MOTH SPECIES RICHNESS AND SIMILARITY AMONG HABITATS IN A *Eucalyptus* - DOMINATED LANDSCAPE

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ABSTRACT

Effects of fragments of native forest between *Eucalyptus* spp. stands on the Lepidoptera community was studied. A total of 790 morphospecies was collected at five sites along a transect: a residual forest and its edge, and into *Eucalyptus* spp. plantation (at 200, 400 and 600 m from the edge). The residual forest and its edge showed similar numbers of moth species, but these were significantly larger than those of the sites in the *Eucalyptus* plantation. Cluster analysis indicated that the sites with eucalyptus have a more similarly structured moth community when compared to these of residual forest and its border.

Key words: Lepidoptera, Atlantic Forest, species richness

INTRODUCTION

Eucalyptus spp. plantations have become an important component of the Atlantic Forest region of Brazil in recent years. These plantations attract many phytophagous insects that can become pests, especially lepidopterans (Zanuncio et al., 1994; Zanuncio et al., 2004). Interest in the native forest remnants near *Eucalyptus* spp. stands is increasing as a result to the supposition that they can act as source of natural enemies that could control outbreaks of pest species (Bragança et al., 1998b). This phenomenon has already been observed in agricultural systems (Altieri & Letourneau, 1984; Andow, 1991; Altieri et al., 1993). Although it is difficult to test this hypothesis, many forestry companies in Brazil have initiated programs to maintain areas of residual forests (usually areas on sloped with difficult access and riparian vegetation) (Bragança et al., 1998a, 1998b) or to manage strips of native vegetation among eucalyptus stands (Zanuncio et al., 1998). Those areas could increase habitat diversity and enhance the diversity of natural enemies of pest species in the whole system (Bragança et al., 1998b; Freitas et al., 2002).

Many questions arise when examining how the insects, especially moths, use eucalyptus forest and nearby habitats: how diverse could a homogeneous *Eucalyptus* spp. plantation be? Are there species restricted to the *Eucalyptus* spp. plantation? How similar are the residual forests, the residual forest edge and the *Eucalyptus* spp. plantation? How are Lepidoptera pest species distributed throughout residual forests and *Eucalyptus* spp. plantations?

The objective of this research was to study the effect of residual native forests around eucalyptus stands on the community structure of moths, and to test the hypothesis that their species richness decreases with the distance from the eucalyptus stand edges.

MATERIAL AND METHODS

The study was carried out in a region with 38,300 hectares planted with *Eucalyptus* spp. intermingled with 15,200 hectares of residual native forests, in Aracruz, Espírito Santo State, Southeastern Brazil. This area is located at 19° 48'S, 40° 97'W, and altitude of 27 m.

We sampled moth species with light traps in five sites (residual forest, edge of this residual forest and in three sites within the *Eucalyptus grandis* Hill ex Maiden and *Eucalyptus saligna* Smith stands). These sites were located in a linear transect across the area. The residual forest (RF) was a 189.5 ha area and was sampled at 400 m from its edge. The site forest edge (ED) was a five meters wide road located between the residual forest and a stand

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of *E. grandis*. The third trap was placed in an *E. grandis* stand (GRA) at 200 m from the forest edge site. The fourth (GRA/SAL1) and the fifth sites (GRA/SAL2) were placed near the limits between *E. grandis* and *E. saligna* stands, at 400 and 600 m from the forest edge site, respectevely. Due to the presence of other residual forests forming a mosaic in the area, the site GRA/SAL2 was positioned 300 m from the next residual forest. A detailed map of the area may be seen in Bragança et al. (1998a, 1998b). *Eucalyptus grandis* and *E. saligna* plantations were five years old and the trees 25 m high at the beginning of the sampling. No cultural practices (either mechanized or chemical) were made six months before and during sampling.

In each site, three samples were taken twice a month, during five months. The light traps were turned on at 4:00 p.m. and turned off at 7:00 a.m. on the next day. A random selection was used to determine the sites to sample at each night, with the restriction that the distances between the selected sites must be equal to or greater than 400 m, avoiding possible interference between light traps (Baker & Sadovy, 1978). The moths studied were those of body length greater than 6 mm. All individuals were assigned initially as morphospecies and compared to the determined material of the scientific entomological collection in the Universidade Federal de Viçosa. When a taxonomic determination was impossible the insect was included in the analysis as a morphospecies. Voucher specimens of moths have been deposited in the entomologycal collection of Aracruz Celulose S. A., in Aracruz, Espírito Santo State, Brazil.

To compare the frequency of restricted species between sites a chi-square analysis was used. As we analysed five different sites (4 degrees of freedom), we choose some comparisons in order to analyze some general hypothesis about species richness in these areas. These comparisons were: i) residual forest + forest edge *vs* eucalyptus sites (GRA, GRA/SAL1, GRA/SAL2); ii) differences between eucalyptus sites; iii) residual forest *vs* forest edge. These planned comparisons were done according to Zar (1984).

A jackknife procedure was used to compare the estimated species richness across sites (Heltshe & Forrester, 1983). This procedure aimed to correct the bias of the observed moth species richness by the repetition estimating species richness when each sample is dropped from the analysis. It also permitted to estimate the variance and a proper statistical test of the null hypothesis of the equal species richness among sites. Many studies had employed this procedure which shows a good precision to correct the bias and estimate variances in species richness (Colwell & Coddington, 1994). A confidence interval to the jackknife estimate of species richness was produced using the variance of the estimate and standard normal theory (Manly, 1991).

Cluster analysis was used to determine the degree of similarity between sites with an Unweight Pair Group Method Average Linkage (UPGMA), and Euclidean distances as a resemblance function (Ludwig & Reynolds, 1988; Manly, 1994).

RESULTS AND DISCUSSION

A total of 8,529 individuals belonging to 790 moth morphospecies (155 identified to species level belonging to 20 families) were collected. Twenty-two pest species were found during the sampling (Table 1).

Table 1. Moth species considered pests of *Eucalyptus* spp. sampled in five sites (residual Atlantic Forest = RF, forest edge = ED, *Eucalyptus grandis* stand at 200 m from the forest edge = GRA, *E. grandis* and *Eucalyptus saligna* stand at 400 m from the forest edge = GRA/SAL1, and *E. grandis* and *E. saligna* stand at 600 m from the forest edge = GRA/SAL2) in Aracruz, Southeastern Brazil.

Moth species	Family	**Sample sites**				
		RF	ED	GRA	GRA/ SAL1	GRA/ SAL2
Primary pests						
Apatelodes sericea Schaus, 1896	Eupterotidae	x	x	x	x	x
Eupseudosoma involuta (Sepp, 1852)	Arctiidae		x	x	x	x
Glena bipennaria (Guenée, 1857)	Geometridae			x	x	x
Glena sp. 1	Geometrida	x		x	x	x
Glena sp. 2	Geometridae		x	x		x
Oxydia vesulia (Cramer, 1779)	Geometridae	x	x	x	x	x
Stenalcidia sp.	Geometridae		x	x	x	x
Thyrinteina arnobia (Cramer, 1778)	Geometridae		x	x	x	x
Thyrinteina leucoceraea (Rindge, 1961)	Geometridae		x	x	x	x
Sarsina violascens (Herrich-Schaeffer, 1856)	Lymantriidae		x		x	x

Table 1. Continuação

Secondary pests						
Aeschropteryx onustaria (Geyer)	Geometridae		x	x	x	x
Automeris melanops (Walker, 1865)	Saturniidae		x	x		
Carthara albicosta Walker, 1865	Noctuidae		x		x	x
Cosmosoma auge (L., 1767)	Amatidae		x			
Eacles penelope ducalis (Walker, 1855)	Saturniidae		x	x	x	x
Hylesia nanus (Walker, 1855)	Saturniidae		x		x	x
Hylesia sp.	Saturniidae	x			x	
Hyperchiria incisa (Walker, 1855)	Saturniidae		x			
Idalus herois (Schaus, 1889)	Arctiidae	x	x	x	x	x
Megalopyge albicollis (Walker, 1855)	Megalopygidae	x				
Periga sp.	Saturniidae	x	x			
Perigea apameoides icole Grote, 1875	Noctuidae		x			

These species were considered as pests using the criteria described by Zanuncio et al. (1994) or because they have occurred at least once in outbreak conditions in Aracruz or other areas in Brazil (primary pests) or they were proved to use *Eucalyptus* spp. as food resource, but have not yet occurred in outbreaks (secondary pests). These pest species represent only a small number of each assemblage and their proportional contribution to species richness increased from the residual forest to the eucalyptus stands (Table 2).

Table 2. Observed species richness, pest species and restricted species of moths collected in five sites along a transect (residual Atlantic Forest, forest edge, *Eucalyptus grandis* stand at 200 m from the forest edge, *E. grandis* and *Eucalyptus saligna* stand at 400 m from the forest edge, and *E. grandis* and *E. saligna* stand at 600 m from the forest edge) in Aracruz, Southeastern Brazil.

Sites	Observed	Pest species		Restricted species	
	species richness	Number	%	Number	%
Residual forest	397	8	2.0	147	37.0
Forest edge	419	18	4.3	96	22.9
E. grandis 200 m	269	13	4.8	38	14.1
E. grandis/*E. saligna* 400 m	298	15	5.0	50	16.8
E. grandis/*E. saligna* 600 m	290	15	5.2	39	13.5

There was a clear gradient in the locally restricted species from the residual forest (37.0% of the total species) to the eucalyptus stands (13.5-16.8%) with intermediate results to the forest edge (22.9%) (Table 2; 2= 78.95; df = 4, P < 0.001). There were more restricted species in the combination of forest edge and residual forest than in the eucalyptus sites (2= 54.31; df = 1; P < 0.001). The residual forest had more restricted species than the edge (2= 19.42; df = 1; P < 0.001) and the three eucalyptus stands had no differences in restricted species proportions (2 = 1.44; df = 2; P = 0.487)

The increase in species richness and the presence of species restricted to the forest edge support the idea that this site represents a defined ecological unit. Although the forest edge is not a distinctive habitat to our senses it had 22.9% of moth species restricted to it. This was probably due to an array of distinct host plants that occur from the edge to the eucalyptus stands and to the residual foresty (M.A.L. Bragança, personal observation), and also to possible microclimatic differences among those areas (Camargo & Kapos, 1995; Chen et al., 1999).

Restricted species usually had low abundance in all sites. This suggests that these species could be not common in these areas and that they do not really contribute to the interactions observed in these systems or, alternatively, they could be habitat or host specialized species and their distribution limited by such factors.

The confidence intervals to the jackknife estimate of species richness show that the residual forest and the forest edge had more species than all other sites (Figure 1). These two sites were not statistically different. The *E. grandis* site had the lowest species richness and the two mixed sites with *E. grandis* and *E. saligna* had similar species richness (Figure 1). Ecological theory usually predicted that lower habitat heterogeneity (both expressed in plant types as plant architecture) lead to a lower microhabitat and resource diversity (Lawton & Strong, 1981; Lawton, 1983). Even when a young plant community could be favoured in the *Eucalyptus* spp. plantation (Silva et al., 1995), this system would support few moth species probably as a result of their low number of host plants (low chemical variation).

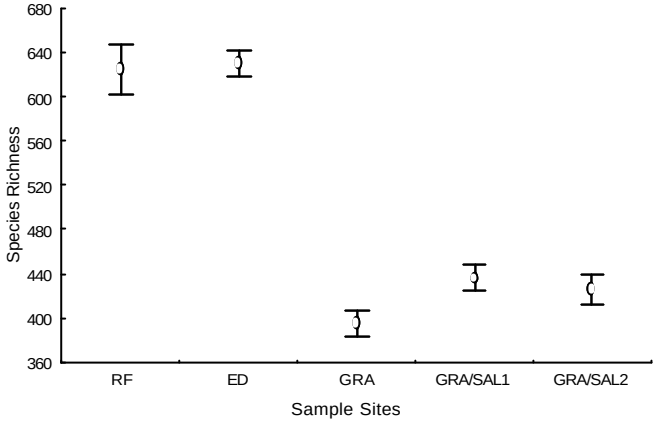

Figure 1. Jackknife estimates of species richness of moths (bars represent a confidence interval at 5%) at five sites in an *Eucalyptus* spp. plantation (residual Atlantic Forest = RF, forest edge = ED, *Eucalyptus grandis* stand at 200 m from the forest edge = GRA, *E. grandis* and *Eucalyptus saligna* stand at 400 m from the forest edge = GRA/SAL1, and *E. grandis* and *E. saligna* stand at 600 m from the forest edge = GRA/SAL2) in Aracruz, Southeastern Brazil.

The cluster analysis (Figure 2) showed that the eucalyptus sites were more similar in their moth community structure (composition and abundance). In these sites the *E. grandis/E. saligna* stands had even higher similarity. Otherwise, the forest edge and the residual forest were similar but with lower degree compared to the eucalyptus stands. There was a decrease of similarity from the eucalyptus stands to the residual forest, mainly due to the presence of restricted species (Table 2). Similar general pattern was observed on the presence of pest species in the assemblages (Figure 3). *Glena bipennaria* occurred only in the eucalyptus sites while *C. auge*, *H. incisa*, *M. albicollis*, *Periga* sp. and *P. apameoides icole* were collected only in the residual forest and its edge (Table 1).

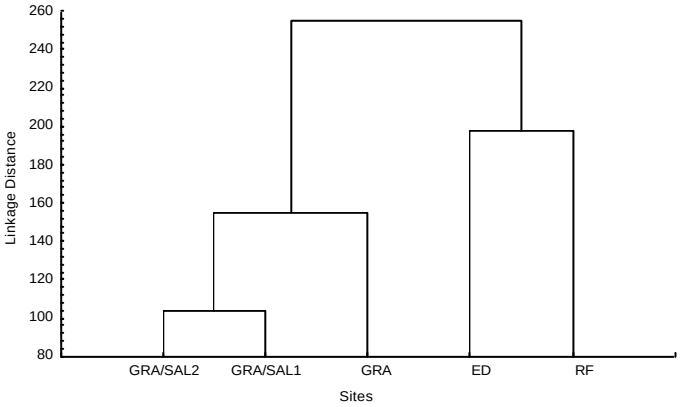

Figure 2. Cluster analysis of five Lepidoptera assemblages (residual Atlantic Forest = RF, forest edge = ED, *Eucalyptus grandis* stand at 200 m from the forest edge = GRA, *E. grandis* and *Eucalyptus saligna* stand at 400 m from the forest edge = GRA/SAL1, and *E. grandis* and *E. saligna* stand at 600 m from the forest edge = GRA/SAL2) using Euclidean distances, in Aracruz, Southeastern Brazil.

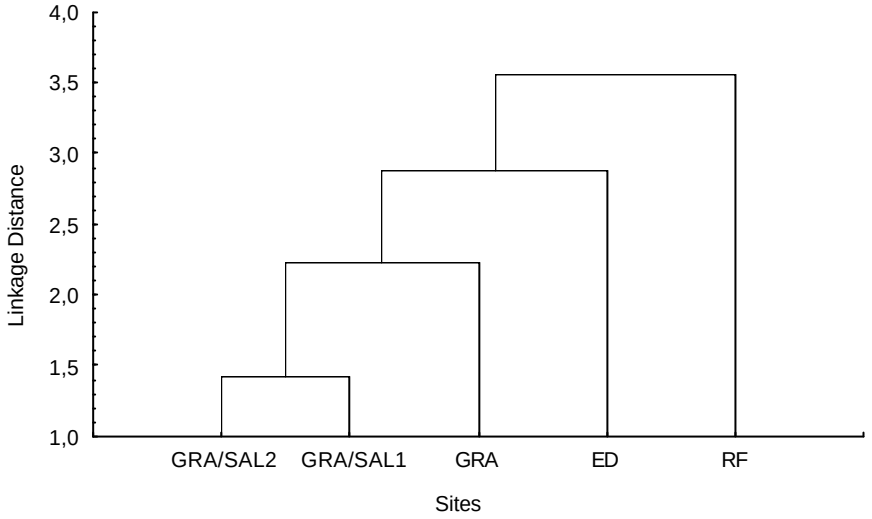

Figure 3. Cluster analysis of the pest species of five Lepidoptera assemblages (residual Atlantic Forest = RF, forest edge = ED, *Eucalyptus grandis* stand at 200 m from the forest edge = GRA, *E. grandis* and *Eucalyptus saligna* stand at 400 m from the forest edge = GRA/SAL1, and *E. grandis* and *E. saligna* stand at 600 m from the forest edge = GRA/SAL2) using euclidean distances, in Aracruz, Southeastern Brazil.

The low similarity between residual forest and forest edge was determined by the great number of restricted species. High structural and resource diversity in these systems could allow a great number of specialized species. Habitat heterogeneity usually lead to an increase in restricted species (Gaston & Lawton, 1990) and each plant group has their associated characteristic insects (Lawton & Schroder, 1977).

Preserved native areas intercalated with *Eucalyptus* spp. plantations were commonly suggested as important to decrease the pest moth species abundance as a result of the increased population of natural enemies (Bragança et al., 1998a, 1998b; Zanuncio et al., 1998). Assuming that natural enemy control of these pest species is effective, local abundance of the pest in a site distant from the residual forest will be a result of the relative spread capacity between the natural enemies and the moth pest. The balance of these forces could produce a great variety of distinct patterns in the abundance of moth species and in their species richness.

If we considered only the dispersing capacity of the moth species we would expect a decrease in their species richness in the eucalyptus area with increasing distance from the residual forest. This hypothesis was not supported by our data. This result could be due to the presence of another area of 300 meters from the GRA/SAL2 site that could be a source of these insects which colonized the eucalyptus area.

CONCLUSION

All analysis revealed the same general patterns in community structure in the five sites studied. Forest edge and residual forest had similar structure (measured by composition and abundance distribution), greatest (and similar) species richness and the highest level of restricted species. The eucalyptus sites had lower species richness, high similarity in structure and a low number of restricted species.

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REFERENCES

ALTIERI, M.A.; LETOURNEAU, D.K. Vegetational diversity and insect outbreaks. **CRC Critical Reviews in Plant Sciences**, Boca Raton, v.2, p.131-169, 1984.

ALTIERI, M.A.; CURE, J.R.; GARCIA, M.A. The role and enhancement of parasitic Hymenoptera biodiversity in agroecosystems. In: LaSALLE, J.; GAULD, I.D. (Ed.) **Hymenoptera and biodiversity**. London: CAB International, 1993. p.257-275.

ANDOW, D.A. Vegetational diversity and arthropod population response. **Annual Review of Entomology**, Palo Alto, v.36, p.561-586, 1991.

BAKER, R.R.; SADOVY, Y. The distance and nature of the light-trap response of moths. **Nature**, Hampshire, v.276, p.818-821, 1978.

BRAGANÇA, M.A.L.; DeSOUZA, O.; ZANUNCIO, J.C. Environmental heterogeneity as a strategy for pest management in *Eucalyptus* plantations. **Forest Ecology and Management**, Wageningen, v.102, p.9-12, 1998a.

BRAGANÇA, M.A.L.; ZANUNCIO, J.C.; PICANÇO, M.; LARANJEIRO, A.J. Effects of environmental heterogeneity on Lepidoptera and Hymenoptera populations in *Eucalyptus* plantations in Brazil. **Forest Ecology and Management**, Wageningen, v.103, p.287-292, 1998b.

CAMARGO, J.L.C.; KAPOS, V. Complex edge effects on soil moisture and microclimate in Central Amazonian forest. **Journal of Tropical Ecology**, Cambridge, v.11, p.205-221, 1995.

CHEN, J.; SAUNDERS, S.C.; CROW, T.R.; NAIMAN, R.J.; BROSOFSKE, K.D.; MROZ, G.D.; BROOKSHIRE, B.L.; FRANKLIN, J.F. Microclimate in forest ecosystem and landscape ecology. **BioScience**, Washington, v.49, p.288-297, 1999.

COLWELL, R.K.; CODDINGTON, J.A. Estimating terrestrial biodiversity through extrapolation. **Philosophical Transactions of the Royal Society (Series B)**, London, v.345, p.101-118, 1994.

FREITAS, F.A.; ZANUNCIO, T.V.; ZANUNCIO, J.C.; BRAGANÇA, M.A.L.; PEREIRA, J.M.M. Similaridade e abundância de Hymenoptera inimigos naturais em plantios de eucalipto e em área de vegetação nativa. **Floresta e Ambiente**, Rio de Janeiro, v.9, p.145-152, 2002.

GASTON, K.J.; LAWTON, J.H. Effects of scale and habitat on the relationship between regional distribution and local abundance. **Oikos**, Lund, v.58, p.329-335, 1990.

HELTSHE, J.F.; FORRESTER, N.E. Estimating species richness using the jackknife procedure. **Biometrics**, Arlington, v.39, p.1-11, 1983.

LAWTON, J.H. Plant architecture and the diversity of phytophagous insects. **Annual Review of Entomology**, Palo Alto, v.28, p.23-39, 1983.

LAWTON, J.H.; SCHRODER, D. Effects of plant type, size of geographical range and taxonomic isolation on number of insect species associated with British plants. **Nature**, Hampshire, v.165, p.137-140, 1977.

LAWTON, J.H.; STRONG, D.R.JR. Community patterns and competition in folivorous insects. **American Naturalist**, Chicago, v.118, p.317-338, 1981.

LUDWIG, J.A.; REYNOLDS, J.F. **Statistical ecology: a primer on methods and computing**. New York: John Wiley & Sons, 1988. 333p.

MANLY, B.F.J. **Randomization and Monte Carlo methods in biology**. London: Chapman and Hall, 1991.

MANLY, B.F.J. **Multivariate statistical methods: a primer**. London: Chapman and Hall, 1994.

SILVA, M.C.JR; SCARANO, F.R.; CARDEL, F.S. Regeneration of an Atlantic forest formation in the understorey of a *Eucalyptus grandis* plantation in South-Eastern Brazil. **Journal of Tropical Ecology**, Cambridge, v.11, p.147-152, 1995.

ZANUNCIO, J.C.; MEZZOMO, J.A.; GUEDES, R.N.C.; OLIVEIRA, A.C. Influence of strips of native vegetation on Lepidoptera associated with *Eucalyptus cloeziana* in Brazil. **Forest Ecology and Management**, Wageningen, v.108, p.85-90, 1998.

ZANUNCIO, J.C.; NASCIMENTO, E.C.; GARCIA, J.F.; ZANUNCIO, T.V. Major lepidopterous defoliators of eucalypt in southeast Brazil. **Forest Ecology and Management**, Wageningen, v.65, p.53-63, 1994.

ZANUNCIO, T.V.; ZANUNCIO, J.C.; FREITAS, F.A.; PRATISSOLI, D.; SEDIYAMA, C.A.Z.; MAFFIA, V.P. Main Lepidoptera pest species collected in an eucalyptus plantation in State of Minas Gerais, Brazil. **Journal of Biology and Conservation**., San José, v.33, n.2, 2004.

ZAR, J.H. **Biostatistical analysis**. Englewood Cliffs: N.J. Prentice-Hall, 1984. 718p.