
Ecological aspects of *Aphylophorales* in the Atlantic rain forest in northeast Brazil

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Aphylophorales (Basidiomycota) were collected in 13 reserves of the Atlantic rain forest in northeast Brazil between October 2000 and June 2002. A hundred and thirty-four species were identified, and 40 of which with more than 10 records were selected for ecological analysis considering the collection period, growth habit, preference for light intensity, decomposition stage of the substrates, and the interaction among these factors. *Aphylophorales* were collected more frequently, being thus more abundant, on November 2001, January and March 2002. The basidiomata were mostly found densely aggregated, in intermediate light-exposed environments and on intermediate to very decayed substrates. Under conditions of less light the species usually occupied more decayed substrates. The similarity among reserves was calculated using all species data and average similarity of groups of reserves grouped by factor ranks compared by Analysis of Similarity (ANOSIM). The number of species and the similarity between areas were positively affected by the degree of conservation of the reserves. Similarity was also positively affected by length of the footpath and negatively by the distance between the areas.

Key words: Brazil, ecology, tropical fungi, tropical forests

Introduction

Species of *Aphylophorales* are mainly saprobiotic on dead wood (Donk, 1964; Talbot, 1973; Kendrick, 1992; Alexopoulos *et al.*, 1996) and are considered the major wood decomposers, especially species of *Polyporaceae*, *Corticaceae* and *Hymenochaetaceae*. Thus, they play a crucial role in nutrient cycling, releasing among other things carbon originally removed from the atmosphere by autotrophic organisms in arboreous and shrubby ecosystems (Gilbertson, 1980). Many species are dangerous parasites, especially in different plant species (Luttrell, 1974; Stalpers and Loerakker, 1982), but many

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others can be used as indicators of disturbance in native forests (Norstedt *et al.*, 2001; Sverdrup-Thygesona and Lindenmayer, 2003) because they are more frequent in less disturbed areas and prefer to colonise larger and more decomposed logs, which become less frequent with selective logging (Samuelsson *et al.*, 1994; Bader *et al.*, 1995, Heilmann-Clausen and Christensen, 2004; Lindhe *et al.*, 2004; Penttilä *et al.*, 2004).

Some studies have considered other aspects of *Aphylllophorales* including systematics (Boidin *et al.*, 1998; Hallenberg and Parmasto, 1998; Góes-Neto *et al.*, 2001, 2002; Hong and Jung, 2004; Bodensteiner *et al.*, 2004; Krüger *et al.*, 2006) and ecology, the latter mostly relating diversity to successional stages of forests (Iwabuchi *et al.*, 1994; Sippola and Renvall, 1999; Nordén and Paltto, 2001; Rolstad *et al.*, 2004), substrate quality (Lindblad, 1998, 2001a; Nordén and Paltto, 2001; Nordén *et al.*, 2004; Heilmann-Clausen and Christensen, 2005), vegetation types (Hattori, 2005), disturbance in forests (Bader *et al.*, 1995; Lodge and Cantrell, 1995; Lindblad, 1998, 2001a), host-specificity (Lindblad, 2000; Gilbert *et al.*, 2002), and rainfall gradient (Lindblad, 2001b). The main objectives of this report were to investigate the preference of *Aphylllophorales* for collection period, growth habit, light intensity, decomposition stage of the substrates, and interaction among these factors, and to determine which factors influence similarity among reserves.

Materials and methods

Aphylllophoraceous fungi were collected in 13 reserves of the Atlantic rain forest in northeast Brazil from October 2000 to May 2002 (Table 1). In each site collecting took place in an area approximately 10 m wide along footpaths and all substrates favourable to *Aphylllophorales* colonisation were surveyed, for instance living trees, dead logs, litter, roots, twigs, and soil. The basidiomata were placed in paper bags, on which were written data about collection site and date, number of basidiomata, growth habit pattern (classified using ranks as: 1-solitary, when only one basidioma was present; 2-less aggregated, basidiomata farther than 1 cm from each other; 3-aggregated, basidiomata closer than 1 cm, but not united; 4-more aggregated, basidiomata united or imbricate; resupinate species were not included; effused-reflexed species were treated as pileate), relative light intensity (classified as: 1- less exposed, basidiomata under fallen logs or beyond the borders of a footpath, but not in an open area; 2- exposed, inside the borders of a footpath; 3- more exposed, basidiomata in open areas of the forests) and degree of substrate decay (according to Bader *et al.* (1995), Renvall (1995) and Lindblad (1998) classified as: 1- less decayed, newly-fallen trees, bark intact; 2- decayed, bark

Table 1. Reserves (ITA: Estação Ecológica Serra de Itabaiana; RS: RPPN Fazenda Rosa do Sol; SP: RPPN Fazenda São Pedro; DI: Reserva Ecológica Dois Irmãos; GUR: Reserva Ecológica de Gurjaú; SAL: Reserva Biológica Saltinho; CD: Refúgio Ecológico Charles Darwin; GUA: Reserva Biológica Guaribas; PAC: RPPN Fazenda Pacatuba; GAR: RPPN Engenho Gargaú; MB: Mata do Buraquinho; MEAF: RPPN Mata Estrela-Senador Antônio Farias; NF: Floresta Nacional de Nísia Floresta), reserve co-ordinates (CO), length of footpath investigated (LF, approximate to 0.5 km), number of species collected in the reserve (NSC), months of the collecting trips (MCT), rank of the degree of conservation (DC), rank of the number of collecting trips (CT).

Reserve	CO	LF	NSC	MCT	DC	TC
ITA	10°45'28''S 37°18'55''W	0.5	37	Jul 2001 Jan, Mar, May 2002	2	1
RS	9°50'24''S 35°54'28''W	0.5	19	Oct 2000 Mar, May, Jul, Nov 2001 Jan, Mar, May 2002	1	3
SP	9°35'50''S 35°57'24''W	2	57	Oct 2000 Mar, May, Jul, Nov 2001 Jan, Mar, May 2002	3	3
DI	8°15'30''S 35°57'00''W	2	48	Mar, May, Jul, Sep, Nov 2001 Jan, Mar, May 2002	3	3
GUR	8°28'66''S 35°03'50''W	2	52	Oct 2000 Mar, May, Jul, Sep, Nov 2001 Jan, Mar, May 2002	3	4
SAL	8°42'00''S 35°10'00''W	2	54	Jul, Sep, Nov 2001 Jan, Mar, May 2002	3	2
CD	7°50'03''S 35°54'23''W	0.5	39	Sep 2000 Mar, May, Jul, Sep, Nov 2001 Jan, Mar, May 2002	2	4
GUA	6°50'19''S 35°07'34''W	2	30	Jul, Nov, 2001 Jan, Mar, May 2002	2	2
PAC	7°05'47''S 35°13'58''W	0.5	14	Oct 2000 Mar, May, Nov 2001 Jan, May 2002	1	2
GAR	7°06'50''S 34°58'41''W	1.5	43	Oct 2000 Mar, May, Jul, Nov 2001 Jan, Mar, May 2002	3	3
MB	7°06'54''S 34°51'47''W	1	26	Nov 2001 Jan, Mar, May 2002	3	1
MEAF	6°22'10''S 35°00'28''W	4	33	Oct 2000 Mar, May, Jul, Nov 2001 Jan, Mar, May 2002	3	3
NF	6°05'28''S 35°12'31''W	1	29	Nov 2001 Jan, Mar, May 2002	2	1

Table 2. Families and species identified (* = species with more than 10 occurrences), substrates (D = decomposing angiosperm, L = living angiosperm, S = soil) and reserves where species were found (see Table 1 for abbreviations).

Families and species	Substrate	Reserve
<i>Corticiaceae</i>		
<i>Gloeocystidiellum lactescens</i> (Berk.) Boidin	D	SAL
<i>Gloeoporus dichrous</i> (Fr.) Bres.	D	SP, CD
<i>Grammothele lineata</i> Berk. & M.A. Curtis	D	SP, GUR
<i>Grammothele subargentea</i> (Speg.) Rajchenb.	D	SP, GUA, GAR, SAL
<i>Hyphodermella corrugata</i> (Fr.) J. Erikss. & Ryvarde	D	NF, ITA
<i>Hypochnicium subrigescens</i> Boidin	D	SP
<i>Phanerochaete chryzorrhiza</i> (Torr.) Budington & Gilb.	D	GAR
<i>Phanerochaete ravenelii</i> (Cooke) Burds.	D	GAR, GUR
<i>Phanerochaete velutina</i> (DC.) Parmasto	D	GAR
<i>Phlebia livida</i> (Pers.) Bres.	D	SAL
<i>Phlebia queletii</i> (Bourdot & Galzin) M.P. Christ.	D	SP
<i>Trechispora farinacea</i> (Pers.) Liberta	D	CD, SAL, DI, MEAF
<i>Trechispora thelephora</i> (Lév.) Ryvarde	D	SP, GUA, GAR, GUR, NF
<i>Tubulicrinis chaetophorus</i> (Höhn.) Donk	D	ITA
<i>Ganodermataceae</i>		
<i>Amauroderma gusmanianum</i> Torrend	S	DI, ITA
<i>Amauroderma macrosporum</i> J.S. Furtado	S	ITA
<i>Amauroderma omphalodes</i> (Berk.) Torrend	S	SP, DI
<i>Amauroderma praetervisum</i> (Pat.) Torrend	S, D	GAR, SAL, DI
<i>Amauroderma schomburgkii</i> (Mont. & Berk.) Torrend	S	SAL
<i>Amauroderma sprucei</i> (Pat.) Torrend	S, D	ITA
* <i>Ganoderma applanatum</i> (Pers.) Pat.	D	SP, MB, PAC, GUR, CD, SAL, DI
<i>Ganoderma resinaceum</i> Boud.	D	MB, GAR, PAC, GUR, SAL
* <i>Ganoderma stiptatum</i> (Murrill) Murrill	D, L	SP, GUA, GAR, GUR, SAL, DI,
<i>Hydnaceae</i>		
<i>Auriscalpium villipes</i> (Lloyd) Snell & E.A. Dick	D	CD
<i>Climacodon pulcherrimus</i> (Berk. & M.A. Curtis) M.I. Nikol.	D	GUA, GAR, GUR, DI

Table 2 continued. Families and species identified (* = species with more than 10 occurrences), substrates (D = decomposing angiosperm, L = living angiosperm, S = soil) and reserves where species were found (see Table 1 for abbreviations).

Families and species	Substrate	Reserve
<i>Gloeodontia discolor</i> (Berk. & M.A. Curtis) Boidin	D	GAR, CD, SAL, NF
<i>Hymenochaetaceae</i>		
<i>Coltricia cinnamomea</i> (Jacq.) Murrill	S	GUA, GUR, ITA
<i>Coltriciella navispora</i> Aime, Henkel & Ryvarden	D	GUA, GUR
<i>Cyclomyces iodinus</i> (Mont.) Pat.	D	GUR, DI, SAL
<i>Dichochaete ceratophora</i> (Job) Parmasto	D	SP
<i>Dichochaete setosa</i> (Sw.) Parmasto	D, L	GUR, SAL
<i>Hydnochaete peroxydata</i> (Berk.: Cooke) Dennis	D	SAL
<i>Hymenochaete</i> aff. <i>pratensis</i> Viégas	L	GAR
<i>Hymenochaete damicornis</i> (Link) Lév.	S	SP, MB, GUA, GAR, GUR, SAL, DI, ITA
* <i>Hymenochaete leonina</i> Berk & M.A. Curtis	D	SP, MB, GUA, GAR, SAL, DI, CD, MEAF
* <i>Hymenochaete luteobadia</i> (Fr.) Höhn. & Litsch.	D	SP, RS, MB, GUA, GAR, GUR, SAL, DI, NF, ITA
<i>Hymenochaete pinnatifida</i> Burt.	D	GAR, GUR, SAL, DI
<i>Hymenochaete rheicolor</i> (Mont.) Lév.	D	GUR
<i>Inonotus venezuelicus</i> Ryvarden	D	MEAF
<i>Phellinus baccharidis</i> (Pat.) Pat.	D	SP, SAL, CD, NF
<i>Phellinus contiguus</i> (Pers.) Pat.	D	SP
<i>Phellinus extensus</i> (Lév.) Pat.	D	CD
* <i>Phellinus fastuosus</i> (Lév.) Ryvarden	D, L	SP, RS, GAR, PAC, GUR, SAL, DI, CD, MEAF
<i>Phellinus ferrugineovelutinus</i> (Henn.) Ryvarden	D	GAR, GUR, SAL, CD, MEAF
<i>Phellinus ferruginosus</i> (Schrad.) Pat.	D	SAL, NF
* <i>Phellinus gilvus</i> (Schwein.) Pat.	D	SP, MB, GUA, GAR, PAC, GUR, SAL, DI, CD, NF, MEAF, ITA
<i>Phellinus grenadensis</i> (Murrill) Ryvarden	D	NF
<i>Phellinus maxonii</i> (Murrill) D.A. Reid	D	SAL, MEAF
<i>Phellinus macrosporus</i> Gibertoni & Ryvarden	D	DI
<i>Phellinus melleoporus</i> (Murrill) Ryvarden	L	MEAF
<i>Phellinus membranaceus</i> J.E. Wright & Blumenf.	D	SAL, CD

Table 2 continued. Families and species identified (* = species with more than 10 occurrences), substrates (D = decomposing angiosperm, L = living angiosperm, S = soil) and reserves where species were found (see Table 1 for abbreviations).

Families and species	Substrate	Reserve
<i>Phellinus neocallimorphus</i> Gibertoni & Ryvarden	D	SP
<i>Phellinus portoricensis</i> (Overh.) M. Fidalgo	D	SP
<i>Phellinus rhytiphloeus</i> (Mont.) Ryvarden	L	MEAF
* <i>Phellinus rimosus</i> (Berk.) Pilát	D, L	GUA, MEAF
<i>Phellinus roseocinereus</i> (Murrill) D.A. Reid	D	DI
<i>Phellinus shaferi</i> (Murrill) Ryvarden	L	SP
* <i>Phellinus umbrinellus</i> (Bres.) S. Herrera & Bondartseva	D, L	SP, GUR, SAL, DI, CD, MEAF, ITA
<i>Phellinus undulatus</i> (Murrill) Ryvarden	D	SP
<i>Phylloporia chrysites</i> (Berk.) Ryvarden	D	NF
<i>Phylloporia pectinata</i> (Klotzsch) Ryvarden	S, D, L	CD, NF, MEAF
<i>Lachnocladiaceae</i>		
<i>Lachnocladium schweinfurthianum</i> P. Henn.	S, D	SP, SAL, DI, ITA
* <i>Scytinostroma duriusculum</i> (Berk. & Broome) Donk	D, L	
<i>Podoscyphaceae</i>		
* <i>Caripia montagnei</i> (Berk.) Kuntze	D	MB, GAR, GUR, CD, SAL, DI, MEAF, ITA
* <i>Cymatoderma dendriticum</i> (Pers.) D.A. Reid	D	GAR, GUR, ITA
<i>Podoscypha bubalina</i> D.A. Reid	D	GUR
<i>Podoscypha fulvonitens</i> (Berk.) D.A. Reid	D	GUR
<i>Podoscypha mellisii</i> (Berk.: Sacc.) Bres.	D	GUR
<i>Podoscypha nitidula</i> (Berk.) Pat.	S, D	PAC, DI, MEAF
* <i>Podoscypha ovalispora</i> D.A. Reid	S, D	GUR, DI, SAL, DI, MEAF
<i>Polyporaceae</i>		
<i>Antrodiella angulatopora</i> Ryvarden	D	SP
<i>Antrodiella hydrophila</i> (Berk. & M.A. Curtis) Ryvarden	D	SP
<i>Antrodiella mollis</i> Gibertoni & Ryvarden	D	DI
<i>Antrodiella semisupina</i> (Berk. & M.A. Curtis) Ryvarden	D	DI
<i>Antrodiella versicutis</i> (Berk. & M.A. Curtis) Gilb. & Ryvarden	D	SP, RS, GAR, GUR, CD, SAL, DI, NF, MEAF, ITA

Table 2 continued. Families and species identified (* = species with more than 10 occurrences), substrates (D = decomposing angiosperm, L = living angiosperm, S = soil) and reserves where species were found (see Table 1 for abbreviations).

Families and species	Substrate	Reserve
<i>Ceriporiopsis flavilutea</i> (Murrill) Ryvarden	D	MEAF
<i>Cerrena sclerodepsis</i> (Berk.) Ryvarden	D,L	SP, ITA
<i>Coriolorpsis badia</i> (Berk.) Murrill	D	GUR
* <i>Coriolorpsis rigida</i> (Berk. & Mont.) Murrill	D	SP, RS, GAR, GUR, SAL, DI, ITA
<i>Daedalea aethalodes</i> (Mont.) Rajchenb.	D	RS, DI, ITA
* <i>Datronia caperata</i> (Berk.) Ryvarden	D	SP, RS, MB, GUA, GAR, PAC, GUR, SAL, DI, NF, MEAF, ITA
<i>Datronia scutellata</i> (Schwein.) Gilb. & Ryvarden	D	ITA
<i>Datronia stereoides</i> (Fr.) Ryvarden	D	CD, NF
* <i>Dichomitus cavernulosus</i> (Berk.) Masuka & Ryvarden	D	RS, MB, GUA, GAR, PAC, CD, SAL, DI, NF, MEAF, ITA
<i>Diplomitoporus navisporus</i> Gibertoni & Ryvarden	D	DI
* <i>Earliella scabrosa</i> (Pers.) Gilb. & Ryvarden	D	SP, GUA, GAR, GUR, SAL, DI
<i>Echinochaete brachypora</i> (Mont.) Ryvarden	D	SP, MB
* <i>Flabellophora obovata</i> (Jungh.) Núñez & Ryvarden	D	SP, MB, GUA, GAR, GUR, CD, SAL, DI, NF, MEAF, ITA
* <i>Fomes fasciatus</i> (Sw.) Cooke	D	SP, MB, GAR, PAC, SAL, DI, CD, NF, MEAF, ITA
* <i>Fomitella supina</i> (Sw.) Murrill	D	SP, MB, GAR, GUR, CD, DI, ITA
* <i>Fomitopsis cupreorosea</i> (Berk.) J. Carranza & Gilb.	D	RS, ITA
<i>Fomitopsis feei</i> (Fr.) Kreisel	D	GAR
<i>Gloeophyllum striatum</i> (Sw.) Murrill	D	NF
* <i>Hexagonia hydroides</i> (Sw.) M. Fidalgo	D	SP, RS, MB, GUA, GAR, PAC, CD, SAL, DI, SAL, NF, MEAF, ITA
* <i>Hexagonia papyracea</i> Berk.	D	RS, GAR, NF, MEAF, ITA
<i>Irpex lacteus</i> (Fr.) Fr.	D	DI
<i>Junghunia nitida</i> (Pers.) Ryvarden	D	SP
* <i>Lentinus crinitus</i> (L.) Fr.	D	SP, RS, MB, GUA, GAR, PAC, GUR, SAL, DI, NF, MEAF, ITA
<i>Lentinus velutinus</i> Fr.	S	MEAF
* <i>Lenzites stereoides</i> (Fr.) Ryvarden	D	SP, MB, GUA, GAR, GUR, CD, ITA

Table 2 continued. Families and species identified (* = species with more than 10 occurrences), substrates (D = decomposing angiosperm, L = living angiosperm, S = soil) and reserves where species were found (see Table 1 for abbreviations).

Families and species	Substrate	Reserve
<i>Navisporus terrestris</i> Gibertoni & Ryvarden	S	MEAF
* <i>Nigrofomes melanoporus</i> (Mont.) Murrill	D, L	SP, MB, GUA, GAR, GUR, CD, SAL, DI
* <i>Nigroporus vinosus</i> (Berk.) Murrill	D	GUA, GAR, SAL, DI, NF
<i>Perenniporia aurantiaca</i> (A. David & Rajchenb.) Decock & Ryvarden	D	RS, GAR, SAL, DI, ITA
<i>Perenniporia contraria</i> (Berk. & M.A. Curtis) Ryvarden	D	CD, SAL
<i>Perenniporia martiusii</i> (Berk.) Ryvarden	D, L	MB, DI, MEAF
<i>Perenniporia medulla-panis</i> (Jacq.) Donk	D	ITA
* <i>Polyporus dictyopus</i> Mont.	D	SP, GUR, CD, SAL, DI, NF, ITA
* <i>Polyporus grammacephalus</i> Berk.	D	SP, RS, GAR, CD, DI, MEAF, ITA
<i>Polyporus guianensis</i> Mont.	D	MB, GUR, CD, SAL
* <i>Polyporus ianthinus</i> Gibertoni & Ryvarden	D	CD, SAL
* <i>Polyporus leprieurii</i> Mont.	D	SP, MB, GUA, GAR, GUR, CD, SAL, DI, ITA
* <i>Polyporus tenuiculus</i> (P. Beauv.) Fr.	D	SP, RS, GUR, CD, SAL, DI, NF, ITA
<i>Polyporus tricholoma</i> Mont.	D	SP
<i>Polyporus virgatus</i> Berk. & M.A. Curtis	D	NF
* <i>Pycnoporus sanguineus</i> (L.) Murrill	D	SP, RS, MB, GUA, GAR, PAC, GUR, SAL, DI, NF
<i>Rigidoporus biokoensis</i> (Bres.: Lloyd) Ryvarden	D	SP, GUR, DI, ITA
* <i>Rigidoporus lineatus</i> (Pers.) Ryvarden	D	SP, MB, GAR, PAC, GUR, CD, SAL, DI
* <i>Rigidoporus microporus</i> (Fr.) Overheem	D	SP, MB, GAR, GUR, CD, SAL, DI
<i>Rigidoporus vinctus</i> (Berk.) Ryvarden	D	SP, SAL
<i>Schizopora flavipora</i> (Berk. & M.A. Curtis: Cooke) Ryvarden	D	RS, GUA, GAR, NF
<i>Schizopora paradoxa</i> (Schrad.) Donk	D	SP, GUA, GUR
<i>Skeletocutis lenis</i> (P. Karst.) Niemelä	D	ITA
<i>Stiptophyllum erubescens</i> (Berk.) Ryvarden	D	MEAF
<i>Trametes cubensis</i> (Mont.) Sacc.	D	GUR, DI
* <i>Trametes membranacea</i> (Sw.) Kreisel	D	GUA, GAR, GUR, SAL, DI
* <i>Trametes pavonia</i> (Hook.) Ryvarden	D	SP, RS, GUR, CD

Table 2 continued. Families and species identified (* = species with more than 10 occurrences), substrates (D = decomposing angiosperm, L = living angiosperm, S = soil) and reserves where species were found (see Table 1 for abbreviations).

Families and species	Substrate	Reserve
<i>Trichaptum perrottetii</i> (Lév.) Ryvarden	D	GUA, GAR
* <i>Trichaptum sector</i> (Ehrenb.) Kreisel	D	SP, RS, MB, GUA, GAR, PAC, GUR, SAL
Schizophyllaceae		
* <i>Schizophyllum commune</i> Fr.	D, L	SP, RS, MB, GAR, PAC, GUR, SAL, NF, MEAF
Stereaceae		
* <i>Lopharia cinerascens</i> (Schwein.) G. Cunn.	D	SP, GAR, GUR, SAL, CD, NF, MEAF, ITA
<i>Mycobonia flava</i> (Berk.) Pat.	D	SP
* <i>Stereum ostrea</i> (Blume & T. Nees) Fr.	D	SP, GUA, GAR, PAC, GUR, CD, SAL, DI, MEAF, ITA
<i>Xylobolus frustulatum</i> (Pers.) Boidin	D	SP

decayed, wood soft up to 3 cm in depth when pushing a knife; 3- more decayed, wood soft more than 3 cm, outline deformed; species on twigs were not included, on litter or roots were treated as 'soil'), and occurrence on soil or on living tree.

Forty species with more than 10 records were used for statistical analysis. The Test of χ^2 (chi-squared) was used to evaluate differences among variables and seasonality; the Pearson correlation (significance tested by a Mantel test) (Bioestat 3.0), the Kruskal-Wallis test, and multi-way table analysis were used to evaluate interaction among classified variables (for this analysis only species with more than 20 records were used). All analysis used 0.05 as significance level.

The index of Jaccard (Krebs, 1989) was used for evaluation of the similarity among areas using presence/absence data for the 134 Aphylophorales species identified in all collections during this study. Unidentified specimens were not included.

The index of Jaccard was also used for the Analysis of Similarities (ANOSIM, Primer 5.2.4), which is a permutation test reflecting the observed differences/similarities between sites/groups, contrasted with differences/similarities among replicates within sites/groups. R_{Global} is the measure of the degree of separation of sites/groups and usually falls between 0 and 1, indicating some degree of discrimination. Under the null hypothesis

replicates are randomly permuted among sites/groups. The significance level is calculated by referring the observed value of R_{Global} to its permutation distribution (Clarke and Warwick, 1994). In the present study, ANOSIM was used to test if average similarities were significantly different among groups using factor ranks for degree of forest conservation (ranked as 1 for less conserved; 2 for moderately conserved; and 3 for more conserved, according to logging history and present stage of recuperation of the forest), length of footpath (ranked as 1 for 0.5 km; 2 for 1 km; and 3 for 2 km) or number of visits (ranked as 1 for 4 visits; 2 for 5-6 visits; 3 for 8 visits; and 4 for 9-10 visits).

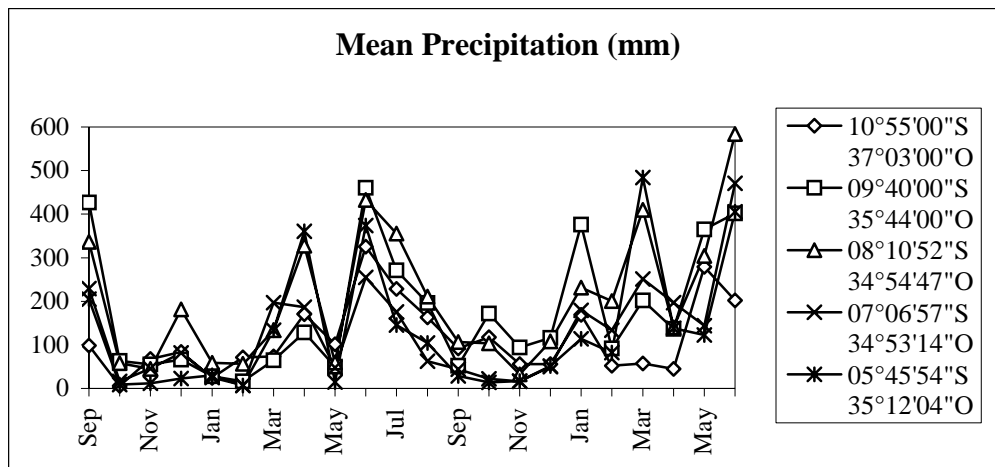


Fig. 1. Monthly precipitation at the meteorological stations (given as map co-ordinates) of the Instituto Nacional de Meteorologia (National Institute of Meteorology) from September 2000 to June 2002. The stations have a range of 150km.

Results

Nine families *sensu* Donk (1964) and Ainsworth *et al.* (1971) and 134 species of *Aphylophorales* were identified, and 40 of them had more than 10 occurrences (Table 2).

The similarity values of Jaccard obtained among *Aphylophorales* communities showed that 51 (56%) pairs of reserves, out of 91 possible pairs, had similarities equal or above 0.40 (Table 3).

The Analysis of Similarities (ANOSIM) showed that there were significant differences among community groups taking into account both the degree of conservation of the areas and the length of the footpath ($R_{Global} = 0.497$, number of permutations = 10.000, $p = 0.003$; $R_{Global} = 0.314$, number of

Table 3. Similarities measured using the index of Jaccard between *Aphylophorales* communities in the study areas.

	RS	MB	GUA	GAR	PAC	GUR	SAL	DI	CD	NF	MEAF	ITA
SP	0.33	0.50	0.39	0.53	0.36	0.59	0.58	0.56	0.47	0.34	0.34	0.43
RS		0.39	0.40	0.45	0.47	0.32	0.35	0.30	0.25	0.45	0.33	0.44
MB			0.55	0.55	0.55	0.48	0.54	0.53	0.36	0.40	0.43	0.43
GUA				0.62	0.33	0.49	0.48	0.49	0.25	0.38	0.38	0.44
GAR					0.37	0.63	0.66	0.58	0.40	0.50	0.42	0.47
PAC						0.33	0.38	0.33	0.20	0.33	0.36	0.19
GUR							0.63	0.62	0.41	0.43	0.34	0.48
SAL								0.65	0.53	0.48	0.45	0.40
DI									0.46	0.34	0.48	0.52
CD										0.38	0.46	0.41
NF											0.44	0.41
MEAF												0.41

permutations = 6930, $p = 0.039$, respectively), but the number of visits/samplings in each area did not ($R_{\text{Global}} = -0.122$, number of permutations = 10000, $p = 0.793$).

The Pearson correlation ($r = -0.1949$) between similarities and distances among reserves was significant (Mantel test: number of permutations = 10.000, $p = 0.0131$).

The Kruskal-Wallis test indicated significant differences of the number of species collected per area among the different degrees of conservation of the areas (KW = 6.4073, $n = 13$, $p = 0.0406$), but not for among number of visits (KW = 1.7464, $n = 13$, $p = 0.6267$) or length of footpath (KW = 5.2637, $n = 13$, $p = 0.0719$).

The test of χ^2 for evaluation of occurrence of *Aphylophorales* according to the collecting trip period, light intensity and classes of decomposition stage of the substrates, and for evaluation of distribution patterns of basidiomata, has demonstrated that these observations were not random (Table 4). *Aphylophorales* were collected more frequently in November 2001, January and March 2002, and have demonstrated clear preferences for intermediate light intensity environments and for decomposed to more decomposed substrates. Their basidiomata showed a tendency to be more aggregated.

When a multi-way table analysis was used to test interaction among classified variables and occurrence of *Aphylophorales*, families and the forty species (Table 5) with more than 10 records, it was demonstrated that, for *Aphylophorales*, there was no interaction between distribution pattern and light intensity. However, interaction was found between distribution pattern and substrate decay and between light intensity and substrate decay. The **Table**

4. Values for χ^2 , degrees of freedom (df) and significance (p) for the number of occurrences (NOC) of *Aphyllophorales* according to the collecting trip period (CTP), growth habit pattern (GHP), light intensity (LE), and decomposition stage of the substrates (DSS).

CTP – NOC	GHP – NOC	LI – NOC	DSS – NOC
Oct/2000 – 60	Solitary – 141	Less exposed – 214	Living tree – 55
Mar/2001 – 129	Less aggregated – 316	Exposed – 679	Less decayed – 58
May/2001 – 101	Aggregated – 177	More exposed – 285	Decayed – 500
Jul/2001 – 141	More aggregated – 336		More decayed – 489
Sep/2001 – 71			Soil – 19
Nov/2001 – 211			
Jan/2002 – 230			
Mar/2001 – 201			
May/2002 – 168			
$\chi^2 = 206.8296$	$\chi^2 = 118.5031$	$\chi^2 = 524.3149$	$\chi^2 = 928.6380$
df = 8	df = 3	df = 2	df = 4
p < 0.01	p < 0.01	p < 0.01	p < 0.01

former was mostly influenced by the occurrence of solitary specimens on living trees more than expected and by the presence of more aggregated basidiomata on living trees less than expected, while the latter, by the occurrence of specimens on less exposed environments and moderately decayed substrates less than expected and by the presence of specimens on less exposed environments and more decomposed substrates more than expected. *Polyporaceae* exhibited the same general pattern for *Aphyllophorales*, but influenced differently: specimens found on less decayed substrate and under more exposed environments, basidiomata found aggregated on less decomposed substrate, more aggregated on more decayed substrate and more aggregated on soil, were all observed more than expected, while the presence of more aggregated basidiomata on less decomposed substrate was less than expected. Interaction between distribution pattern and substrate decay was also found in *Hymenochaetaceae* and *Podoscyphaceae*. In the former less aggregated basidiomata on living trees were found more than expected, while more aggregated basidiomata on living trees were observed less than expected (as showed by *Aphyllophorales*); in the latter, less aggregated basidiomata on soil were observed more than expected. *Hexagonia hydroides* and *Schizophyllum commune* showed interaction only between distribution pattern and light intensity: in the former more aggregated basidiomata on less exposed environments were found more than expected, while in the later solitary specimens were found on less exposed environments less than expected. *Hymenochaete leonina* and *Polyporus leprieurii* showed interaction between

Table 5. Multi-way table analysis for interaction among variables (DP = distribution pattern, LI = light intensity, and SD = substrate decay) according to taxa (*Aphyllophorales*, families, and species with more than 20 records for each pair or variables; empty spaces = non-pileate species, except for *Coriolopsis rigida* and *Rigidoporus microporus*, with less than 20 records for a pair of variables); significance level of 0.05; (* = significant).

Taxon	Relation	χ^2
<i>Aphyllophorales</i>	DP X LI	9.82
<i>Aphyllophorales</i>	DP X SD	39.49*
<i>Aphyllophorales</i>	LI X SD	64.70*
<i>Ganodermataceae</i>	DP X LI	6.85
<i>Ganodermataceae</i>	DP X SD	7.47
<i>Ganodermataceae</i>	LI X SD	8.25
<i>Hymenochaetaceae</i>	DP X LI	4.97
<i>Hymenochaetaceae</i>	DP X SD	25.99*
<i>Hymenochaetaceae</i>	LI X SD	2.89
<i>Podoscyphaceae</i>	DP X LI	3.9
<i>Podoscyphaceae</i>	DP X SD	26.39*
<i>Podoscyphaceae</i>	LI X SD	4.21
<i>Polyporaceae</i>	DP X LI	7.38
<i>Polyporaceae</i>	DP X SD	24.39*
<i>Polyporaceae</i>	LI X SD	18.80*
<i>Stereaceae</i>	DP X LI	3.94
<i>Stereaceae</i>	DP X SD	4.08
<i>Stereaceae</i>	LI X SD	2.07
<i>Caripia montagnei</i>	DP X LI	2.43
<i>Caripia montagnei</i>	DP X SD	1.4
<i>Caripia montagnei</i>	LI X SD	0.37
<i>Coriolopsis rigida</i>	DP X LI	
<i>Coriolopsis rigida</i>	DP X SD	
<i>Coriolopsis rigida</i>	LI X SD	3.4
<i>Datronia caperata</i>	DP X LI	1.76
<i>Datronia caperata</i>	DP X SD	3.69
<i>Datronia caperata</i>	LI X SD	3.66
<i>Dichomitus cavernulosus</i>	DP X LI	
<i>Dichomitus cavernulosus</i>	DP X SD	
<i>Dichomitus cavernulosus</i>	LI X SD	4.64
<i>Flabellophora obovata</i>	DP X LI	5.53
<i>Flabellophora obovata</i>	DP X SD	2.69
<i>Flabellophora obovata</i>	LI X SD	0.13
<i>Fomes fasciatus</i>	DP X LI	5.99
<i>Fomes fasciatus</i>	DP X SD	3.07
<i>Fomes fasciatus</i>	LI X SD	0.42
<i>Hexagonia hydroides</i>	DP X LI	10.31*
<i>Hexagonia hydroides</i>	DP X SD	0.99

Table 5 continued. Multi-way table analysis for interaction among variables (DP = distribution pattern, LI = light intensity, and SD = substrate decay) according to taxa (*Aphylophorales*, families, and species with more than 20 records for each pair or variables; empty spaces = non-pileate species, except for *Corioloopsis rigida* and *Rigidoporus microporus*, with less than 20 records for a pair of variables); significance level of 0.05; (* = significant).

Taxon	Relation	χ^2
<i>Hexagonia hydroides</i>	LI X SD	0.11
<i>Hymenochaete leonina</i>	DP X LI	
<i>Hymenochaete leonina</i>	DP X SD	
<i>Hymenochaete leonina</i>	LI X SD	5.96*
<i>Hymenochaete luteobadia</i>	DP X LI	0.14
<i>Hymenochaete luteobadia</i>	DP X SD	0.54
<i>Hymenochaete luteobadia</i>	LI X SD	1.89
<i>Lentinus crinitus</i>	DP X LI	1.58
<i>Lentinus crinitus</i>	DP X SD	12.70*
<i>Lentinus crinitus</i>	LI X SD	0.15
<i>Lopharia cinerascens</i>	DP X LI	
<i>Lopharia cinerascens</i>	DP X SD	
<i>Lopharia cinerascens</i>	LI X SD	4.49
<i>Nigrofomes melanoporus</i>	DP X SD	2.63
<i>Nigrofomes melanoporus</i>	LI X SD	1.3
<i>Nigrofomes melanoporus</i>	DP X LI	5.07
<i>Phellinus fastuosus</i>	DP X LI	2.12
<i>Phellinus fastuosus</i>	DP X SD	7.3
<i>Phellinus fastuosus</i>	LI X SD	2.8
<i>Phellinus gilvus</i>	DP X LI	1.36
<i>Phellinus gilvus</i>	DP X SD	2.00
<i>Phellinus gilvus</i>	LI X SD	0.96
<i>Podoscypha ovalispora</i>	DP X LI	1.25
<i>Podoscypha ovalispora</i>	DP X SD	6.23
<i>Podoscypha ovalispora</i>	LI X SD	2.47
<i>Polyporus leprieurii</i>	DP X LI	2.52
<i>Polyporus leprieurii</i>	DP X SD	2.74
<i>Polyporus leprieurii</i>	LI X SD	4.30*
<i>Pycnoporus sanguineus</i>	DP X LI	5.32
<i>Pycnoporus sanguineus</i>	DP X SD	4.05
<i>Pycnoporus sanguineus</i>	LI X SD	2.52
<i>Rigidoporus microporus</i>	DP X LI	
<i>Rigidoporus microporus</i>	DP X SD	
<i>Rigidoporus microporus</i>	LI X SD	2.68
<i>Schizophyllum commune</i>	DP X LI	13.55*
<i>Schizophyllum commune</i>	DP X SD	2.34
<i>Schizophyllum commune</i>	LI X SD	0.65
<i>Scytinostroma duriusculum</i>	DP X LI	

Table 5 continued. Multi-way table analysis for interaction among variables (DP = distribution pattern, LI = light intensity, and SD = substrate decay) according to taxa (*Aphylophorales*, families, and species with more than 20 records for each pair or variables; empty spaces = non-pileate species, except for *Corioloopsis rigida* and *Rigidoporus microporus*, with less than 20 records for a pair of variables); significance level of 0.05; (* = significant).

Taxon	Relation	χ^2
<i>Scytinostroma duriusculum</i>	DP X SD	
<i>Scytinostroma duriusculum</i>	LI X SD	2.67
<i>Stereum ostrea</i>	DP X LI	3.91
<i>Stereum ostrea</i>	DP X SD	3.02
<i>Stereum ostrea</i>	LI X SD	0.55

light intensity and substrate decay: in the former less the occurrence of specimens on less exposed environments and on more decayed substrate was more than expected, while in the latter, the presence of specimens on less exposed environments and decomposed substrate was less than expected and on more decomposed substrate was more than expected. *Lentinus crinitus* was the only species to show interaction between distribution pattern and substrate decay, mostly influenced by the presence of solitary specimens on more decomposed substrate more than expected.

Discussion

The occurrence of *Aphylophorales* mostly on decomposing angiosperms confirms the importance of *Aphylophorales* in wood decay (Donk, 1964; Talbot, 1973; Gilbertson, 1980; Gilbertson and Ryvarden, 1986; Kendrick, 1992; Alexopoulos *et al.*, 1996). Among lignicolous species, *Pycnoporus sanguineus*, *Schizophyllum commune* and *Lentinus* spp. are associated to open areas inside forests, suggesting adaptation to less humid environments or with higher temperatures (Lodge and Cantrell, 1995), while *Phenerochaete velutina* is registered as an efficient decomposer in forests (Boddy and Watkinson, 1995). Terrestrial species may use soil organic material or are possibly mycorrhizal or root parasites, while species found in association with living trees may suggest parasite relationship, although some are restricted to the non-living heartwood and do not invade or kill living tissues (Gilbertson, 1980; Gilbertson and Ryvarden, 1986; Ryvarden and Gilbertson 1993).

In a previous study about *Aphylophorales* in Reserva Ecológica de Gurjaú and in Reserva Ecológica de Dois Irmãos, Gibertoni (1999) found similarity of 0.26 between these areas, and this value was considered to be very

low. In the present study, most of similarity values among communities of Aphyllophorales might be considered high. Similarities have shown to be influenced mostly by the degree of conservation, indicating that more conserved areas tend to have similar communities. Similarities may also be related to the distance among areas, as indicated by the Pearson correlation between this factor and similarities measured by the index of Jaccard. Therefore, similarity among areas tends to diminish with the increase of distance between them. Lindblad (2001a) found a similarity of 0.60 between communities of wood inhabiting fungi in a primary and a nearby, old secondary forest in Costa Rica, but this result was lower than expected from the null hypothesis that species composition did not differ between the forests.

The degree of conservation of the areas positively affected the diversity of Aphyllophorales, with more species being collected in less disturbed areas. This was also observed by Bader et al. (1995) and Lindblad (1998, 2001a) for wood inhabiting fungal communities. The number of registered species, however, was not affected by number of collecting trips or length of footpath.

Specimens of *Aphyllophorales* were collected more frequently in November 2001, January and March 2002, which are months of the dry season in northeast Brazil. During this study, small and unusual peaks of precipitation were observed during the dry season in October 2001, January and March 2002 (Fig. 1). Lindblad (2001b) found higher number of species during the rainy months in three kinds of forests in Costa Rica (dry, moist, and wet forests). However, when each site was separately evaluated, the dry forest has exhibited higher number of fructifications during the peak of the rainy season, while the other forests have shown higher number of fructifications after a dry period. This would suggest that basidiomata might appear in a similar, critical level of humidity. This may be achieved after a rainy period in the dry forest and after a dry period in wet and moist forests.

The tendency of basidiomata of *Aphyllophorales* to be found more aggregated is probably due to the range of the vegetative mycelium, which is influenced by some factors as log size, resource availability or competition with other species on the same log (Bader *et al.*, 1995; Lindblad 2001a, b). *Aphyllophorales* has demonstrated preference for intermediate light intensity environments (neither in shadow, nor in open areas). Some species of *Aphyllophorales* are adapted to low moisture conditions or higher temperatures (factors related to luminosity), and are associated to open areas inside forests, but, in general, communities of decomposer fungi are disturbed by openings in the canopy (Lodge and Cantrell, 1995).

Interestingly, most *Aphyllophorales* showed a clear preference for decomposed to more decomposed substrates, differently from what Lindblad

(2001a, b) found in tropical forests in Costa Rica, where *Aphylllophorales* either had a slight tendency to colonise substrates in initial stage of decay or had no preference for stage of decay. However, that observation was similar to boreal forests in Sweden (Bader *et al.*, 1995) and in Norway (Lindblad, 1998), where most species were found in intermediate stage of decay. This may be influenced by decomposition ability of the fungi or by availability of substrate in the areas. The species collected have shown ability of colonising logs in intermediate or late stage of decay, and were probably dependent on other organisms that decompose new-fallen logs to colonise more decayed substrates. In managed forests, the lack of logs in late stage of decay restricts the presence of species which use preferentially more decayed wood. In natural or less disturbed areas availability of logs in late stage of decay allows the presence of species that colonise this kind of substrate (Bader *et al.*, 1995; Boddy and Watkinson, 1995; Lodge and Cantrell, 1995; Lindblad, 1998, 2001a, b).

The presence of more aggregated basidiomata in more decayed substrates is probably due to a lack of available space for colonisation (Bader *et al.*, 1995; Lindblad, 1998, 2001a, b). *Polyporaceae* showed this pattern, but somewhat contrastingly aggregated basidiomata were also found on less decomposed substrates. More aggregated basidiomata of *Polyporaceae* was also observed on soil, indicating these are characteristic of the group more than availability of resources. *Podoscyphaceae* showed a different pattern, as it tended to be found less aggregated on soil, and this situation offers less restriction to mycelium spatial development.

The occurrence of basidiomata on more decayed substrates in less light-exposed environments may indicate that *Aphylllophorales* in this study is a group of mostly non-pioneer species, adapted to areas inside forests, where late-fallen logs, higher humidity and lower temperatures are found (Lodge and Cantrell, 1995). *Hymenochaete leonina* and *Polyporus lepreurii* showed the same tendency as *Aphylllophorales*, pointing that these species might be used as indicator species of the conservation status of an Atlantic rain forest area. *Polyporaceae*, however, showed contrary tendency, being mostly found on recently fallen trees and more exposed environments. The family might indicate disturbed areas inside a forest or in its borders.

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