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Article

Population Dynamics of Lepidoptera Pests in *Eucalyptus urophylla* Plantations in the Brazilian Amazonia

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Abstract: Forestry companies study the population dynamics of insect pests in Integrated Pest Management for cost effectiveness. The objective of this study was to obtain qualitative and quantitative information on population fluctuation of the Lepidopteran defoliators of *Eucalyptus urophylla* plants in the Brazilian Amazon rainforest. In all, 402 species were collected, of which 10 were primary pests, nine were secondary pests, and the remaining bore no definite relevance to eucalyptus. Primary pests formed a low percentage of the total species, although they recorded a high percentage of the total number of individuals. The abundance of secondary pests, except in Caracuru, was less than 150 specimens annually. Primary pests showed higher population peaks during periods of low precipitation. The small number of species and the high abundance of primary and secondary pests could be due to the availability of food, or a deficiency in natural biological control. This suggests the possibilities of population outbreaks in the eucalyptus plantations. The period of highest occurrence for insect species in these crops

must be identified so that suitable strategies can be developed for Integrated Pest Management.

Keywords: eucalyptus; light trap; monitoring; moths; integrated pest management

1. Introduction

Eucalyptus accounts for about 62% of the 5.4 million hectares of Brazilian forest plantations, mainly *Eucalyptus grandis*, *E. urophylla*, and *E. saligna* [1]. These species are grown for essential oils, charcoal, cellulose, and wood production [2,3], which reduce the pressure on native Brazilian forests [4]. Eucalyptus hybrids are important to forestry in the tropical regions, but seem to be more susceptible to pests than the pure species [5].

The increase in food supply for phytophagous insects, the low diversity of natural enemies, and the expansion of eucalyptus plantations are factors that contribute to the adaptation of new pests in these systems [6–8]. Lepidopteran defoliators are among those causing the most severe and most frequent damage in these cultures [6,9].

Lepidoptera in eucalyptus plantations are distinguishable into three types: (I) primary pests (which can reach population outbreak levels), (II) secondary pests (which feed on eucalyptus but without outbreaks), and (III) the species with undefined importance, that may or may not feed on eucalyptus [7,9–11].

Monitoring Lepidoptera helps to assess the occurrence of pests and species with the potential for population outbreaks [11]. Forestry companies study insect population dynamics in Integrated Pest Management programs to cut costs of insecticides, equipment and labor in the eucalyptus plantations [12].

The biodiversity of the Amazon rainforest is hardly known. More than 70% of the species supported there have not been described, and the low number of surveys conducted shows that this paucity of knowledge looks set to continue [13]. Capturing insects with light traps, chiefly the defoliator lepidopterans, which are more active at night, is a strategy employed in biodiversity studies [14–16].

The objective of this study was to obtain qualitative and quantitative information regarding the population fluctuation of defoliator lepidopterans in *Eucalyptus urophylla*, in the Pará and Amapá States of the Brazilian rainforest over a five-year period.

2. Experimental Section

2.1. Study Sites

Surveys were conducted in four plantation stands composed of *Eucalyptus urophylla* S.T. Blake from six months of age to two years, approximately 50 km apart from each other, in Ponte Maria, Pacanari and Caracuru, Almeirim municipality, Pará State and Felipe, Laranjal do Jari, Amapá State, between September 1992 and August 1997 (Table 1).

Table 1. Sampling sites in Caracuru, Pacanari and Ponte Maria, Pará State and Felipe, Amapá State, Brazil.

Characteristics	Caracuru	Pacanari	Ponte Maria	Felipe
Latitude	00°32' S	00°36' S	00°47' S	00°54' S
Longitude	52°51'W	52°36' W	52°47' W	52°21' W
Altitude	110 m	126 m	88 m	164 m
Planting date of *Eucalyptus*	March 1990	March 1992	March 1991	March 1990
Annual rainfall	1988.0 mm	2066.5 mm	2276.0 mm	2276.0 mm
Annual average temperature	28.0 °C	27.5 °C	27.3 °C	27.5 °C
Annual average relative humidity	86.6%	-	84.0%	84.0%

2.2. Lepidoptera Sampling

Each area was monitored every two weeks for sixty continuous months (120 trap-nights per site) using one light trap (Model Intral AL 012) equipped with fluorescent black-light bulb F15 T12 LN (wavelength from 290 to 450 mm), powered by a 12-V and 55 A battery. The light trap was set at the midpoint of each eucalyptus stand [15], 2 m from the ground, and operated from 6 p.m. to 6 a.m., accumulating 1560 trap-hours at each site. A plastic bag, containing paper strips, and a bottle with ethyl acetate was coupled to the funnel trap to speed-up death and reduce damage to the collected insects.

The insects collected were sorted, packed, and sent to the Laboratory of Biological Control of Insects of the Department of Entomology at the Universidade Federal de Viçosa (UFV) in Viçosa, Minas Gerais State, Brazil. Insects were identified by the taxonomists from the Center for Phytophagous Insect Identification of the Universidade Federal do Paraná and other centers, and by comparing them with the specimens from the Regional Museum of Entomology/UFV (UFVB). They were deposited in the collections of the Regional Museum of Entomology/UFV and the collection of Jari Celulose, Papel e Embalagens S.A., in Monte Dourado, State of Pará, Brazil.

The lepidopteran specimens collected were divided into groups I, II, and III, representing the primary pests, secondary pests, and species without defined importance to eucalyptus, respectively [11].

2.3. Data Analysis

Climatic data were collected from the weather stations of Monte Dourado (Ponte Maria and Felipe), São Miguel (Caracuru and Pacanari). Rainfall refers to the accumulated total for the month, while temperature indicates the monthly average of the collection period. Abundances were transformed to a logarithmic scale to assist visualization and interpretation of the results where necessary.

3. Results and Discussion

A total of 402 species of Lepidoptera were collected; 10 primary pest species, 9 secondary pests, and the rest without defined importance to eucalyptus. In all 31,865 individuals were collected over five years (total effort = 6240 trap-hours). Among these, 43.53% comprised primary pests, 4.99% secondary pests, and 51.48% species without defined importance.

The number of primary pest species was similar in all the locations; however, Ponte Maria had eight secondary pest species, one less than the other locations. These species belonged to the families Arctiidae, Geometridae, Lymantriidae, and Notodontidae, the first with the highest number of species (Table 2). Secondary pests were from six families, with Saturniidae presenting the largest number of species (Table 3).

Primary pests showed a lower percentage of species, 3.08%, 2.88%, 3.04%, and 3.28%, and a substantial percentage of individuals, 14.54%, 44.68%, 68.46%, and 20.65%, in Ponte Maria, Pacanari, Caracuru and Felipe, respectively. In Pacanari and Caracuru, 85.40% of the total individuals were the primary pests, while in the other two sites with plantations near native forests, this value was only 7.28% and 7.32%, respectively (Figure 1A). The occurrence of secondary pests was similar in the four sites (Figure 1B) and the species without defined importance had a higher number of individuals in Ponte Maria (Figure 1C). The most collected species of group I in Ponte Maria were *Stenalcidia grosica*, mainly in the fourth year; *Thyrinteina arnobia* in the fifth, and *Oxydia vesulia* in the third, corresponding to 31.23%, 30.83%, and 11.82% respectively, of the total individuals of primary pests. In Pacanari, *T. arnobia* showed peaks in the second, fourth, and fifth years, while *S. grosica* peaked in the fourth, corresponding to 39.60% and 37.12%, respectively, of the total collected. These two species accounted for 84.54% of the total specimens collected in Caracuru, with outbreaks of *T. arnobia* (64.67%) in the fourth and fifth years, and *S. grosica* (19.87%) in the fourth. The most collected species in Felipe were *S. grosica* (29.91%) with a higher incidence in the fourth year, *O. vesulia* (23.46%) in the second, and *T. arnobia* (17.03%) in the fifth.

The number of species of group II varied between locations over the five years of the study and a sharp decline in the number of species was recorded, mostly in the last year. The abundance of secondary pests, except in Caracuru, with a greater number of individuals in the second year, was noted to be less than 150 specimens per year, with lower values in the first and fifth years at all locations (Figures 1B, 2C, 3C, 4C and 5C).

In Ponte Maria, *Idalus admirabilis* with 31.62%, *Eacles ducalis* with 21.94%, and *Eacles imperialis magnifica* with 20.79%, were the most collected species of this group. In Pacanari, *I. admirabilis* and *E. ducalis* were the most frequent, with 55.42% and 20.08% of the number of individuals, respectively, while in Caracuru, *I. admirabilis* was the most collected secondary pest, with 65.3% of the individuals. In Felipe, the most frequent secondary pest species were *I. admirabilis* and *E. ducalis*, with 52.47% and 14.81% of the individuals, respectively.

The number of individuals of the species of group III decreased towards the end of the collecting period in the eucalyptus plantations. The occurrence of these insects increased between the first and second year in Felipe (Figure 5D) and with a higher number in Ponte Maria (Figure 2D). Moreover, this number decreased, in Pacanari, from the first to the third year, increased in the fourth, and decreased in the fifth with the lowest number of individuals in all sites (Figure 3D).

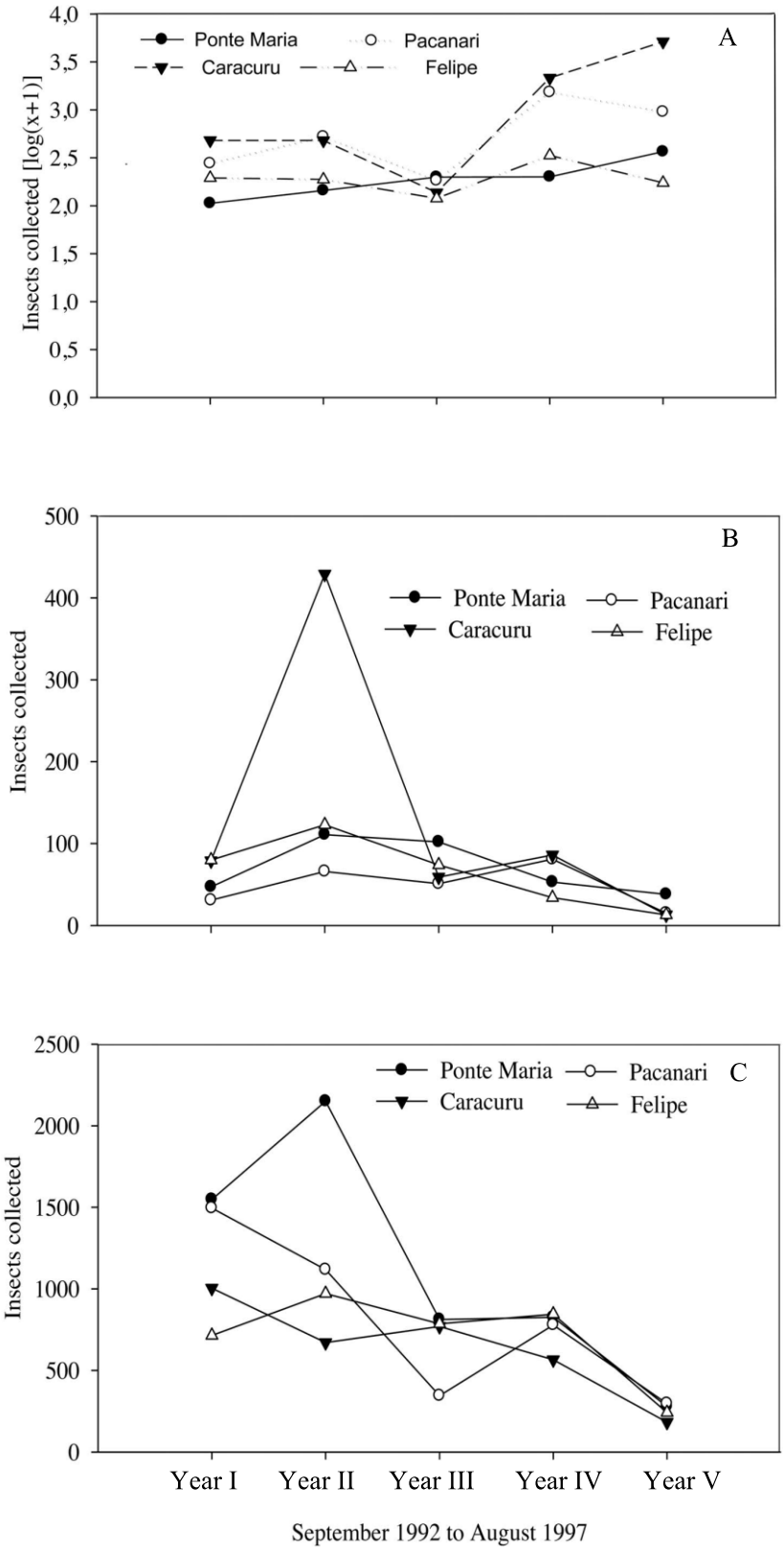
Table 2. Number of individuals of Lepidoptera primary pest species collected in *Eucalyptus urophylla* plantations in Monte Dourado, Pará and Amapá States, Brazil. T is Sub-total; GT is Grand Total.

Site	**Ponte Maria**						**Pacanari**						**Caracuru**						**Felipe**						**GT**
Family/Year	I	II	III	IV	V	T	I	II	III	IV	V	T	I	II	III	IV	V	T	I	II	III	IV	V	T	
Arctiidae																									
Eupseudosoma aberrans	24	17	16	12	9	78	56	64	40	41	14	215	147	44	43	32	18	284	28	27	9	11	0	75	652
Eupseudosoma involuta	16	15	18	4	1	54	90	27	14	16	1	148	99	164	7	15	11	296	22	11	6	1	2	42	540
Geometridae																									
Glena sp.	0	8	7	2	6	23	0	39	8	63	17	127	4	17	15	54	1	91	5	11	2	6	2	26	267
Oxydia vesulia	2	27	81	6	4	120	26	8	24	11	1	70	27	12	5	18	1	63	32	87	57	61	0	237	490
Stenalcidia grosica	15	39	65	137	61	317	15	82	46	1091	50	1284	75	50	27	1385	129	1666	54	14	33	181	20	302	3,569
Thyrinteina arnobia	19	12	5	13	264	313	11	247	44	266	802	1370	27	17	15	411	4950	5420	3	1	4	36	128	172	7,275
Lymantriidae																									
Sarsina violascens	8	14	1	18	9	50	6	3	4	18	12	43	23	2	17	189	18	249	37	21	4	26	10	98	440
Notodontidae																									
Misogada blerula	11	8	3	3	2	27	20	52	1	15	3	91	76	17	1	46	0	140	3	13	0	7	0	23	281
Nystalea nyseus	10	3	2	2	10	27	52	1	1	3	52	109	3	148	7	3	3	164	11	3	4	5	11	34	334
Psorocampa denticulata	1	1	1	3	0	6	0	1	1	0	0	2	0	8	0	0	0	8	0	0	0	1	0	1	17
Total						1015						202						312						58	13,865

Table 3. Number of individuals of Lepidoptera secondary pest species collected in *Eucalyptus urophylla* plantations in Monte Dourado, Pará and Amapá States, Brazil. T is Sub-total; GT is Grand Total.

Site	**Ponte Maria**						**Pacanari**						**Caracuru**						**Felipe**						**GT**
Family/Year	I	II	III	IV	V	T	I	II	III	IV	V	T	I	II	III	IV	V	T	I	II	III	IV	V	T	
Amatidae																									
Cosmosoma auge	1	5	3	4	1	14	2	1	0	2	0	5	3	0	3	0	0	6	0	0	3	1	0	4	29
Arctiidae																									
Idalus admirabilis	9	34	30	17	21	111	9	41	26	53	9	138	45	299	38	48	5	435	40	67	45	16	2	170	854
Eucleidae																									
Phobethon hypparchia	1	5	2	3	2	13	0	1	6	4	2	13	0	15	3	11	0	29	10	2	0	1	1	14	69
Megalopygidae																									
Megalopyge albicollis	1	6	24	3	3	37	2	4	4	4	1	15	2	52	1	0	0	55	4	15	9	0	0	28	135
Mimallonidae																									
Mimallo amilia	2	7	8	1	1	19	6	1	6	0	0	13	4	38	6	2	0	50	4	15	0	0	0	19	101
Saturniidae																									
Eacles ducalis	5	14	32	16	10	77	10	13	7	17	3	50	11	18	1	0	6	36	4	15	11	9	9	48	211
Automeris illustris	0	0	0	0	0	0	0	1	2	1	0	4	1	3	0	2	0	6	0	1	4	5	1	11	21
Eacles imperialis magnifica	24	37	3	9	0	73	7	3	0	0	0	10	5	0	1	0	0	6	13	7	1	0	0	21	110
Dirphia sp.	4	3	0	0	0	7	0	1	0	0	0	1	8	4	6	23	2	43	5	1	1	2	0	9	60
Total						157						249						91						324	1590

Figure 1. Number of individuals of Lepidoptera primary pests (**A**), secondary pests (**B**), and species with no defined importance to eucalypts (**C**) collected in *Eucalyptus urophylla* plantations in Ponte Maria, Pacanari, Caracuru, Pará State, and Felipe, Amapá State, Brazil.



The occurrence of the lepidopteran defoliators in the different locations studied showed higher population peaks of primary pests during the low rainfall periods (Figures 2B, 3B, 4B, and 5B).

No individual of primary pest was collected in Ponte Maria in January of the first, second, and fourth years, and in May of the fifth. The highest peaks of species of this group occurred in July, April, July, June, and November, respectively, from the first to the fifth year. Species belonging to group II did not occur between October and December of the first year; in October of the second; November of the third, January of the fourth, and February and June of the fifth. Species without importance to the eucalypts showed population peaks with high fluctuations, especially in August of the first year and in March of the second (Figure 2)

Primary pests were not collected in Pacanari between September and January of the first year; January and December of the fourth; and January and February of the last year. The highest population peaks of this group were recorded in April, October, October, July, and September, from the first to fifth year, respectively. Secondary pests were not collected between September and December of the first year; March and November of the second; May, September, and October of the third; January and November of the fourth; and from April to May and November to December in the last year of the evaluation. This group showed the highest population peak in June of the fourth year. Species without defined importance showed the highest population peak in February of the first year (Figure 3).

In Caracuru, primary pests were not found in October and November of the second year, in December of the fourth, and January to February and May of the last year. The secondary pests did not occur in November of the first year; in November and December of the third; in November of the fourth; and in March, May, July, and September to November of the fifth, with a population peak in April of the second year. The population peak of the species of the third group showed a higher variation from the second half of the collection period (Figure 4).

The collections in Felipe showed that primary pests were not observed in October of the second year, and January and November of the fourth. The highest population outbreaks of this group were recorded in June, May, September, July, and September, from the first to the fifth year, respectively. The secondary pests were not collected between September and November of the first year; in December of the third; in January and February and from October to November of the fourth, and in January, March, May, June, August, and November of the last year. The highest population peak of this group was recorded in April of the second year while the lowest was noted in the fifth year. Peak population of the species without defined importance for eucalypts showed a low variation over the years (Figure 5).

Species of primary and secondary pests included 48.52% of the total number of individuals, which was only 4.72% of the total species, showing their adaptation to the eucalyptus plantations [7,9,11,12,17]. Species of the native vegetation may migrate to the eucalypts due to the abundant food supply where they can become pests in several regions of Brazil [8,12]. The low number of species and the high number of the individuals of these two groups could probably be due to availability of food or to poor natural biological control to reduce their populations [10]. The high number of individuals of these groups suggests the possibility of population outbreaks in eucalyptus plantations. However, food supply is not the only factor to favor outbreaks of Lepidoptera; some environmental conditions unfavorable to plants also play a role [18].

Figure 2 Rainfall (mm) and temperature (°C) (**A**), population dynamics of primary pests (**B**), secondary pests (**C**), and species with no defined importance to eucalypts (**D**) in Ponte Maria, Pará State, Brazil.

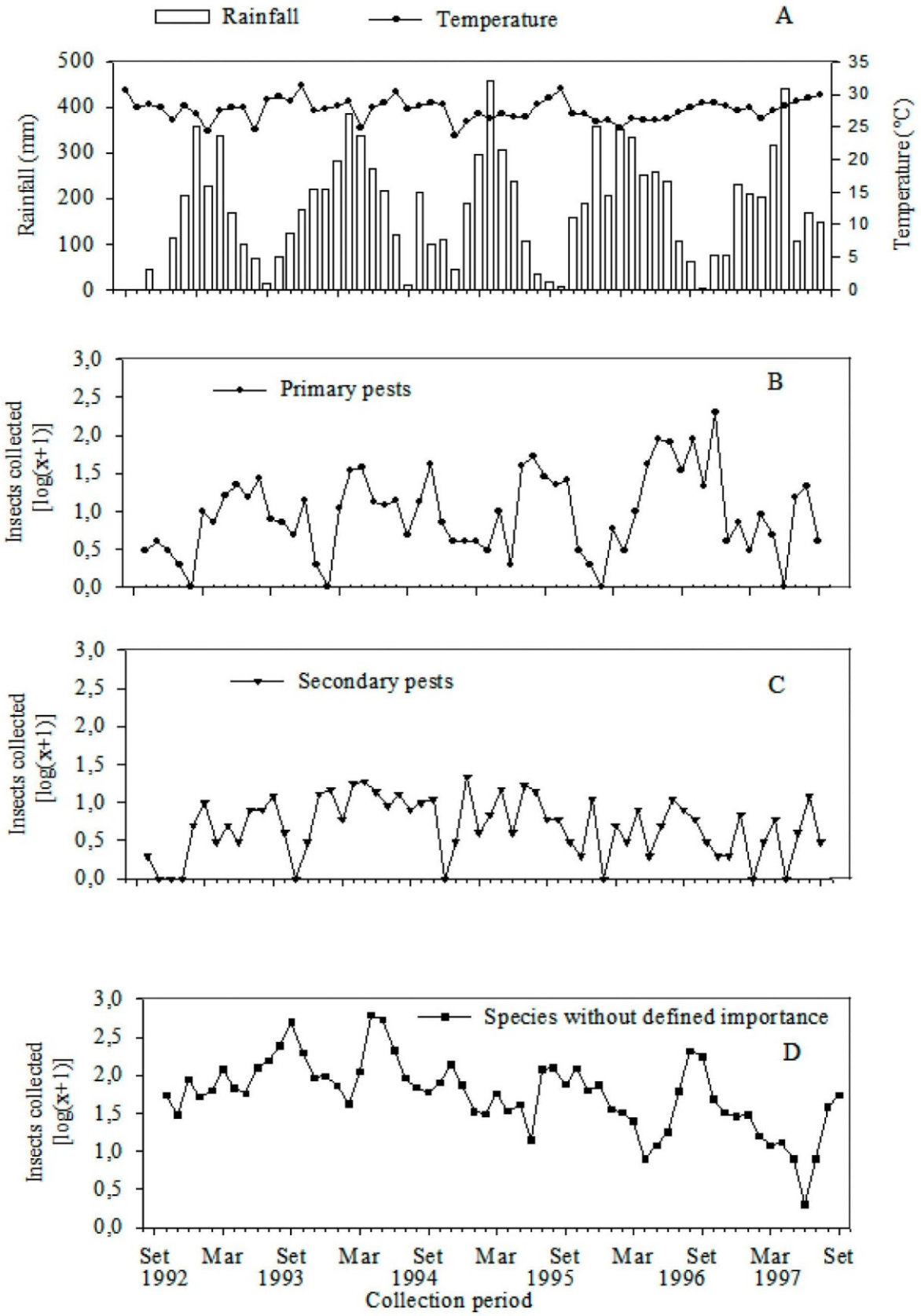


Figure 3 Rainfall (mm) and temperature (°C) (**A**), population dynamics of primary pests (**B**), secondary pests (**C**), and species with no defined importance to eucalypts (**D**) in Pacanari, Pará State, Brazil.

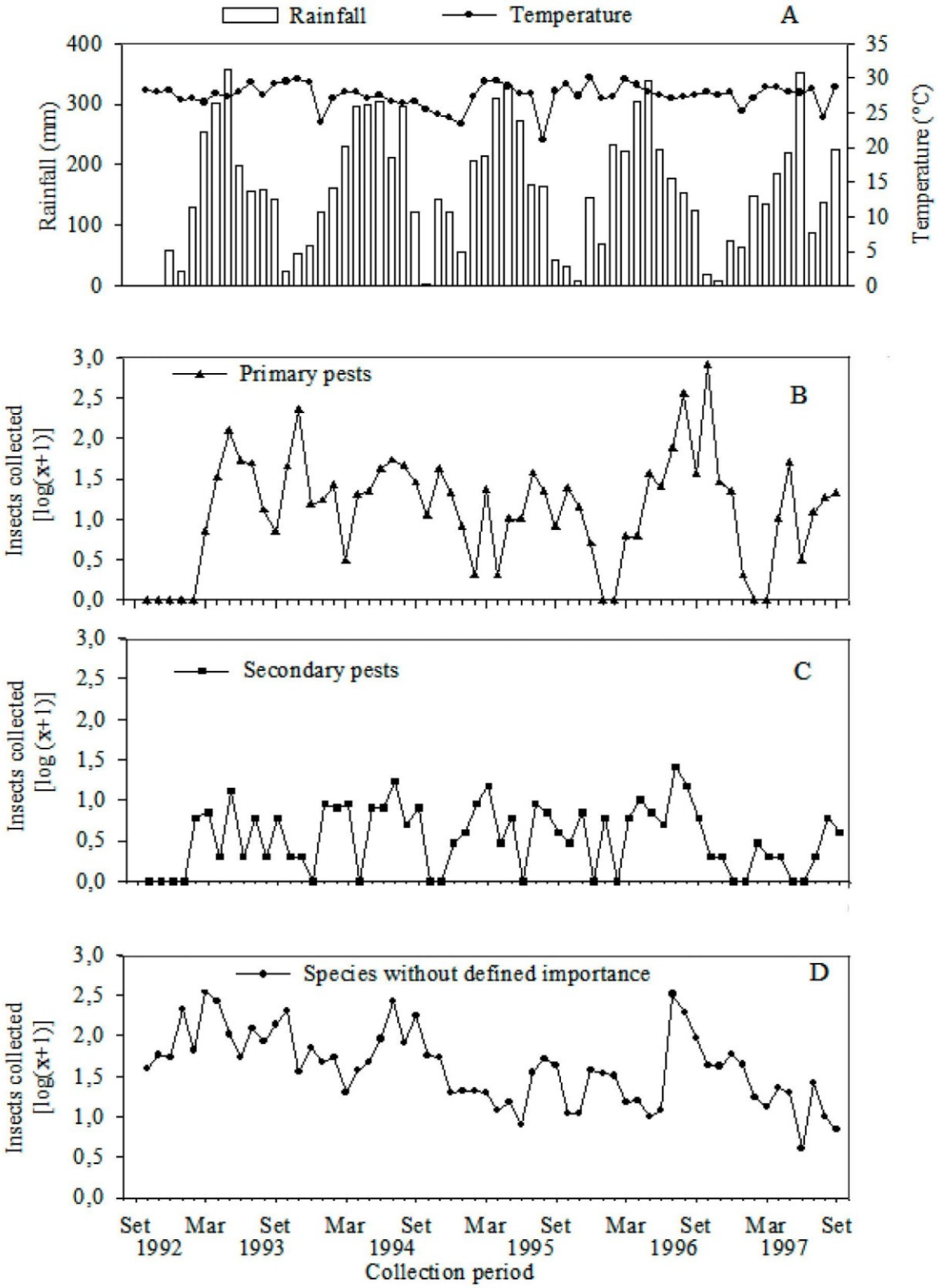


Figure 4. Rainfall (mm) and temperature (°C) (**A**), population dynamics of primary pests (**B**), secondary pests (**C**), and species with no defined importance to eucalypts (**D**) in Caracuru, Pará State, Brazil.

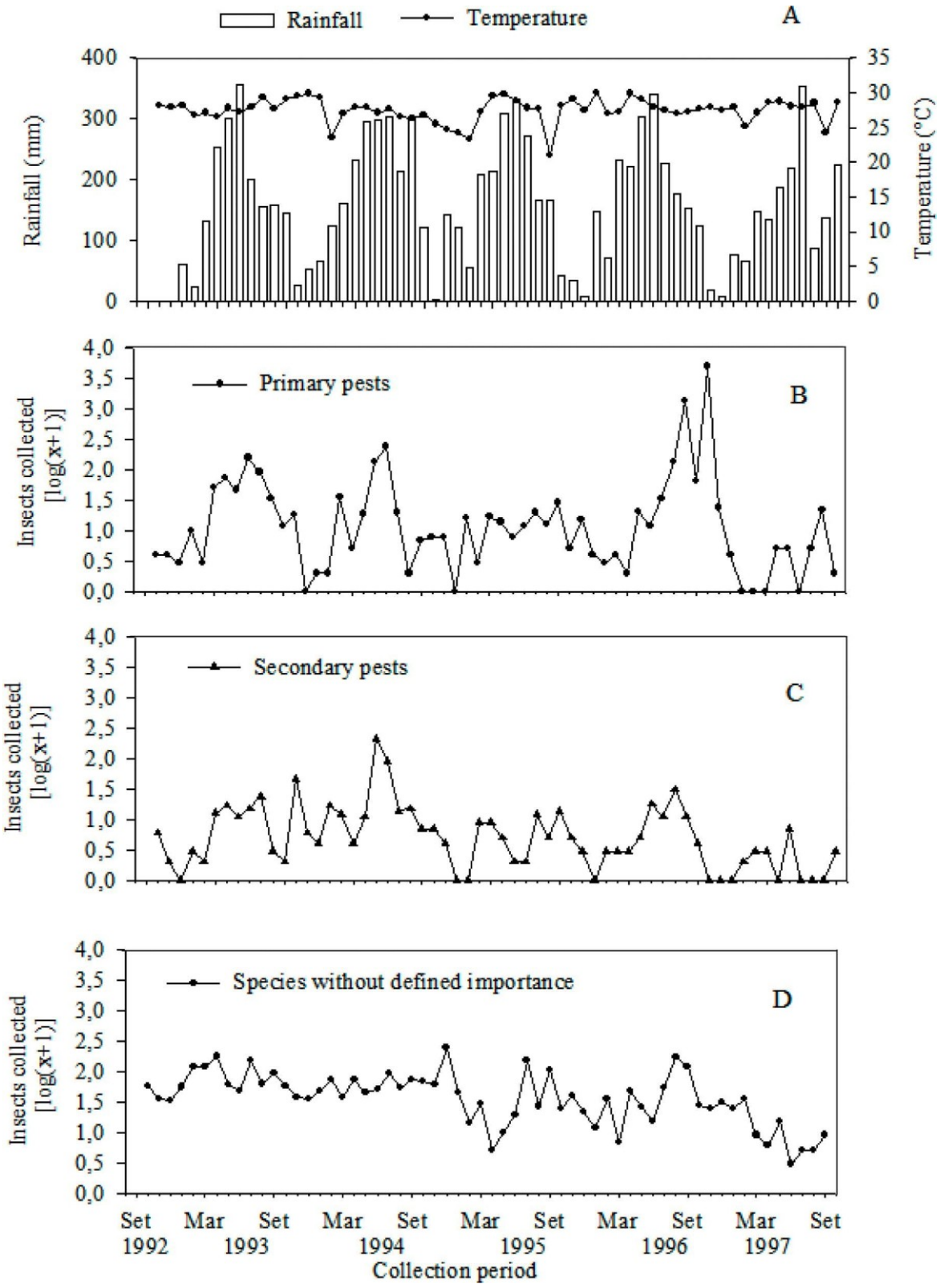
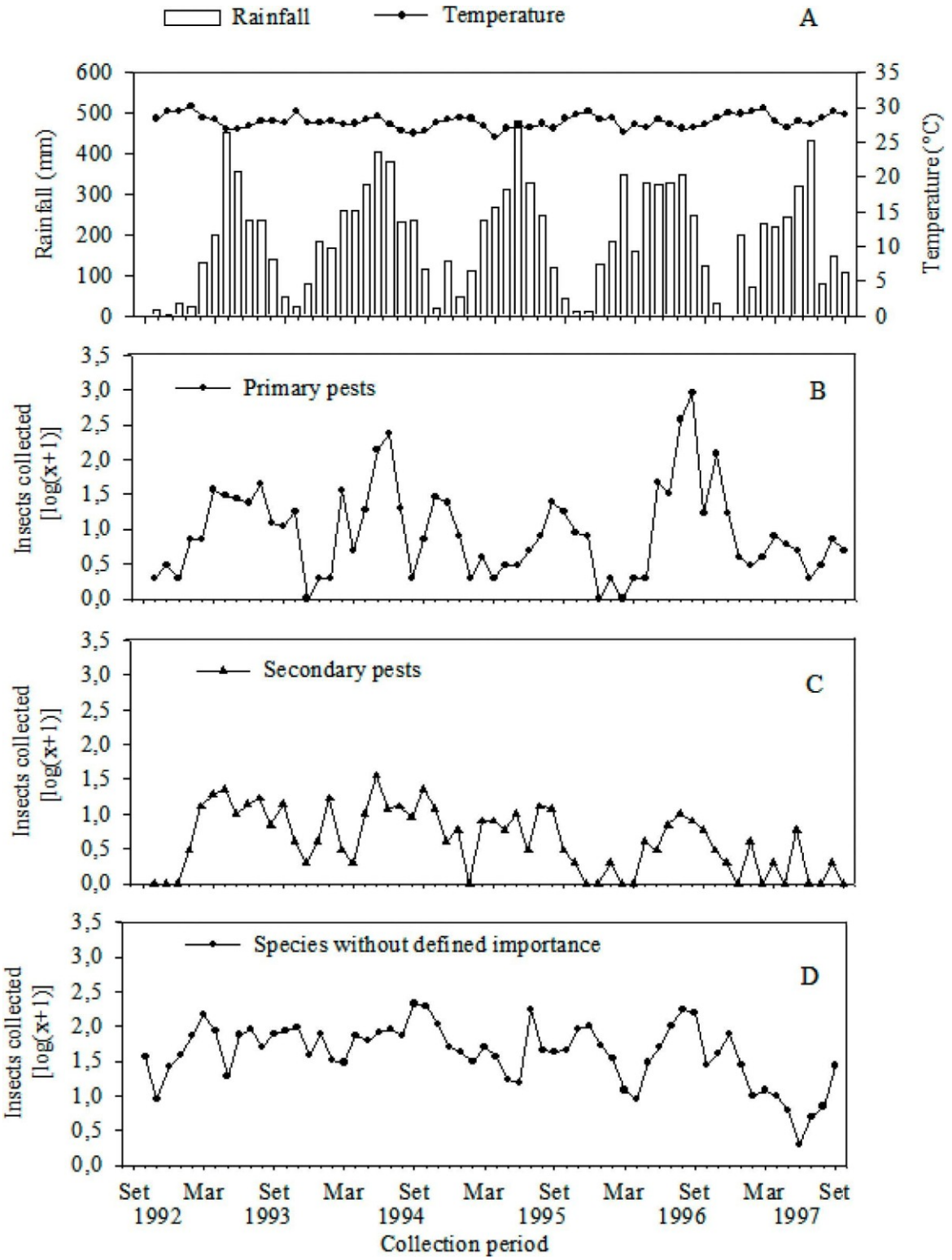


Figure 5. Rainfall (mm), temperature (°C) (**A**), population dynamics of primary pests (**B**), secondary pests (**C**), and species with no defined importance to eucalypts (**D**) in Felipe, Amapá State, Brazil.



Stenalcidia grosica and *T. arnobia* were found to be the most abundant primary pests. They were present in all the locations studied during the five-year period. The first one, abundant and frequent in other regions of Brazil [7,9,10], showed a similar trend, as the second most collected, and exceeding *T. arnobia* in some sites, suggesting that it deserves attention in monitoring. The same should be applied to *T. arnobia*, with a history of outbreaks in eucalyptus and one of the most important defoliators of this plant [9,19]. *Psorocampa denticulata* showed low abundance of occurrence. It did not occur in most years, and showed reduced frequency in the total number of individuals; however, it is one of the most frequent in other Brazilian regions [6,11,12,16] during periods of rainfall [11]. This species exhibits diapause in the pre-pupal stage and requires periods of low and high humidity to complete the cycle. The high rainfall period in the region may not be favorable for this insect.

The population peaks of group I pests were similar to those of the other areas of Brazil, usually during the drier months and with warmer temperatures when the plants may exhibit stress mainly due to water deficit [6,7,11,12,20]. Stress in the eucalyptus trees may favor the establishment of insect pests, due to lowered plant defenses [7,21].

The small number of individuals occurring in the plantations of Ponte Maria and Felipe may be related to the proximity of remnant Amazonian native forest, which favors migration of natural enemies to eucalyptus plantations to regulate the populations of these insects. This was reported for the Lepidoptera collected in *Eucalyptus cloeziana* plantations in Minas Gerais State, Brazil, near forest reserves [22].

The abundance of primary and secondary pests in Felipe and Ponte Maria showed the importance of the proximity of natural forest areas to the plantations, although with smaller areas than those of Pacanari and Caracuru, which were distant from the plantations. Fragments and corridors of native forest in eucalyptus monocultures can increase the diversity of natural enemies and reduce difficulties with the insect pests [10,23,24]. Furthermore, the distance between the plantations and natural vegetation may be more important than the reserve area, possibly because of the source of natural enemies.

Secondary pests include those registered in other regions of Brazil; however, *I. admirabilis* deserves more attention as the number of individuals of this species ranked between third and fifth place of all primary and secondary pests. These results are similar to those reported for eucalyptus plantations in Goiás and Minas Gerais States, Brazil [9,12,17].

The low abundance within species that show no defined importance to eucalypts, as in other regions of Brazil, suggests that they do not feed on the eucalyptus trees, but on plants of the understory vegetation or those near plantations [10,12].

The low variation in the number of species of groups I and II reinforces the hypothesis that some species are adapted to thrive on eucalyptus, unlike the large number of those of group III. This can be explained by the herbivore host plants present and cultural practices, such as weeding, which may restrict the food supply for the species of this group. Eucalyptus plantations normally have fewer interventions from the third or fourth years, which may favor the persistence and proliferation of natural enemies to control the insect defoliators [25].

4. Conclusions

It is important to identify the period of the highest occurrence of insects in the eucalypt plantations, especially those of groups I and II. This information will enable the development of suitable integrated pest management strategies that can reduce the costs and facilitate the monitoring and control programs of insect pests. There is a relationship between the population of Lepidoptera pests and climatic variables. The more abundant primary pests were *T. arnobia*, *S. grosica*, and *O. vesulia* that had population peaks during periods of low rainfall. As the abundance of these pests has not changed during the period of five years it is necessary to continue monitoring these areas throughout the planting cycle. Additionally, it provides information on the degree of adaptation of primary and secondary pest species and the potential of other species to become pests.

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Conflicts of Interest

The authors declare no conflict of interest.

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