ELSEVIER

Forest Ecology and Management 142 (2001) 183–191

Forest Ecology and Management

www.elsevier.com/locate/foreco

Ambrosia and bark beetles (Scolytidae: Coleoptera) in pine and eucalypt stands in southern Brazil

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Received 18 September 1999; accepted 26 January 2000

Abstract

More than 95% of the reforested area in Brazil is covered by exotic *Eucalyptus* and *Pinus* plantations. Native Scolytidae, mostly ambrosia beetles, appear to be rapidly adapting to these exotic trees, and reports of economic damage are becoming frequent. The objectives of our research were to survey, characterize and compare the Scolytidae fauna present in a *P. taeda* and an *E. grandis* stand in Telêmaco Borba, Paraná state, Brazil. Beetles were caught in ethanol baited ESALQ-84 vane traps in weekly collections from July 1995 until July 1997. In all, 87 species were trapped, 62 in the pine and 75 in the eucalypt stand. The most abundant beetle species in the pines were *Hypothenemus eruditus*, *Xyleborinus gracilis*, *Cryptocarenus* sp. and *Xylosandrus retusus*, while the most frequent were *H. eruditus*, *Cryptocarenus* sp., *H. obscurus*, *Ambrosiodmus obliquus*, and *X. gracilis*. In the eucalypt stand, *H. eruditus*, *X. retusus*, *H. obscurus*, *X. ferrugineus* and *Microcorthylus minimus* were the most abundant species, and *H. eruditus*, *H. obscurus* and *M. minimus* were the most frequently trapped. The majority of the species, regardless of the forest community, were most active between August (end of winter) and October (mid-spring). Significantly more *H. eruditus*, *X. gracilis*, *Cryptocarenus* sp., *Corthylus obliquus*, *Hypothenemus bolivianus*, *A. obliquus*, *Sampsonius dampfi* and *Xyleborus affinis* were trapped in the pine stand, while *X. retusus*, *H. obscurus*, *X. ferrugineus*, *Xyleborinus linearicollis*, *Corthylus* sp. and *Corthylus convexicauda* were caught in higher numbers in the eucalypt stand. Approximately 50% of the species trapped were found in both communities. Morisita's similarity index indicates the composition of the two communities is very similar, suggesting that most of the beetles are polyphagous. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Ambrosia beetles; Brazil; *Eucalyptus grandis*; *Pinus taeda*; Scolytidae; Survey

1. Introduction

In Brazil, most managed forest plantations are composed of exotic tree species, where *Eucalyptus* (Myrtaceae) and tropical and sub-tropical *Pinus* species (Pinaceae) comprise, respectively, ca. 62 and 35% of the total reforested area (ANFPC, 1996). While several native plants belong to the Myrtaceae family, there are only three native Pinaceae in Brazil (Marchiori, 1996), none of the genus *Pinus*.

Since their introduction, eucalypt trees have been attacked by various native insect pests, especially defoliating caterpillars and leaf-cutting ants (Iede, 1985), while pine trees remained nearly free of major insect pests (Schönherr, 1991). Beetles of the family

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PII: S0378-1127(00)00349-2

Scolytidae are one of the most destructive pests of conifers (Wood, 1982). In Brazil, records of scolytid attacks on live eucalypts date back to the early introduction of those trees (Iglesias, 1914; Pinheiro, 1962), but damage was of little economic importance. Conversely, there are no records of attacks on live pines (Flechtmann et al., 1995).

However, the importance of scolytid beetles in Brazilian forests may be changing. There are recent reports of attacks of scolytids on live eucalypts (Rocha, 1993; Farias, 1996), and those beetles are being found in increasing populations in pine plantations, where they occasionally cause economic damage to logs stored in the forest and at sawmills (Flechtmann et al., 1995).

Knowledge of the composition of the insect fauna in plantations, and its spatial and temporal distribution, are one of the basic components in an integrated management program (Lindgren and Borden, 1983). Traditionally, one of the best tools to survey and monitor insects is by traps baited with attractants (Chénier and Philogène, 1989; Turchin and Odendaal, 1996). In Brazil, a type of vane flight impact trap baited with ethanol is the most common for survey and monitoring of scolytid beetles (Flechtmann et al., 1995).

The objectives of our experiment were to survey stands of *Eucalyptus grandis* Hill ex Maiden and loblolly pine (*Pinus taeda* L.) to determine their scolytid species composition, to analyze the beetle community structure, to learn seasonal fluctuation of scolytids and to ascertain the similarity in scolytid occurrence between the two forest communities.

2. Materials and methods

2.1. Sites

The traps were deployed in an *E. grandis* (provenance: Coff's Harbour) and in a *P. taeda* stand, both owned by Klabin Fabricadora de Papel e Celulose S/A, and located in Telêmaco Borba, Paraná state, Brazil, at the approximate geographic coordinates of 24°12′ latitude S and 50°36′ longitude W, and at an altitude of 885 m above sea level. The region is subtropical; the average temperature of the coldest and warmest months of the year are, respectively, 15.3 and 22.4°C (Köppen, 1948).

The *E. grandis* stand was 42.9 ha in size, was planted in January 1987, had a density of 338 trees/ha, mean DBH of 25.0 cm, tree height of 32.7 m and basal area of 16.54 m^2/ha. The *P. taeda* stand, of 62.7 ha, was planted in July of 1972, had 265 trees/ha, DBH of 38.4 cm, tree height of 32.1 m and basal area of 30.53 m^2/ha.

2.2. Traps and deployment

We employed the vane trap model ESALQ-84 (Berti Filho and Flechtmann, 1986), baited with 95% ethanol. Traps were placed in five lines per stand, each line with five traps; the spacing among traps was 100 m within and between lines. Beetles trapped were collected every 7 days (after which the bait was replinished), starting on 28 July 1995 and ending on 25 July 1997, with a total of 105 weeks of collections.

2.3. Experimental design and data analysis

The experimental design was a randomized complete block. Beetle catch data were transformed into $\sqrt{(x+0.5)}$ (Phillips, 1990) to remove heteroscedasticity. Since there is no clear distinction among the four seasons (Flechtmann et al., 1995), we divided the year into a warm (average temperature of 21.04°C, rainfall of 6.62 mm) and a cold (average temperature of 17.32°C, rainfall of 2.32 mm) season. Beetle catches between seasons and between sites were compared by Kruskal–Wallis test (proc NPAR1WAY; SAS, 1990). The two forest communities were characterized over seasons by the faunistic indices of relative density (abundancy) and frequency (Brower and Zar, 1977); Shannon's diversity index (Shannon and Weaver, 1964); eveness (Pielou, 1966) and Jaccard's (Jaccard, 1901) and Morisita's similarity indices (Morisita, 1959). Relative density (abundancy) refers to the total number of specimens for a particular species divided by the total number of all beetles trapped, while frequency expresses the number of collection dates in which a species was trapped, divided by the total number of collections; Shannon's diversity index is based on the sum of the relative diversity of each beetle species; eveness expresses how close the diversity index is to a maximum possible diversity. Jaccard's similarity index takes into consideration only the number of species in each and both communities, while Morisita's similarity index allows the number of specimens trapped plus the number of species to be taken into account.

3. Results

A total of 89 scolytid species were trapped. A complete list of species caught will not be provided in this paper because Stephen L. Wood (Brigham Young University, Provo Utah) is currently working on a revision of the South-American scolytids. Species included in the analyses, except for diversity and similarity (when all species were used), were *Cryptocarenus seriatus* Eggers, *Cryptocarenus* sp., *Hypothenemus bolivianus* (Eggers), *Hypothenemus eruditus* Westwood and *Hypothenemus obscurus* (Fabricius) in the Cryphalini; *Corthylus convexicauda* Eggers, *Corthylus obliquus* Schedl, *Corthylus* sp. and *Microcorthylus minimus* Schedl in the Corthylini; and *Ambrosiodmus hagedorni* (Iglesias), *Ambrosiodmus obliquus* (LeConte), *Xyleborinus gracilis* (Eichhoff), *Sampsonius dampfi* Schedl, *Xyleborus affinis* Eichhoff, *Xyleborus ferrugineus* (Fabricius), *Xyleborinus linearicollis* Schedl, *Xyleborus squamulatus* Eichhoff and *Xylosandrus retusus* (Eichhoff) in the Xyleborini. These species accounted for >93% of the specimens collected in each community.

On the loblolly pine site we trapped 18,877 beetles in 62 species. *H. eruditus*, *X. gracilis*, *Cryptocarenus* sp. and *X. retusus* were the most abundant species, respectively, accounting for >70% of all scolytids trapped. *H. eruditus*, *Cryptocarenus* sp., *H. obscurus*, *C. obliquus* and *X. gracilis* were the most frequent species, which were trapped on >80% of the collection dates (Table 1).

The distribution of the beetles was influenced by the season: 8763 scolytids were trapped in the cold season; and 10,114 were caught in the warm season. Significantly more *Cryptocarenus* sp., *H. bolivianus*, *A. obliquus*, *X. ferrugineus* and *X. retusus* were trapped in the warm season, while *C. obliquus*, *M. minimus*, *H. eruditus*, *S. dampfi*, *X. gracilis*, and *X. squamulatus* were caught in higher numbers in the cold season (Fig. 1). The most abundant species in the cold season were *H. eruditus*, *X. gracilis*, *C. obliquus* and *Cryptocarenus* sp., respectively (>78% total specimens), while the most frequent beetles were *C. obliquus*, *M. minimus*, *Cryptocarenus* sp. and *H. eruditus* (>80%, Table 1). The composition of the most abundant and frequent species changed during the warm season; *H. eruditus*, *Cryptocarenus* sp., *X. gracilis* and *X. retusus* were respectively the most abundant species (>70% total beetles), and *H. eruditus*, *H. obscurus*, *X. gracilis*, *Cryptocarenus* sp., *X. ferrugineus* and *H. bolivianus* were the most frequent (>80%, Table 1). The diversity and eveness of species were higher in the warm than in the cold season (Table 1).

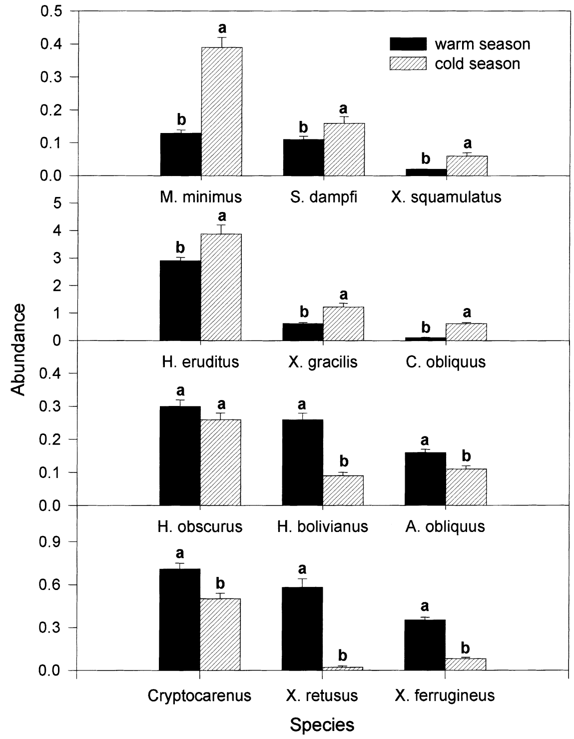

Fig. 1. Mean (±SE) weekly numbers of Scolytidae species caught in ethanol traps in *P. taeda* stand in Telêmaco Borba, Paraná state, Brazil, from July 1995 until July 1997. Means followed by the same letter within each species are not significantly different (p<0.05, χ^2-test).

The majority of the species trapped were most active from the end of the winter (August) through mid-spring (September and October), including *H. bolivianus*, *H. eruditus*, *H. obscurus*, *A. hagedorni*, *S. dampfi*, *X. gracilis*, *X. linearicollis*, *X. squamulatus* and *X. retusus*. *X. ferrugineus* was most abundant from

Table 1
Distribution of indices of relative density (*A*), frequency (*F*), Shannon's diversity, eveness, Jaccard's similarity, and Morisita's similarity for Scolytidae species trapped in ethanol traps in *E. grandis* and *P. taeda* stands in Telêmaco Borba, Paraná state, Brazil, from July 1995 until July 1997

Species	*Eucalyptus grandis* stand						*Pinus taeda* stand					
	2 years		Cold season		Warm season		2 years		Cold season		Warm season	
	A (%)	*F* (%)	*A* (%)	*F* (%)	*A* (%)	*F* (%)	*A* (%)	*F* (%)	*A* (%)	*F* (%)	*A* (%)	*F* (%)
Ambrosiodmus hagedorni	1.26	40.00	1.76	38.64	1.01	40.98	0.89	63.81	0.67	54.55	1.08	70.49
Ambrosiodmus obliquus	1.22	45.71	1.04	34.09	1.32	54.10	1.94	68.57	1.43	54.55	2.38	78.69
Corthylus convexicauda	0.75	32.38	1.04	40.91	0.60	26.23	0.05	8.57	0.05	9.09	0.05	8.20
Corthylus obliquus	0.44	20.95	1.06	31.82	0.12	13.11	4.49	80.95	7.74	95.45	1.68	70.49
Corthylus sp.	0.86	46.67	0.89	34.09	0.84	55.74	0.03	4.76	–	–	0.05	8.20
Cryptocarenus seriatus	1.07	50.48	1.61	47.73	0.79	52.46	0.66	55.24	0.64	52.27	0.67	57.38
Cryptocarenus sp.	4.40	84.76	6.82	90.91	3.18	80.33	8.64	87.62	6.28	90.91	10.69	85.25
Hypothenemus bolivianus	2.93	45.71	2.05	25.00	3.38	60.66	2.63	61.90	1.18	31.82	3.89	83.61
Hypothenemus eruditus	31.34	92.38	41.24	84.09	26.33	98.36	46.07	92.38	48.75	81.82	43.75	100.0
Hypothenemus obscurus	10.80	89.52	7.23	77.27	12.61	98.36	3.90	85.71	3.24	70.45	4.48	96.72
Microcorthylus minimus	5.59	78.10	6.72	86.36	5.02	72.13	3.37	80.95	4.93	93.18	2.03	72.13
Sampsonius dampfi	1.78	59.05	2.48	56.82	1.43	60.56	1.79	63.81	1.96	68.18	1.64	60.66
Xyleborinus gracilis	4.99	69.52	7.66	63.64	3.63	73.77	12.12	80.95	15.28	68.18	9.38	90.16
Xyleborinus linearicollis	4.88	70.48	7.23	59.09	3.69	78.69	2.37	47.62	2.98	27.27	1.85	62.30
Xyleborus affinis	0.29	29.53	0.21	20.45	0.33	36.07	0.57	40.95	0.58	36.36	0.56	44.26
Xyleborus ferrugineus	9.67	71.43	1.47	45.45	13.83	90.16	3.29	68.57	0.95	47.73	5.32	83.61
Xyleborus squamulatus	0.93	43.81	1.98	56.82	0.40	34.43	0.52	25.71	0.78	31.82	0.30	21.31
Xylosandrus retusus	12.63	58.10	2.63	20.45	17.70	82.25	4.79	38.10	0.23	9.09	8.74	59.02
Shannon's diversity	2.45		2.35		2.37		2.06		1.91		2.07	
Eveness	0.57		0.57		0.58		0.50		0.50		0.54	
Jaccard's index	2-year season: 0.5222				cold season: 0.5441				warm season: 0.5286			
Morisita's similarity	2-year season: 0.8812				cold season: 0.9564				warm season: 0.8308			

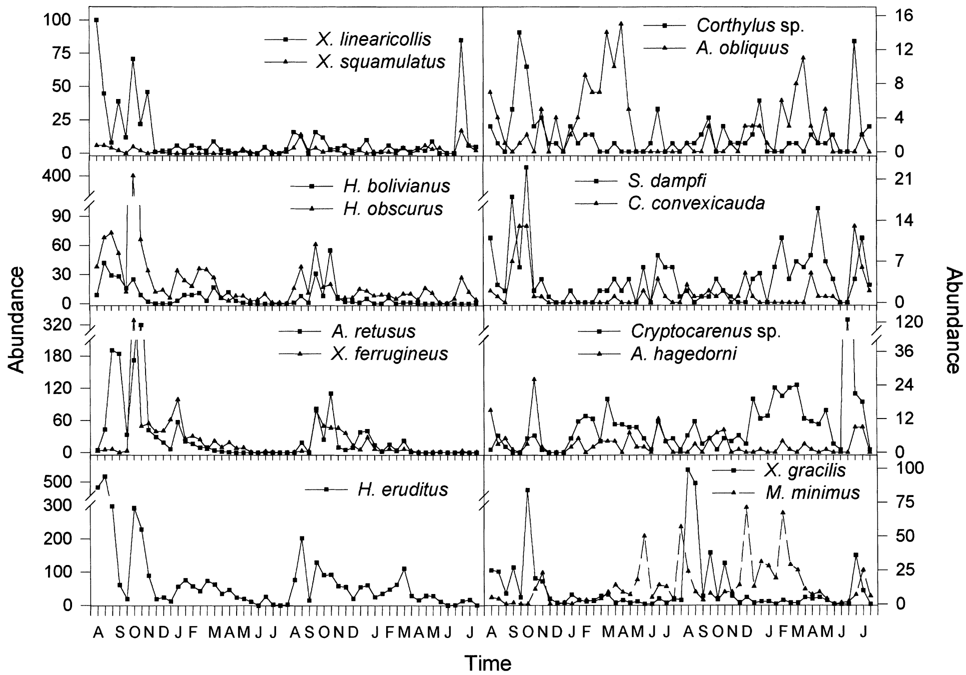

Fig. 2. Total number of selected Scolytidae trapped in ethanol traps collected biweekly in *E. grandis* stand in Telêmaco Borba, Paraná state, Brazil, from July 1995 until July 1997.

October to January, *M. minimus* from December to February, *Cryptocarenus* sp. from January to March, *A. obliquus* from February to April and *C. obliquus* from May to July (Fig. 2).

On the eucalypt site, 12,335 beetles including 75 species were trapped. The most abundant species, *H. eruditus*, *X. retusus*, *H. obscurus*, *X. ferrugineus* and *M. minimus*, respectively, accounted for >70% of the specimens. *H. eruditus*, *H. obscurus* and *M. minimus* were present on >80% of the collection dates (Table 1).

Catches of beetles during the warm season were about double those in the cold season (8186 vs. 4149). Distribution of catches of the most common species were similar to those observed in loblolly pine stands, except for *H. obscurus*, which was trapped significantly more in the warm than in the cold season (χ^2=41.35, p=0.0001, df=1), and for *X. linearicollis*, *S. dampfi* and *M. minimus*, which were caught in higher numbers in the cold season, but that were not statistically different than trappings in the warm season (p=0.05). In the warm season, *H. eruditus*, *X. retusus*, *X. ferrugineus* and *H. obscurus* constituted >70% of the specimens, and *H. eruditus*, *H. obscurus*, *X. ferrugineus* and *X. retusus* were the most frequent species, being present in >80% of the collection dates. For the cold season, *H. eruditus*, *X. gracilis*, *H. obscurus*, *X. linearicollis* and *Cryptocarenus* sp. were the most abundant species, contributing to >70% of the specimens trapped, while *Cryptocarenus* sp., *M. minimus* and *H. eruditus* were the most frequent species, present in >80% of the collection dates (Table 1). Indices of similarity and eveness were higher in the warm season than in the cold season (Table 1).

The seasonal trapping pattern of the most common species was very similar to that observed in the loblolly pine stands, with the majority of the species being most active between August and October (Fig. 3).

Several of the species were captured in numbers significantly higher in one forest type over the other. Significantly more *H. eruditus*, *X. gracilis*, *Cryptocarenus* sp., *C. obliquus*, *H. bolivianus*, *A. obliquus*, *S. dampfi* and *X. affinis* were trapped in the pine

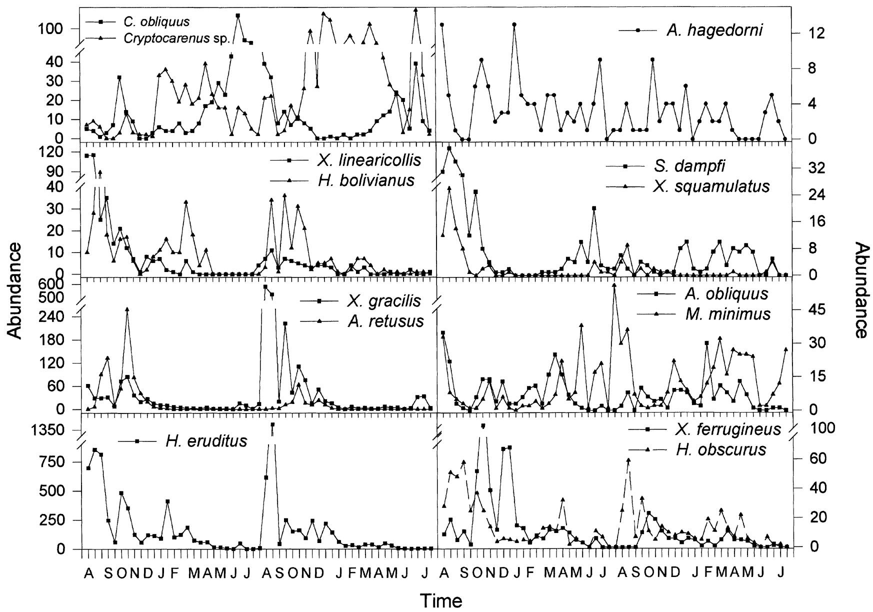

Fig. 3. Total number of selected Scolytidae trapped in ethanol traps collected biweekly in *P. taeda* stand in Telêmaco Borba, Paraná state, Brazil, from July 1995 until July 1997.

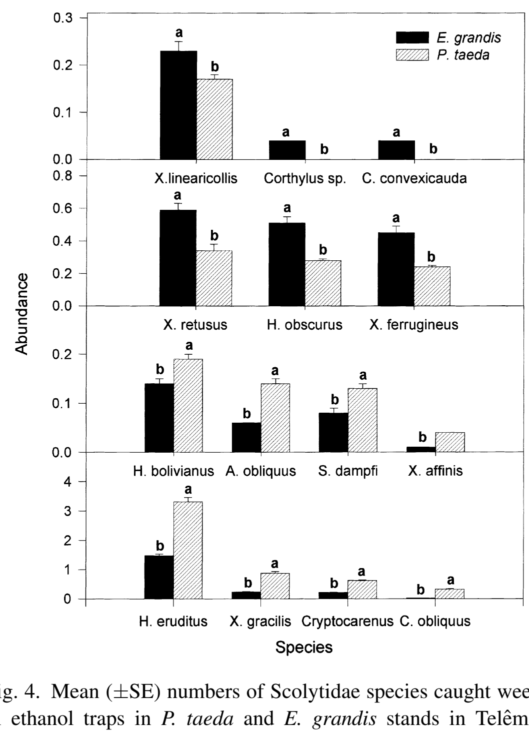

Fig. 4. Mean (±SE) numbers of Scolytidae species caught weekly in ethanol traps in *P. taeda* and *E. grandis* stands in Telêmaco Borba, Paraná state, Brazil, from July 1995 until July 1997. Means followed by the same letter within each species are not significantly different (p<0.05, χ^2-test).

plantation than in the eucalypt stand. However, more *X. retusus*, *H. obscurus*, *X. ferrugineus*, *X. linearicollis*, *Corthylus* sp. and *C. convexicauda* however were caught in the eucalypt than in the pine stand (Fig. 4).

Forty-seven species (ca. 52% of all species trapped) were common to both pine and eucalypt stands. The similarity between the two communities was intermediate according to Jaccard's index, and significantly greater when computed by Morisita's index. The communities were more similar to each other in the cold season than in the warm season (Table 1).

4. Discussion

The number of species caught in the eucalypt stand (75) was greater than previously reported in similar stands in southern Brazil (Carvalho, 1984; Carrano-Moreira, 1985; Costa et al., 1992a; Flechtmann and Gaspareto, 1997). Xyleborine beetles predominated, consistent with results of surveys performed at other Brazilian localities (Pinheiro, 1962; Carvalho, 1984; Carrano-Moreira, 1985; Zanúncio et al., 1986; Marques, 1989). However, *H. eruditus* was by far the most abundant species in number of individuals trapped in our study (Table 1).

It appears that *Premnobius cavipennis* Eichhoff is the predominant species in eucalypt stands north of the Tropic of Capricorn (≈23° latitude south). *H. eruditus* however seems to be a secondary species (Rocha, 1993; Flechtmann et al., 1995; Farias, 1996; Flechtmann and Gaspareto, 1997). South of the Tropic of Capricorn though, *P. cavipennis* is nearly absent. *H. eruditus*, along with other *Hypothenemus* species, are consistently the most abundant scolytids (Carrano-Moreira, 1985; Marques, 1989; Costa et al., 1992a).

P. cavipennis and *X. ferrugineus* are the most aggressive scolytids in eucalypt stands, where they can attack healthy standing trees and saplings (Pedrosa-Macedo, 1988; Rocha, 1993; Farias, 1996). Those species, which are abundant north of the Tropic of Capricorn, occurred in low abundance at our study site, indicating that plantations in this area might be at a lower risk for attack by scolytids than those above this latitude.

The number of species trapped in the loblolly pine stand (62) is consistent with other surveys conducted year-round in pine stands (Marques, 1989; Flechtmann et al., 1995). Surveys conducted in loblolly pine stands at the same geographical location yield fewer species when trapping is conducted only in the warm season (Marques, 1984; Carrano-Moreira, 1985) compared to year-round trapping (Marques, 1989). In our surveys, 48 species were trapped in the warm season, as opposed to the 62 species during the whole year period.

In the loblolly pine stand, xyleborine species were more common than species in other tribes, which agrees with previous surveys (Marques, 1984; Carrano-Moreira, 1985; Marques, 1989). As in the eucalypt stand, *H. eruditus* was the most abundant species, accounting for ca. 46% of all individuals trapped (Table 1). These numbers are similar to surveys done in loblolly pine stands of comparable age (Marques, 1989; Costa et al., 1992b). However, in younger loblolly stands, *H. eruditus* can account for >90% of all scolytids (Carrano-Moreira, 1985). Apparently the higher abundance of this species is the result of more frequent thinnings, which produce large amounts of breeding material for brood development of this beetle (Flechtmann et al., 1995).

In Brazil, most of available records on surveys of scolytids in pine stands are from localities below 20° South latitude. Based on those results, it appears that by moving South as tropical pines (*Pinus oocarpa* and *Pinus caribaea*) are progressively replaced by subtropical pine plantations (loblolly and slash, *Pinus elliottii* Engelmann), the scolytid composition, formerly characterized by a greater number of species and individuals of Xyleborini beetles, changes progressively towards a greater proportion of Corthylini species (mainly *Amphicranus*, *Corthylus*, *Corthylocurus*, *Monarthrum* and *Tricolus*) and Cryphalini (mainly *Hypothenemus*) individuals.

X. ferrugineus and *X. affinis*, considered to be two of the most aggressive ambrosia beetle species in Brazil and other tropical regions (Beaver, 1988; Pedrosa-Macedo, 1988; Flechtmann et al., 1995), are very abundant above the Tropic of Capricorn (Flechtmann et al., 1995), but they were trapped in comparatively low numbers in our site (Table 1).

The abundance of the scolytids varied over time, resulting in a differentiated composition of the most abundant species during the warm and cold seasons (Table 1). The peaks of flight for the main species common to both pine and eucalypt stands were very similar, suggesting that climatic factors play a more important role in regulating flight periods than stand or host species (Figs. 2 and 3). Regardless of the season and stand, *H. eruditus* was the most abundant species (Table 1).

The high frequency index values for many of the species found both in eucalypt and in loblolly pine stands (Table 1) show that several scolytids can be found nearly year-round in these plantations. Hence, it is to be expected that logs stored in the field could be attacked by beetles at any time of the year. However, most scolytids have their peak flights from August (when average temperatures start to increase) until October (Figs. 2 and 3). Thus, this period should be avoided if possible for logging operations and log storage in the field.

The observed Shannon's diversity was higher for eucalypt stands than in pine stands (Table 1); Carrano-Moreira (1985) observed that in this same region, the diversity was twice as high in *Eucalyptus dunnii* Maiden than in loblolly pine. These results indicate that the process of adaptation of scolytid species from their hardwood hosts to the exotic trees is somewhat easier on the broadleaf eucalypt than on coniferous pines.

The similarity between the two communities in relation to scolytid fauna, based exclusively on the number of species trapped (Jaccard) was moderate. When using Morisita's index, which takes into consideration both the number of species and the relative abundances of each species, the similarity between pine and eucalypt stands proved to be high (Table 1). Overall, Jaccard's index shows that ca. 50% of the beetle species were found in both stands, and the composition of the most abundant species is very similar. Moreover, this suggests that many of these beetles are polyphagous, which is a general characteristic of tropical scolytid species (Schedl, 1958; Browne, 1961; Beaver, 1977).

Acknowledgements

We would like to thank Klabin Fabricadora de Papel e Celulose S/A and Luiz Cordeiro for the financial support in conducting this experiment and James Hanula (USDA Forest Service, Forestry Sciences Lab., Athens, GA) and Mark Dalusky (Department of Entomology, University of Georgia, Athens, GA) for critical review of the manuscript.

References

ANFPC, 1996. Relatório estatístico florestal. ANPFC, São Paulo.

Beaver, R.A., 1977. Bark and ambrosia beetles in tropical forests, In BIOTROP Special Publication 2, Bogor, pp. 133–149.

Beaver, R.A., 1988. Biological studies on ambrosia beetles of the Seychelles (Col., Scolytidae and Platypodidae). Z. ang. Entomol. 105, 62–73.

Berti Filho, E., Flechtmann, C.A.H., 1986. A model of ethanol trap to collect Scolytidae and Platypodidae (Insecta, Coleoptera). IPEF 34, 53–56.

Brower, J.E., Zar, J.H., 1977. Field and laboratory methods for general ecology. Wm. C. Brown Company Publishers, Dubuque.

Browne, F.G., 1961. The biology of Malayan Scolytidae and Platypodidae. Malay. For. Rec. 22, 1–255.

Carrano-Moreira, A.F., 1985. Análise faunística de Scolytidae em comunidades florestais no estado do Paraná. M.S. thesis. Universidade Federal do Paraná, Curitiba.

Carvalho, A.O.R., 1984. Análise faunística de Scolytidae em comunidades florestais no estado do Paraná. M.S. thesis. Escola Superior de Agricultura Luiz de Queiroz, Piracicaba.

Chénier, J.V.R., Philogène, B.J.R., 1989. Field responses of certain forest Coleoptera to conifer monoterpenes and ethanol. J. Chem. Ecol. 15, 1729–1745.

Costa, E.C., Link, D., Marques, E.N., Grützmacher, A.D., Trevisan, R., 1992a. Scolytidae de Santa Maria e arredores. I – Associados a *Eucalyptus* spp. In Proceedings, 7. Congresso Florestal Estadual, 21–24 September 1992. Universidade Federal de Santa Maria, Nova Prata, pp. 921–927.

Costa, E.C., Link, D., Marques, E.N., Grützmacher, A.D., Silva, N.H.A., 1992b. Scolytidae de Santa Maria e arredores. II – Associados a *Pinus* spp. e *Pinus taeda*, In Proceedings, 7. Congresso Florestal Estadual, 21–24 September 1992. Universidade Federal de Santa Maria, Nova Prata, pp. 928–933.

Farias, E.N.M., 1996. Estudos populacionais de Scolytidae em reflorestamentos de *Eucalyptus grandis* Hill ex Maiden, em Antônio Dias, Minas Gerais. M.S. thesis. Universidade Federal de Viçosa, Viçosa.

Flechtmann, C.A.H., Couto, H.T.Z., Gaspareto, C.L., Berti Filho, E., 1995. Scolytidae em Reflorestamento com Pinheiros Tropicais. IPEF, Piracicaba.

Flechtmann, C.A.H., Gaspareto, C.L., 1997. Scolytidae em pátio de serraria da fábrica Paula Souza (Botucatu/SP) e fazenda Rio Claro (Lençóis Paulista/SP). Sci. For. 51, 61–75.

Iede, E.T., 1985. Perspectivas da pesquisa na área de entomologia para controle de pragas florestais no sul do Brasil, In Proceedings, IUFRO Workshop on Protection of Forests in the Tropics, 24–30 November 1985. Univ. Fed. Paraná, Curitiba, pp. 129–134.

Iglesias, F., 1914. Ipidae brazileiros, diagnose de duas especies novas. Rev. Museu Paulista 9, 128–130.

Jaccard, P., 1901. Distribution de la flore alpine dans le Bassin des Dranses et dans quelques régions voisines. Bull. Soc. Vaudoise Sci. Nat. 37, 239–272.

Köppen, W.P., 1948. Climatologia, con un estudio de los climas de la tierra. Fondo de Cultura Economica, Mexico.

Lindgren, B.S., Borden, J.H., 1983. Survey and mass trapping of ambrosia beetles (Coleoptera: Scolytidae) in timber processing areas on Vancouver Island. Can. J. For. Res. 13, 481–493.

Marchiori, J.N.C., 1996. Dendrologia das Gimnospermas. Editora da Universidade Federal de Santa Maria, Santa Maria, Ser. Livros Didáticos.

Marques, E.N., 1984. Scolytidae e Platypodidae em *Pinus taeda*. M.S. thesis. Universidade Federal do Paraná, Curitiba.

Marques, E.N., 1989. Índices faunísticos e grau de infestação por Scolytidae em madeira de *Pinus* spp. Ph.D. thesis. Universidade Federal do Paraná, Curitiba.

Morisita, M., 1959. Measuring of interspecific association and similarity between communities. Mem. Fac. Sci. Kyusyu Univ. Ser. E 3, 65–80.

Pedrosa-Macedo, J. H., 1988. Atividades de pesquisas em entomologia florestal na UFPR, In Encontro Sobre Pragas Florestais, 7–8 December 1988. Instituto de Pesquisas e Estudos Florestais, São Paulo, pp. 1–6.

Phillips, T.W., 1990. Responses of *Hylastes salebrosus* to turpentine, ethanol, and pheromones of *Dendroctonus* (Coleoptera: Scolytidae). Fl. Entomol. 73, 286–292.

Pielou, E.C., 1966. Species-diversity and pattern-diversity in the study of ecological succession. J. Theoret. Biol. 10, 370–383.

Pinheiro, J.V., 1962. Contribuição para o conhecimento de insetos dos eucaliptais no Brasil. An. Brasil. Econom. Flor. 14, 245–255.

Rocha, M.P., 1993. Os escolitídeos e a qualidade de sítio em povoamentos de *Eucalyptus grandis* W. Hill ex Maiden. M.S. thesis. Universidade Federal de Curitiba, Curitiba.

SAS, 1990. SAS/STAT user,s guide, Vol. 2. SAS Inst. Inc., Cary, NC.

Schedl, K., 1958. Breeding habits of arboricole insects in central Africa. In Proceedings, 10th International Congress of Entomology, Vol. 1, 17–25 August 1956. Montreal, pp. 183–197.

Schönherr, J., 1991. Proteção florestal: duas décadas de pesquisa em Curitiba, In Simpósio, O Desafio das Florestas Neotropicais, 7–12 April 1991. Univ. Fed. Paraná, Curitiba, pp. 188–203.

Shannon, C.E., Weaver, W., 1964. The mathematical theory of communication. The University of Illinois Press, Indiana.

Turchin, P., Odendaal, F.J., 1996. Measuring the effective sampling area of a pheromone trap for monitoring population density of southern pine beetle (Coleoptera: Scolytidae). Environ. Entomol. 25, 582–588.

Wood, S.L., 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Great Basin Natural. 6, 1–1359.

Zanúncio, J.C., Moura, J.J.L., Moreira, A.C., 1986. Coleópteros associados a *Eucalyptus* spp. em Minas Gerais, In Proceedings, 10th Congresso Brasileiro de Entomologia, 1986. SEB, Rio de Janeiro, 395 pp.