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Seasonal pattern of insect abundance in the Brazilian cerrado

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Abstract In Brazil, a severe dry season lasting for approximately 5 months and frequent fires make life difficult for cerrado insects. In certain aspects, the cerrado can be considered to be an understudied ecosystem; even basic information such as knowledge about the annual peak in abundance of different insect orders is unknown. Insect abundance patterns have only been investigated for a few groups in the cerrado region. Thus, our study concerns the temporal distribution of insect abundance in the savanna-like vegetation of the central Brazilian cerrado (*sensu stricto*) in Distrito Federal. The region has a well-defined, long dry season between May and September. The insects were sampled by window, malaise tent and pitfall traps within 1 year. We used a multiple linear regression to analyse the relationship between abundance of insects of each order and climate variables. A total of 50 127 individuals from 15 orders was collected. The orders were Coleoptera (26%), Hymenoptera (23%), Diptera (20.5%), Isoptera (20%), Homoptera (4%), Lepidoptera (4%), Orthoptera (1.5%) and Hemiptera (1%). The abundance of Diptera, Homoptera, Lepidoptera and Orthoptera was randomly distributed over time, Isoptera peaked in the first half of the wet season, Coleoptera and Hemiptera in the second half of the wet season and Hymenoptera in each season. A significant correlation was found only between Coleoptera and delayed climatic variables. There were no obvious trends that might help explain the abundance patterns observed. The study provides baseline information about phenological patterns of insect abundance and permits evaluation of this group as a resource for various food chains and different trophic levels.

Key words: Coleoptera, Diptera, Hymenoptera, insect orders, malaise tent, pitfall, savanna vegetation, seasonality, window trap.

INTRODUCTION

Seasonality is a common phenomenon among insects (Wolda & Wong 1988). Insect abundance can change over time for a variety of reasons, including macroclimatic and microclimatic changes, and variation in the availability of food resources (Wolda 1988). To understand how tropical insect populations respond to seasonal variations, it is fundamental to clarify first their phenological patterns and life strategies (Braby 1995b).

Wolda (1978a,b) proposed two general hypotheses to explain the variability in abundance of tropical insects: climatic predictability and seasonal variation of food resources. The former suggests that populations should fluctuate less in areas where the climate is more predictable. The latter hypothesis implies that insect numbers should be directly related to seasonal variations in the abundance of food resources.

In tropical savannas, the difficult period for most herbivorous insects is usually the dry season, when leaves undergo a reduction in nutritional quality (Braby 1995a). For example, caterpillars of *Picnotema* sp. (Lepidoptera, Zygaenidae), which in the cerrado of Brasília use *Davilla elliptica* as a host plant, are dormant from July until October (second half of the dry season and beginning of the wet season), remaining buried in the soil among the roots of the host plants (Rodrigues 1992).

Information and data on insect abundance patterns and on the influence of climatic changes on insect communities have only been obtained for a few groups in the cerrado region (Vieira *et al.* 1996; Diniz 1997). In our paper we analyse temporal patterns in insect abundance, sampled by window, malaise tent and pitfall traps and attempt to elucidate general patterns and discuss potential factors influencing insect abundance.

METHODS

The study area lies within the Roncador Ecological Reserve (RECOR/IBGE; 47°51′W, 15°55′S), 35 km south of Brasília, in the Distrito Federal, Brazil, in an area of savanna-like vegetation (cerrado) at 1100 m a.s.l. (Fig. 1). The climate of the cerrado is seasonal, characterized by a well-defined dry season (May to

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September), when the average rainfall is 23.9 mm, the relative humidity is 58.2%, the coldest months (June and July) have an average minimum temperature of 12°C and a maximum temperature of 25°C. For the seven months of wet season, the average rainfall is 184.7 mm, the relative humidity is 75.7%, the average minimum temperature is 17°C and the average maximum temperature is 26°C (Fig. 2).

We carried out collections every 2 weeks from May 1997 to April 1998, in cerrado *sensu stricto*, a predominantly arboreal-shrub phytophysiognomy with a herbaceous stratum, 20–50% tree cover and average tree height of 3–6 m (Ribeiro & Walter 1998). A 1-ha grid was marked with 24 collection points separated by 15 m. On each monthly collection date we randomly assigned one trap to a new position. The positions remained set over the duration of the study period.

Traps used were malaise tent (bi-directional surface of 2 m^2), pitfall (20 cm^3) and window trap (80 cm × 80 cm). All samples were taken to the laboratory, where

Fig. 1. Map of South America showing Brazil (grey), Cerrado distribution (dark grey) and Distrito Federal (black box) where the study area (RECOR/IBGE) is located.

insects were removed, separated by order and counted. For the analyses, we used the total number of individuals in each order from all traps. Only data on the most abundant orders were analysed.

As the abundance of insects over time does not increase linearly, but constitutes a periodic process, we used a circular analysis (Zar 1996). We used r and s_0 to classify the distribution of abundances for each order, during the year, as random or clustered. The measure of concentration, r, can vary from 0 (the maximum dispersion) to 1 (when all data are concentrated in the same direction), and s_0 is the circular standard deviation (Zar 1996).

A multiple linear regression was used to analyse the relationship between abundance of insects of each order and the following climatic variables: maximum and minimum temperature (°C), relative humidity (%) and precipitation (mm). For the analyses we used climate variables from the month of collection (control variable) or from the month before the collection (delayed variable). The Meteorological Station at the Roncador Ecological Reserve (RECOR/IBGE) provided the climate data for the area in which insects were collected.

RESULTS

A total of 50 127 insects from 15 orders were collected. The seven least abundant orders (Collembola, Blattaria, Psocoptera, Embioptera, Thysanoptera, Neuroptera, Odonata) represented only 1% (650 individuals) of the total and were not considered further. The most abundant orders were Coleoptera (26%), Hymenoptera (23%), Diptera (20.5%), Isoptera (20%), Homoptera (4%), Lepidoptera (4%), Orthoptera (1.5%) and Hemiptera (1%). Isoptera were never caught in the malaise tent, and neither malaise nor pitfall traps caught Hemiptera. The window trap was the most efficient collection technique for the eight most abundant orders, sampling 85% (42 360 individuals) of the total number of insects.

The distribution of insect abundance during the year was random for Diptera, Homoptera, Lepidoptera

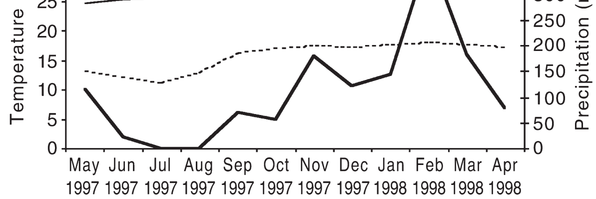

Fig. 2. Climate data for cerrado from the Meterological Station at the Roncador Ecological Reserve (RECOR/IBGE). (···), minimum temperature average; (—), maximum temperature average; (**—**), total precipitation.

and Orthoptera (Table 1). Considering the orders with clustered distributions, Isoptera peaked in the first half of the wet season, Coleoptera and Hemiptera in the second half, and Hymenoptera peaked once in each season. Within the same season, there were variations in the abundance of insects (Fig. 3).

In February, there was a decline in total insect abundance (Fig. 3). This was the month with the highest rainfall (376.9 mm). In other months of the wet season, rainfall varied between 57.2 and 182.1 mm (Fig. 2). Climatic factors showed a significant correlation only with Coleoptera (Table 2). For that order, insect abundance was positively correlated with maximum temperature and humidity of the previous month.

DISCUSSION

Each sampling technique catches only a portion of the community (Wolda & Wong 1988; Casson & Hodkinson 1991). Differences among sampling techniques reflect the fact that different taxa may be more common in certain microenvironments. In window traps, most individuals collected were from the order Coleoptera, whereas in the malaise tent, most were from the order Diptera. This was also found in tree canopies within an Australian rainforest (Basset 1988) and in a tropical lowland forest in Costa Rica (Boinski & Fowler 1989), where similar trapping methods were used.

The causes of fluctuations in insect abundance and the differences among species are still not completely understood. There are probably multiple processes, both biotic and abiotic responsible for the phenomenon.

Previous studies conducted in tropical areas have shown a similar increase in insect abundance in the wet season as seen in our study for Coleoptera, Hemiptera and Isoptera. Many tropical insects have their highest abundance in the wet season; for example, *Drosophila*

Table 1. Distribution, r (measure of concentration), s_0 (circular standard deviation) and season of abundance peak of insects from the study site

Order	Distribution	r	s_0	Season
Coleoptera	Clustered	0.424	75.042	Wet
Hemiptera	Clustered	0.376	80.116	Wet
Isoptera	Clustered	0.502	67.347	Wet
Hymenoptera	Clustered	0.181	105.932	Dry/wet
Diptera	Random	0.206	101.941	–
Homoptera	Random	0.240	96.884	–
Lepidoptera	Random	0.232	98.040	–
Orthoptera	Random	0.304	88.491	–

Table 2. Relationships between abundance of insects and climatic variables from multiple linear regression analysis

Order	r^2	F	P	Climatic variable
Coleoptera	0.344	0.916	0.504	Control
	0.691	10.080	0.005*	Delayed (maximum temperature and humidity)
Diptera	0.421	1.272	0.366	Control
	0.572	2.339	0.154	Delayed
Hemiptera	0.322	0.832	0.545	Control
	0.314	0.801	0.561	Delayed
Homoptera	0.405	1.193	0.392	Control
	0.615	2.791	0.112	Delayed
Hymenoptera	0.162	0.337	0.845	Control
	0.487	1.661	0.262	Delayed
Isoptera	0.464	1.516	0.296	Control
	0.261	0.619	0.663	Delayed
Lepidoptera	0.239	0.550	0.706	Control
	0.517	1.877	0.219	Delayed
Orthoptera	0.145	0.297	0.871	Control
	0.340	0.900	0.512	Delayed

Control, climatic variables from the month of collection; delayed, with a delayed month in relation to the collection; *significant relationship ($P < 0.05$).

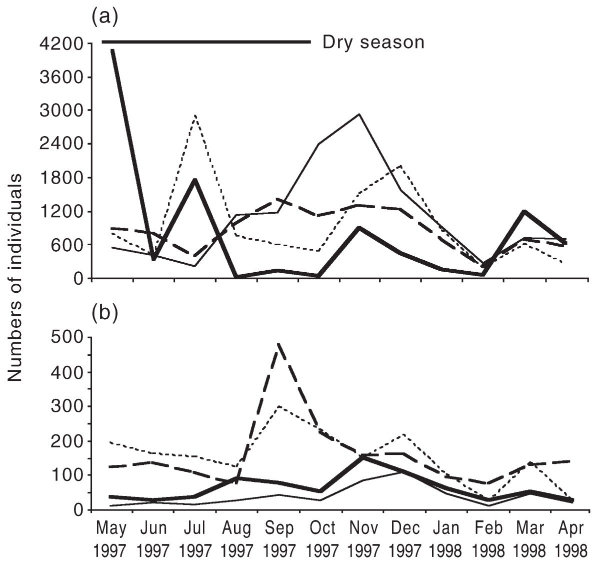

Fig. 3. Numbers of individuals of the most abundant orders collected from May 1997 to April 1998 in the study area. (a) (—), Coleoptera; (- - -), Diptera; (· · ·), Hymenoptera; (**—**), Isoptera. (b) (—), Hemiptera; (- - -), Homoptera; (· · ·), Lepidoptera; (**—**), Orthoptera.

in Brazil (Dobzhansky & Pavan 1950), tree insects in Costa Rica (Boinski & Scott 1988; Boinski & Fowler 1989), several groups of insects in Panama (Ricklefs 1975; Willis 1976; Wolda 1978a,b; Wolda & Fisk 1981; Ackerman 1983; Shelly 1988), Granada (Tanaka & Tanaka 1982), Australia (Frith & Frith 1990) and Kenya (Denlinger 1980).

In more humid tropical habitats (1500–4000 mm precipitation) than the cerrado, where sampling methods included arthropod light traps (Smythe 1982), malaise tent (Buskirk & Buskirk 1976) and sweep nets (Fodgen 1972; Janzen 1973a,b; Buskirk & Buskirk 1976), little, if any, reduction in insect abundance has been shown to occur during the dry season. A sharp reduction in the abundance of arthropods during the dry season seems to be restricted to tropical habitats that have a severe dry season (Janzen & Schoener 1968; Janzen 1973a,b; Wolda 1977). There may be several explanations for this decrease. For example, stress caused by food shortage (Janzen 1973b) or conditions unsuitable for development, which are in turn related to a series of strategies and adaptations, such as dormancy, diapause and migration (Janzen & Schoener 1968; Denlinger 1980; Wolda 1988; Braithwaite 1991).

For insects, in general, the dry season did not coincide with a sharp drop in abundance, with 22% of individuals being collected during this period. A reduction in abundance was observed during the dry season for only Coleoptera and Hemiptera (13% of the individuals were collected in the dry season for both Orders).

Conversely, several groups of insects are known to decline in number during the mid-wet season, sometimes exhibiting an abundance that is lower than that observed during the dry season (Robinson & Robinson 1970; Smythe 1974). According to Boinski and Fowler (1989), the mid-wet season presents the most stress and least amount of food for arthropods. A decrease in rainfall levels may increase the numbers and alter the composition of populations of adult Hemiptera and Homoptera species in Jamaica (Rees 1983). Total abundance of insects from the cerrado area was lowest in February, which represents the mid-wet season and is the month of greatest precipitation.

In Costa Rica, Lepidoptera differed from all other taxa, decreasing in numbers in the wet season (Boinski & Scott 1988). In the cerrado area, only Hymenoptera peaked in abundance during the dry season.

The plant species of the cerrado have a great diversity of phenological strategies, with sprouting, new leaf production, flowering and fruiting occurring in different species over the entire year (Oliveira 1998). Thus, different species of herbivorous insects peak in abundance depending upon the time that the resource they exploit is most abundant.

Each taxon could respond differently relative to the seasons, so that the effects of the wet or the dry season could be reflected in numeric responses in arthropod populations. Studies conducted in temperate areas, such as Texas, USA, demonstrated a positive correlation between the abundance of arthropods and the precipitation levels during the 2 weeks that preceded the insect peak (Dunham 1978). In the savannas of Kenya, the relationship between the rains and insect abundance was shown to be quite clear for some species, but for many other species, abundance was independently distributed relative to the rains (Denlinger 1980).

Only the abundance of Coleoptera had a significant relationship with climatic variables in our study. For the seasonality analysis, we utilized insect orders. Of course, some orders have species in different trophic levels that depend upon different food resources. In this case, the abundance of insect orders becomes difficult to predict because it can be affected by other variables. However, some similar studies have found correlations between abundance and seasonality even at this taxonomic level. In the present study we used circular analysis to examine phenological patterns, thus complicating comparisons with other studies that used other analytical techniques. We are presently developing studies at the Family level to define trophic groups and establish relationships between these groups and food resources linked to climatic factors.

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