Rev. Biol. Trop., 41 (3): 755-760, 1993

Size, taxonomic and biomass distributions of flying insects in Central Amazonia: Forest edge vs. understory

Harold G. Fowler[1], Carlos A. Silva[1] and Eduardo Venticinque[2]
[1] Departamento de Ecologia, Instituto de Biociências, UNESP, 13506-900 Rio Claro, SP, Brazil.
[2] Departamento de Zoologia, Instituto de Biociências, UNESP, 18600 Botucatu, SP, Brazil.

(Rec. 17-VIII-1992. Acep. 30-IV-1993)

Abstract: Significantly more individuals and biomass of flying insects were present at the forest edge than in the understory throughout the year, as monitored by flight interception traps, in Central Amazonia. Numbers and biomass of flying insects increased at higher rates at the edge with rainfall, associated with termite swarming behavior and increased Homopteran density. The most abundant insects were Diptera, Coleoptera, Hymenoptera and Isoptera, whose ranked abundances varied with respect to forest edge and understory, as well as with season.

Key words: Amazon forest, insect, density, biomass, edge, understory.

The implantation of large-scale agricultural and ranching projects, stimulated by government incentives during the mid 1960's until 1990, resulted in clearing large areas of Brazilian Amazon forest and the formation of forest fragments (Dantas 1979). Forest fragmentation exposes species assemblages to changes in habitat heterogeneity and an increase predominance of edge effects (Klein 1989). Edge effects have become increasingly important in natural area management (Fowler *et al.* 1991). Given stronger microclimatic gradients at forest edges than in forest interiors (Lovejoy 1985), the effects of tropical seasonality (Wolda 1978) should be more pronounced at forest edges.

Animal studies in the Amazon, with few exceptions (Powell and Powell 1987, Klein 1989), have focused on vertebrates, primarily birds (Bierregaard and Lovejoy 1989). This is surprising, given the astronomical diversity of insects within the Amazon forest (Elton 1973, 1975, Penny and Arias 1982, Young 1982). The purpose of this work is to study the edge effects on flying insect assemblages in pristine edges of Central Amazonian forest, to examine contrasting and abrubt edges of a forest fragment (Lovejoy 1985), as well as the taxonomic, size and seasonal distributions of insects at forest edges and in Amazonian forest understories.

MATERIAL AND METHODS

Studies were conducted in an area of upland tropical humid forest, "terra firme", of the Central Amazon. We used a 10 ha forest fragment reserve, "Colosso", isolated in 1980, of the Biological Dynamics Project of Forest Fragments, located approximately 80 km north of Manaus (2° 25' S, 59° 50' W). The forest surrounding the reserve was cut and burned at the time of isolation, and now consists of grasses and second growth forest. The region has an average rainfall of 2 200 mm, with a marked seasonality of precipitation. The dry season runs from June to October. The rest of the year is the wet season (Bierregaard and Lovejoy 1989).

Flight interception traps (Southwood 1978) were constructed by suspending, with a nylon rope, a clear glass plate (20 X 20 cm) 1.7 m above ground level. Transparent plastic sheets were placed on each side of the glass plate and were covered with Tanglefoot (R) adhesive. For randomly chosen locations within the forest fragment and on the forest edge, four traps each were run from the 8th to the 10th of October, 1988. For the remaining collections (21 November - 21 December, 1988; 24 February - 9 March, 1989; 19 -27 April, 1989; and 12-21 June, 1989), five traps were used for each. Samples were frozen until examined.

Captured insects were identified to order using the keys of Borror and Delong (1988). Individual insects were measured for maximal body length after removal from the sticky trap with gasoline. After drying, a subsample was weighed to establish relationships between body length and dry weight for each order. Because derived length-weight relationships did not significantly differ from those published by Rogers *et al.* (1977), these equations for Coleoptera, Diptera. Lepidoptera, Hymenoptera, Hemiptera, Homoptera, and Orthoptera were used for biomass estimates. Because of variable sampling periods, data were standardized by calculating the rate of capture of both individuals and biomass/m^2 /day. For statistical analysis, each side of the sticky trap was treated separately, giving a total of 48 for forest interior and 46 for forest edge (data from one trap were lost). Sample constancies were calculated by examining the number of total traps containing an order divided by the total number of traps used during the study.

RESULTS AND DISCUSSION

Fewer individuals were captured in the forest understory than at the forest edge (Table 1) ($z = -32.790$, $p < 0.0001$). In absolute numbers, the numbers of insects at edges was much greater than in the interior ($X^2 = 192.189$, $p = 0.00001$). The number of individuals per order was significantly correlated ($p < 0.05$) between interior and edge ($r = 0.9768$), as were their sample constancies ($r = 0.9543$). The number of individuals present at the edge was an increasing function of number in the interior (number at edge = 1.7051 + 34.1607[number in interior], $F = 270.539$, $P < 0.0001$). Sample constancy for insect orders was also significantly correlated ($p < 0.05$) with order abundance for both edge ($r = 0.8385$) and interior ($r = 0.8973$).

Isoptera and Homoptera were significantly more abundant at the edge than in the interior, while for Diptera and Hymenoptera the inverse was found (Table 1). Ranked importance of the orders based upon total individuals captured during this study, however, was not significantly different between edge and interior (Kruskal-Wallis test $p > 0.05$).

Insect numbers and size distributions varied significantly between forest interior and edge in all samples (Fig. 1), with the forest edge always having significantly higher abundances, and generally larger individual sizes than the interior. However, only the monthly abundances of very small insects, 1-2 mm and 2-3 mm, or insects larger tha 3 mm were significantly correlated (Table 2).

Estimated densities and biomasses of flying insects at the edge and interior (Fig. 2) also varied significantly through the study period. Insect densities and biomasses were more strongly related with rainfall at the edge ($r = 0.7937$ and $r = 0.7394$, respectively) than in the interior ($r = 0.5038$ and $r = 0.4790$, respectively). Insect biomass at the edge was strongly correlated with density at the edge ($r = 0.9846$) and the interior (0.8748) as well as with interior insect biomass ($r = 0.9443$).

Sample to sample variations in the importance of insect orders (Fig. 3) were also found (Kruskal-Wallis test $p < 0.05$). Notably, Isoptera and Homoptera were much more abundant at the forest edge during October (Fig. 3a) and April (Fig. 3d), while Diptera dominated both interior and edge communities in February (Fig. 3c) and July (Fig. 3e). During December (Fig. 3b) the Hymenoptera were much less represented in the edge than in the interior.

The density of flying insects was greater at forest edges than in the forest interior, increasing 30% faster. Correspondingly, flying insect biomass also was larger at the edges. Larger insect densities are generally less than those of smaller insects (Morse *et al.* 1988, Lawton 1989, Blackburn *et al.* 1990), but tend to eat more (Pagel *et al*, 1991).

Diptera and Hymenoptera were relatively more abundant in the interior. As both groups were characterized by smaller individuals, the effects

TABLE 1

The constancies and relative frequencies of insect orders associated with forest edges and interiors of the Central Amazon over a 9 month period captured with flight interception traps. Forest edge: individuals (N = 7388), traps (N = 48); forest interior (N = 4001), traps (N = 46)

	Forest Interior		Forest Edge	
Order	Constancy	Frequency	Constancy	Frequency
Diptera*	1.00	0.4004	1.00	0.3610
Coleoptera	1.00	0.2644	1.00	0.2550
Hymenoptera*	1.00	0.1825	1.00	0.1401
Isoptera*	0.85	0.1347	0.83	0.2150
Orthoptera	0.15	0.0017	0.35	0.0033
Dermaptera	0.04	0.0007	0.18	0.0008
Thysanoptera	0.10	0.0015	0.02	0.0014
Homoptera*	0.21	0.0037	0.64	0.0140
Hemiptera	0.38	0.0092	0.52	0.0074
Lepidoptera	0.04	0.0005	0.12	0.0010
Trichoptera	0	0	0.08	0.0004
Ephemoptera	0	0	0.02	0.0001
Zoraptera	0	0	0.02	0.0001
Embioptera	0.02	0.0002	0	0
Neuroptera	0	0	0.02	0.0001
Psocoptera	0.02	0.0002	0.04	0.0003

Significant values: *p<0.01 for a Z test for equality of respective proportions in each sampled community.

TABLE 2

Correlation matrix of abundances between size classes of flying insects captured at flight interception traps in the Central Amazon. Significant correlations are in italics

size class: (mm body length)	1-2	2-3	3-4	4-5	5-6	6-8	8-10
2-3	*0.854*						
3-4	0.418	0.592					
4-5	0.049	0.042	0.306				
5-6	0.494	0.580	*0.903*	0.201			
6-8	0.095	0.193	*0.832*	0.319	*0.736*		
8-10	0.196	0.340	*0.856*	0.297	*0.721*	*0.721*	
=> 12	0.365	0.559	*0.743*	-0.121	*0.701*	0.511	*0.633*

of microclimate may be more intense, as smaller insects tend to dehydrate at a fast rate (Lawton 1989). Additionally, most of the Hymenoptera captured were parasitic, which may attest to a higher abundance of potential hosts at other substrate levels which were not sampled. The Isoptera and Homoptera were more common at the edge than in the interior. Concurrently, and in comparison with the interior, large populations of homopteran-

Although biomasses remained fairly constant in the interior, increasing significantly only in April, they fluctuated greatly at the edge. Densities were significantly lower in December, and significantly higher in April in the interior, although significant differences were found between all months at the forest ed-

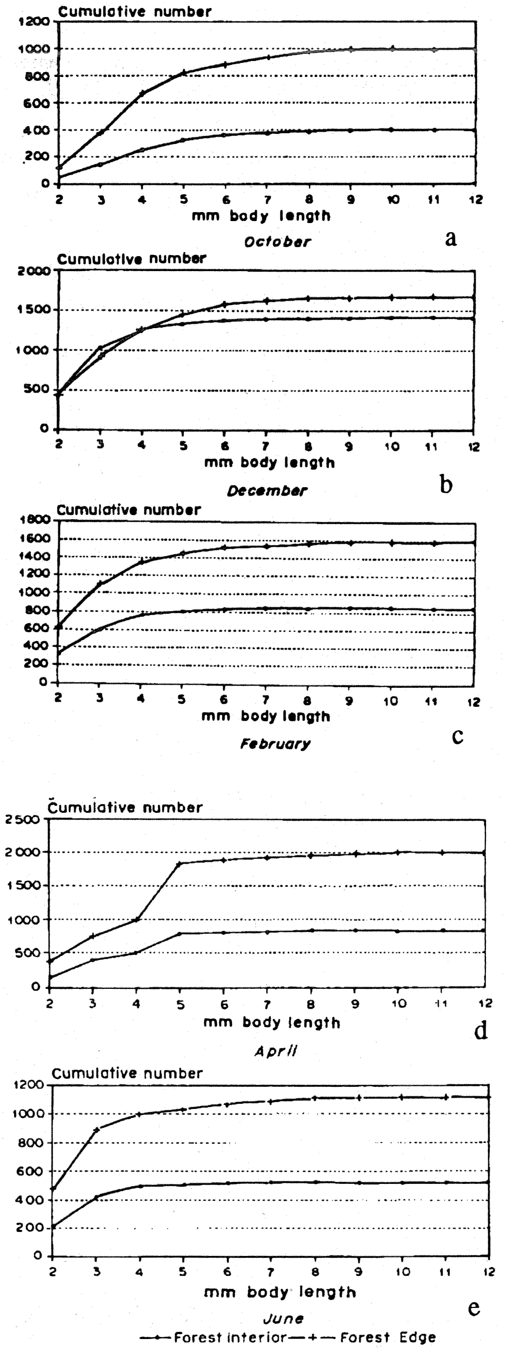


Fig. 1. The cumulative size distributions of flying insect communities sampled at different periods in forest interior and edges in the central Amazon basin and compared by a x2 test, * $p<0.05$; ** $p<0.01$. 1a. October size distributions and total captures**. 1b. December size distributions** and total captures**. 1c. February size distributions**. 1d. April size distributions** and total captures**. 1e. June size distributions* and total captures**.

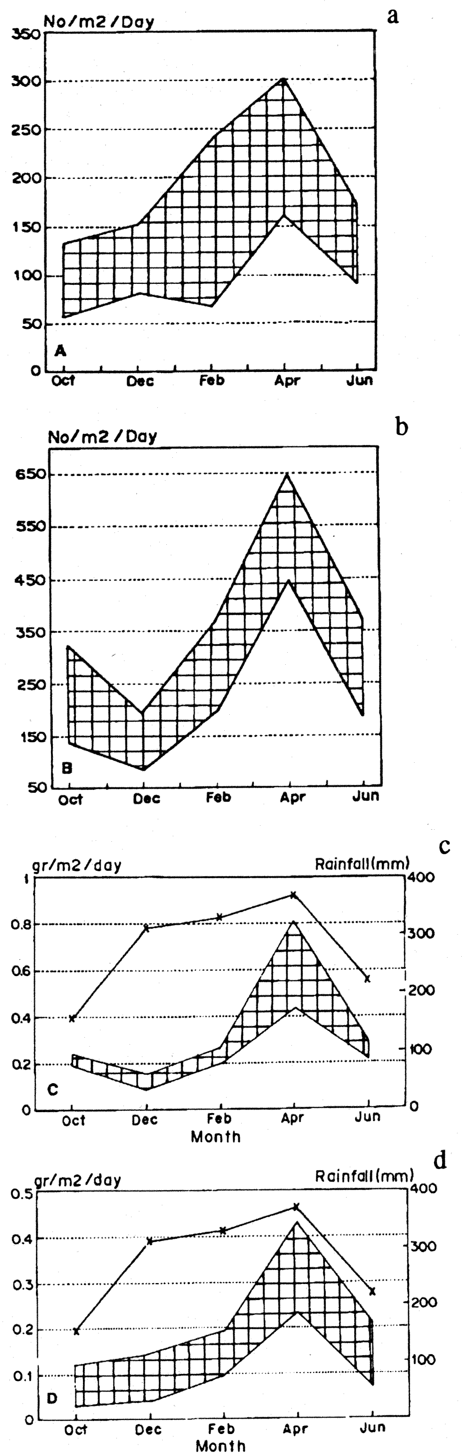


Fig. 2. Standard error of monthly estimates of insect density at the edge (2a) and the interior (2b), and insect biomass at edge (2c), and interior (2d) of a central Amazonian forest.

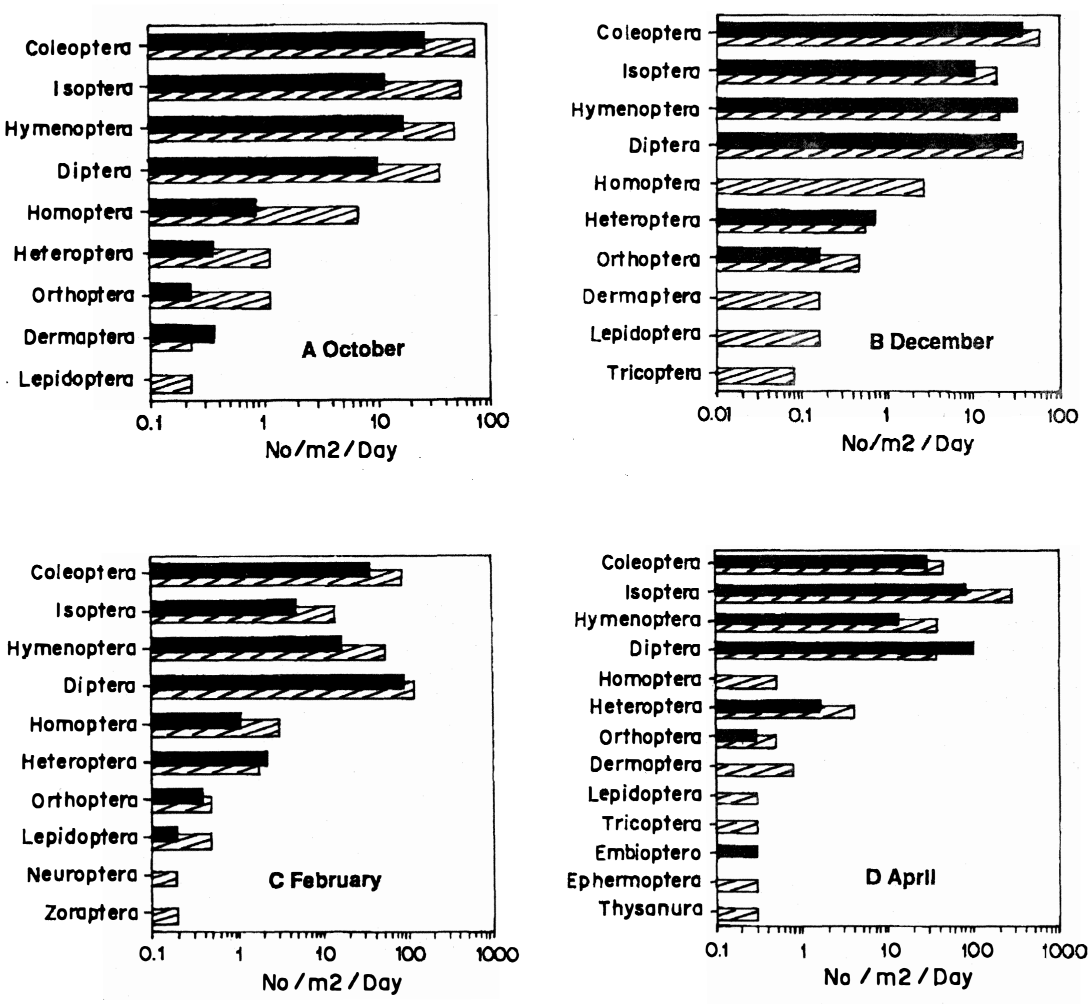
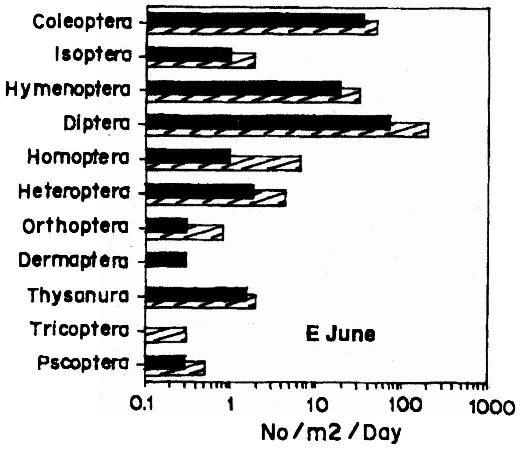


Fig. 3. The abundance of insect orders at edges and interior (black) of Amazonian forest.



ge. Even in the forest interior, different insect orders demonstrated higher relative frequencies at differing periods of the year. These results are different fron those found by Wong (1984) for understory insects of Malaysia, but are as variable as those reported by Wolda (1976) for Panamanian insect communities.

Although the taxonomic resolution of our data is only at the insect order, we have shown that the dynamics of flying insect communities differ more in numbers and biomass in the forest interior than at the edge. Our estimates of insect density and biomass are comparable with results from other sampling methods from the same area

(Penny and Arias 1982). Our results highlight the strong edge effects associated with Amazonian forest fragmentation, and suggest that insects, which are dominant regulators of nutrient cycles and energy fluxes in tropical forests (Wilson 1987), should receive higher priorities in efforts of trying to elucidate the ecological consequences of deforestation of tropical systems (Fowler *et al.* in prep.)

ACKNOWLEDGEMENTS

Research was supported by the Smithsonian Institution/World Wildlife Fund/Instituto Nacional de Pesquisas da Amazônia collaborative Biological Dynamics Project of Forest Fragments. We especially thank João de Deus Fragata for field assistance, and Marina Wong and Maria Thereza Fink for their constant encouragement and support. Additional support was provided by the Conselho Nacional de Desenvolvimento Científica e Tecnologica (CNPq) of Brazil, through grants nos. 300171/88-9 and 500185/88-3. This is publication # 98 of the BDFFP Technical Series.

RESUMEN

Las densidades y biomasas de insectos voladores son mayores en el borde que en el interior de un lugar de la selva amazónica, según estudio con trampas adhesivas. Tales valores aumentaron 30% más rápidamente en el borde. Las densidades y biomasas en el borde se correlacionaron con la lluvia, lo cual correspondió especialmente con un aumento de Isoptera y Homoptera. Los órdenes mas abundantes fueron Diptera, Coleoptera, Hymenoptera, e Isoptera, los cuales variaron en abundancia con la época del año y fueron diferentes en borde e interior de la selva.

REFERENCES

Basset, Y. & A.H. Arthington. 1992. The arthropod community of an Australian rainforest tree: abundance of component taxa, species richness and guild structure. Aust. J. Ecol. 17: 89- 98.

Bierregaard, R.O., Jr. & T.E. Lovejoy. 1989. Effects of forest fragmentation on Amazonian understory bird communities. Acta Amazon. 19: 215-241.

Blackburn, T.M., P.H. Harvey & M.D. Pagel. 1990. Species number, population density and body size relationships in natural communities. J. Anim. Ecol. 59: 335-346.

Borror, D.J. & D.M. Delong. 1988. Introduç,o ao estudo dos insetos. Edgard Blucher, S,o Paulo. 653 p.

Dantas, M. 1979. Pastagens da Amazônia central: ecologia e fauna do solo. Acta Amazon. 9: 2-54.

Elton, C.S. 1973. The structure of invertebrate populations o7 3 inside neotropical rain forest. J. Anim. Ecol. 42: 55-104. Elton, C.S. 1975. Conservation and the low population density of invertebrates inside neotropical rain forests. Biol. Conserv. 7: 1-15.

Fowler, H.G., L.F.T. di Romagnano & A.M. Dias de Aguiar. 1991. A teoria de biogeografia de ilhas e a preservaçao: um paradigma que atrapalha? Rev. Geografia 10: 39-50.

Klein, B.C. 1989. Effects of forest fragmentation on dung and carrion beetle communities in central Amazonia. Ecology 70: 1715-1725.

Lawton, J.H. 1989. What is the relationship between population density and body size in animals? Oikos 55: 429-434.

Lovejoy, T.E. 1985. Forest fragmentation in the Amazon: a case study, p. 243-251, *In* H. Messel (ed.). The study of populations. Pergamon, New York.

Morse, D.R., N.E. Stork & J.H. Lawton. 1988. Species number, species abundance, and body length relationships of arboreal beetles in Bornean lowland rainforest trees. Ecol. Entomol. 13: 25-37.

Pagel, M.D., P.H. Harvey & H.C.J. Godfray. 1991. Species- abundance, biomass, and resource-use distribution. Am. Nat. 138: 836-850.

Penny, N. & J.R. Arias. 1982. Insects of an amazonian forest. Columbia University, New York. 269 p.

Powell, A.H. & G.V.N. Powell. 1987. Population dynamics of male Euglossine bees in Amazonian forest fragments. Biotropica 19: 176-179.

Rogers, L.E., R.L. Buschbom & C.R. Watson. 1977. Length-weight relationships of shrub-steppe invertebrates. Ann. Entomol. Soc. Am. 70: 51-63.

Southwood, T.R.E. 1978. Ecological methods. 2nd ed. Halstead, New York. 524 p.

Stork, N.E. 1987. Guild structure of arthropods from Bornean rain forest. Ecol. Entomol. 12: 69-80.

Wilson, E.O. 1987. The little things that run the world.Conserv. Biol. 1: 344-346.

Wolda, H. 1976. Seasonal fluctuations in rainfall, food and abundance of tropical insects. J. Anim. Ecol. 47: 369-381.

Wong, M. 1984. Understory foliage arthropods in the virgin and regenerating habitats of Pasoh Forest Reserve, West Malaysia. Malay. Forest. 47: 43-69.

Young, A.M. 1982. Population biology of tropical insects. Plenum, New York. 683 p.