eichl. (Combretaceae)	* <i>Neoxythece elegans</i> (A.DC.) Aubr. (Sapotaceae)	<i>Astrocaryum jauari</i> Mart. (Arecaceae)
* <i>Caesaria aculeata</i> Jacq. (Flacourtiaceae)	<i>Thiloa paraguariensis</i> Eichl. (Combretaceae)	* <i>Calophyllum brasiliense</i> Camp. (Clusiaceae)
* <i>Ceiba pentandra</i> Gaert. (Bombacaceae)	* <i>Virola elongata</i> (Bth.) Warb. (Myristicaceae)	<i>Eschweilera albiflora</i> (A.DC.) Miers (Lecythidaceae)
<i>Crataeva bentharii</i> Eichl. (Capparidaceae)		* <i>Gustavia augusta</i> L. (Lecythidaceae)
<i>Gustavia hexapetala</i> (Aubl.) Smith (Lecythidaceae)		* <i>Hevea spruceana</i> Muell. Arg. (Euphorbiaceae)
<i>Heisteria spruceana</i> Engl. (Olacaceae)		<i>Parinari excelsa</i> Sabine (Chrysobalanaceae)
* <i>Hura crepitans</i> L. (Euphorbiaceae)		* <i>Vatairea guianensis</i> Aubl. (Fabaceae)
* <i>Lecointea amazonica</i> Ducke (Caesalpiniaceae)		
* <i>Piranhea trifoliata</i> Baill. (Euphorbiaceae)		
<i>Pseudoxandra polyphleba</i> R.E. Fries (Annonaceae)		
<i>Rhedia brasiliensis</i> (Mart.) Tr. & Pl. (Clusiaceae)		
<i>Triplaris surinamensis</i> Cham. (Polygonaceae)		
* <i>Virola surinamensis</i> (Rol.) Warb. (Myristicaceae)		
<i>Vitex cymosa</i> Bth. ex Spreng. (Violaceae)		
<i>Zanthoxylum compactum</i> (Huber. ex Albuquerque) Wat. (Rutaceae)		

