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Spatio-Temporal Trends of Insect Communities in Southern Brazil

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Abstract: In this study, insect seasonality using Malaise traps at eight stations was investigated from abundance collections taken between August 1986 and July 1988 in four climatic regions and one transitional region of Paraná State, Southern Brazil. Temperature and humidity were also measured to represent environmental conditions at the eight stations. One station was located in the coastal region, one in the coastal mountain range, one in the first and third plateaus and three stations were located in the second plateau. All insects were counted and identified to order. Randomization-based techniques were used to assess insect abundance variation by season for the nine most abundant taxa. An Analysis of Similarity (ANOSIM) using stations and seasons as factors and a non-metric multidimensional scaling (NMDS) to assess the 2-D projection of station along axes of abundance were used to assess insect community dissimilarities. A Mantels test assessed correlations between the abundance similarity matrix and the matrix for the environmental factors. Of the most common orders, the most abundant was Diptera, followed by Hymenoptera, Lepidoptera, Collembola, Homoptera, Coleoptera, Psocoptera, Orthoptera and Hemiptera. Insect orders were generally most abundant during the spring and summer, but least abundant during the winter. Following ANOSIM analysis, station location and season best explained variations in abundance. The NMDS analysis found that the coastal station differed most from all the other stations. Humidity was positively correlated with insect abundance.

Key words: Seasonality, insect, biodiversity, climate change, malaise, Brazil

INTRODUCTION

Insects in tropical and subtropical regions exhibit seasonal variation in abundance due in part to cycles of wet and dry weather (Tauber *et al*., 1986; Ricklefs and Schluter, 1994). Patterns of insect seasonality may vary for different species and habitats. A description and understanding of insect seasonality patterns by habitat and species may provide information for conservation practices leading to maintenance of biodiversity.

Maintenance of biodiversity is a goal shared by conservationist and managers of natural resources. High biodiversity has been associated with high productivity and maintenance of key ecological services (Tillman *et al*., 1996; McCann, 2000; Apigian *et al*., 2006). Insects are a critical aspect in biodiversity studies, yet are neglected in most global conservation efforts (Kim, 1993a, b). Insect conservation is complex due to the various species distinct life-history characteristics, which may

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cause diverse responses to anthropogenic and natural phenomena. Interaction between insects and other organisms are also mostly complex and critical in ecosystem functioning. Insects play critical roles in pollination, defoliation and are prey for a suite of carnivores (Samways, 1994). Pollinator insects have recently declined in North America (Stockstad, 2007; Anderson and East, 2008) and are expected to cause economic hardship in the agricultural sector. Declines in pollinator species have also caused detrimental ecological effects, especially where the number plant species is high (Vamosi *et al*., 2005). Insects are also key in nutrient cycling (Morehouse *et al*., 2008; Stadler *et al*., 2006; Lindsay and French, 2005) and in initiating the decay of vegetation, adding to their value as conservation targets.

For long-term conservation of insect to be successful, data on population structure, dynamics, movement and insect-habitat interactions are key. Studies of insect populations have been conducted in dry forests (Bendicho-Lopez *et al*., 2006; Schoning *et al*., 2008), eucalypt forests (Andrew and Hughes, 2005; Radho-Toly *et al*., 2001), hardwood forests (Coddington *et al*., 1996) and tropical forests (Richards and Windsor, 2007; Tylianakis *et al*., 2005), mostly in developed regions and Central America. Other than tropical rainforests, few studies have been conducted in South American habitats (Marinoni and Ganho, 2003).

In South American subtropical regions, research has centered on insect ecology, distribution and pest management. Gonçalves-Avim and Fernandes (2001) found that the pattern of galling insect richness in four neotropical savannas is closely dependent on the richness of associated plant species. Spagarino *et al*. (2001) noted substantial changes in insect diversity following tree harvest of *Nothofagus* forests in south Patagonia. Insect movement has also been examined for pest species in Brazil. The southern green stink bug (*Nezara viridula*) has been found to have little gene flow among several sub-populations in the southern region of Brazil (Sosa-Gomez *et al*., 2005), adding to the importance of endemism patterns when determining conservation priorities. Similarly, in Argentina, high levels of insect endemism have been found in the arid region of Monte Desert (Roig-Juñent *et al*., 2001), pointing to the need of such studies to delineate essential areas to be considered for conservation.

In this study insect seasonality, the predictable fluctuations in the timing of life history events over a year (Wolda, 1988; Hopkins and Memmott, 2003), was examined as a function of habitat types in the southern Brazilian state of Paraná. This study may offer baseline data for further studies relating insect diversity with habitat change. Studies such as this are becoming ever more important in the face of global climate change, especially in tropical and subtropical regions, where ecological data tend to be scarce.

MATERIALS AND METHODS

Study Area

The state of Paraná has a warm temperate climate. The costal zone is separated from the interior highland by a mountain range home to a luxuriant sub-tropical flora and diverse fauna. The highland region is separated into three plateaus. The first plateau is between 850 and 1100 m and stretches to a range of inner mountains, marking the beginning of the second plateau, with an average altitude of over 1100 m. A precipitous drop in altitude to approximately 400 m marks the beginning of the third plateau, which extends westward to the state's international border, where the altitude is less than 200 m. This plateau covers over seventy percent of the state's area (Fig. 1).

Insects were collected at single stations from the coastal zone, from a transitional region between the coast and the first plateau and from the first plateau. Three additional stations were located on the second plateau and two on the third plateau (Fig. 1). The coastal station was in the Sapitanduva wildlife preserve, near the city of Antonina. Sapitanduva comprises a dense evergreen lower montane forest with a high incidence of bromeliads (Hatschbach, 1972). The area is 60 m altitude with an

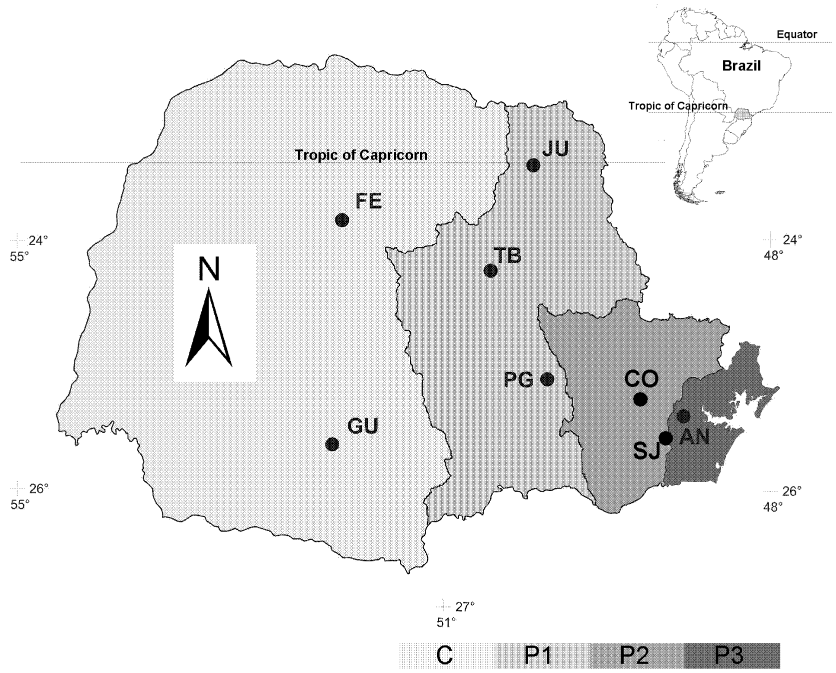

Fig. 1: Brazilian state of Paraná indicating sampling stations (AN-Antonina, SJ-São José dos Pinhais, CO-Colombo, PG-Ponta Grossa, TB-Telêmaco Borba, JU-Jundiaí do Sul, GU- Guarapuava and FE-Fênix) and geographic regions (C-coastal region, P1, P2 and P3 are, respectively, 1st, 2nd and 3rd plateaus)

average mean annual precipitation between 1900 and 2000 mm and a mean annual temperature between 20 and 21°C. According to Holdridge's life zone classification (Holdrige, 1967), the coastal station is a transition between a humid and very humid sub-tropical forest.

Transitional between the coast and the first plateau, station São José dos Pinhais was in the mountain range west of the Brazilian coast. Station São José dos Pinhais was at approximately 1000 m in a region averaging 1900 to 2000 mm annual precipitation and a mean annual temperature between 17 and 18°C. Holdrige's life zone classification for the mountain region is transitional between a humid sub-tropical lower montane forest and a very humid subtropical lower montane forest.

Station Colombo was on the first plateau at an altitude of 940 m with average annual precipitation between 1400 and 1500 mm and an annual mean temperature of 11°C. According to Holdrige's life zone classification, the first plateau is of a humid sub-tropical lower montane forest.

Stations on the second plateau were near the cities of Ponta Grossa, Telêmaco Borba and Jundiaí do Sul. The station near Ponta Grossa was in Vila Velha State Park, a mixed broad-leaf forest of predominantly *Araucaria angustifolia* in a savanna region (Veloso and Goes, 1982). The region is over 850 m altitude with a mean annual rainfall between 1500 and 1600 mm and a mean annual temperature between 16 and 17°C. According to Holdridge, the region's vegetative cover is classified as humid sub-tropical lower montane.

In Telêmaco Borba, the station was in Samuel Klabin wildlife preserve, where a mixed-type montane forest predominates (Veloso and Goes, 1982). This area is at an altitude of 750 m with a mean annual precipitation between 1300 and 1400 mm and an annual average temperature between 18 and 19°C. The region is classified as humid sub-tropical according to Holdridge's life zones.

Station Jundiaí do Sul was at the Monte Verde homestead, where the vegetation is semi-deciduous (Veloso and Goes, 1982). This station was at 500 m high with a mean annual precipitation between 1300 and 1400 mm and an annual average temperature between 21 and 22°C. According to Holdridge, the region is classified as a transitional zone between a humid sub-tropical pre-montane forest and a dry tropical pre-montane forest.

On the third plateau, the stations were near the cities of Guarapuava and Fênix. In Guarapuava, insects were collected at the Santa Clara homestead in a transitional region between a mixed-type montane forest and a semi-deciduous forest. The region averages 740 m above sea level with mean annual precipitation between 1600 and 1700 mm and a mean annual temperature between 18 and 19°C. The region's vegetation is classified as a humid sub-tropical forest according to Holdridge.

The collection in Fênix was conducted in the Vila Rica state preserve, a semi-deciduous forest (Veloso and Goes, 1982) 350 m in altitude. The preserve has a mean annual precipitation between 1400 and 1500 mm and an average annual temperature between 21 and 22°C. According to Holdridge, the area is a transition between a dry pre-montane tropical forest and a humid pre-montane tropical forest.

Collections

Data were collected for insect abundance and environmental factors from eight stations in four geographic regions and one transitional region from the state of Paraná, Brazil (Fig. 1). Insect were collected between August, 1986 and July, 1988 (Marinoni and Dutra, 1993) using a Malaise trap modified by Townes (1972) to intercept flying insects. Traps were placed in an undisturbed area with the trap guide oriented along the north-south axis and the collection vial placed at the north end. Vials were emptied once a week and insects preserved in 70% alcohol. Insects were counted and identified to order following Naumann (1973).

Temperature and humidity data were also gathered to depict environmental conditions prevailing during insect collections. Because rain data tends to be highly variable and biases abundance estimates when intense, humidity was used as an indication of precipitation. Temperature and humidity data were obtained from the Agricultural Institute of Paraná, from the Klabin Industry and from the weather center of Paraná. Data were the average between the daily maximum and minimum.

Data Analysis

Data were analyzed using univariate and multivariate methods. Univariate methods were used on the predominant orders to assess variation in abundance with time. Multivariate methods were used considering all orders captured in traps to examine relationships among stations.

Univariate data were analyzed using randomization. Randomization was used because of its robustness against heteroschedasticity (Efron and Tibshirani, 1986, 1993; DiCiccio and Efron, 1996), a characteristic of the data used in this study. To detect seasonal patterns, the difference of the mean abundance within a season and the mean abundance outside a season was calculated by sampling station averaged over time independently for all seasons. That difference was set aside and the entire data randomized to generate another difference in an identical manner, the pseudo-difference. Fifty-thousand pseudo-differences were generated to calculate significance levels. Significance levels were estimated by comparing the actual difference with the distribution of pseudo-differences. Only seasonality for the orders comprising over 1% of the total catches (excluding the over dominant Dipterans) averaged over stations and years were examined (Table 1).

Multivariate analysis was conducted to assess patterns in insect abundance by season and station and to correlate the environmental factors with insect abundance. Data were square-root transformed to down-weigh dominant species. As for the univariate analysis, randomization of data was used to generate significance levels. Data were randomized 50000 times for multivariate analyses. An analysis of similarity and its associated R statistics (ANOSIM, Clarke, 1993; Clarke *et al*., 2006) was used to assess patterns of abundance. The ANOSIM was 2-way factorial with season and station as the factors. High ANOSIM R statistics is an indication of a high factor effect. Non-metric multidimensional scaling (NMDS) was used to assess insect community separation according to stations. For abundance data, the Bray-Curtis similarity index was used and for the environmental data, Euclidean distances were used. To estimate environmental patterns on insect seasonality, a Mantels test was used to correlate abundance with temperature and with humidity by station averaged over seasons.

RESULTS

Dipterans were the most abundant order collected (Table 1) and were consistently most abundant at every station visited. Hymenopterans, Lepidopterans, Coleopterans, Homopterans and Collembolans were the next most abundant orders throughout all stations. Orthopterans, Psocopterans and Hemipterans were the third group in abundance. All other 12 orders were of marginal importance over all stations (Table 1).

The station Antonina had the highest abundance for the orders Thysanura and Strepsiptera. Station Fênix produced the most Dermaptera, station Ponta Grossa produced the most Psocoptera and station Telêmaco Borba ranked first for Collembola. Station Jundiaí do Sul had the highest abundance for Ephemeroptera, Orthoptera, Isoptera, Embioptera, Hemiptera, Homoptera, Neuroptera, Coleoptera, Tricoptera, Lepidoptera, Diptera and Hymenoptera. Stations Guarapuava, São José dos Pinhais and Colombo did not rank first in abundance for any insect order (Table 1).

Univariate data indicated that season had a strong effect in all orders assessed. The effect for season, however, was not uniform across all orders. The Coleopterans, Homopterans, Hymenopterans, Lepidopterans and Orthopterans showed reduced numbers for most stations in the fall and winter. Those same insect orders, except for the Orthopterans, showed elevated numbers for most stations in the spring. Dipteran season for low abundance was mostly restricted to the fall and the season of high abundance was mostly in the spring. Collembolans, Hemipterans and Psocopterans had a more irregular pattern of abundance by season and station (Table 2).

The ANOSIM test indicated a strong effect for both season and station ($R = 0.7$, $p<0.01$ for both factors), indicating a varying pattern of insect abundance according to time and location when including all orders. Stations and seasons separated fairly well in 2-D following MDS analysis. The Antonina station separated the most from among the other stations (Fig. 2). The low stress value for the MDS was an indication of the high confidence of the observed station separation.

Environmental data from stations Antonina, Colombo, Guarapuava and São José dos Pinhais showed high humidity and little seasonality. The remaining stations had lower humidity in the winter and spring compared with the summer and fall. Temperatures followed seasonal norms for all stations. Among all stations, Colombo consistently had the lowest temperatures during all seasons. Correlation between humidity and insect abundance patterns by station and season following a Mantels test was strong ($R^2 = 0.47$, $p = 0.024$). There was no correlation between temperature and abundance following a Mantels test ($R^2 = -0.05$, $p = 0.520$).

Table 1: Insect mean abundance ± standard error of the average over 1986-88 by taxonomic order and location

	Station								
Orders	AN	CO	SJ	FE	JU	GU	PG	TB	Totals
Diptera*	783.4±58.57	350.9±28.68	651.3±115.49	1111.0±113.87	3821.9±338.52	588.4±47.99	3438.2±240.10	1036.5±92.38	840543
Hymenoptera*	75.0±11.74	50.2±6.880	31.2±6.1400	115.8±12.780	377.7±27.990	55.6±5.590	223.3±16.660	146.7±16.19	73030
Lepidoptera*	32.3±2.220	50.1±4.410	37.2±4.8100	91.7±10.870	393.3±54.910	69.8±5.270	128.7±9.7100	38.7±3.500	54793
Collembola*	48.2±5.460	12.0±1.220	81.9±10.650	11.8±2.7200	87.1±11.260	20.6±1.700	21.1±1.8800	195.0±28.55	30553
Homoptera*	32.4±2.320	7.8±0.900	26.0±3.9900	128.5±17.000	175.8±24.510	12.5±1.390	58.7±5.1400	34.1±4.400	29062
Coleoptera*	35.0±2.410	24.6±2.730	26.2±5.3400	37.4±5.4400	120.6±12.300	23.4±2.250	93.5±7.4900	47.8±6.490	28172
Psocoptera*	4.5±0.550	3.8±0.610	2.1±0.3100	13.2±1.3200	14.7±1.5700	7.1±0.660	15.2±1.6300	8.8±0.990	4931
Orthoptera*	3.4±0.370	2.1±0.350	7.8±2.3300	3.3±0.4600	8.0±1.6600	2.6±0.330	4.0±0.4800	1.9±0.390	2102
Hemiptera*	1.8±0.330	0.7±0.150	1.0±0.2200	3.7±0.5600	15.1±5.3500	2.0±0.230	2.5±0.2800	2.8±0.390	1823
Neuroptera	0.5±0.140	0.2±0.060	0.3±0.0900	0.7±0.1800	4.8±3.0400	0.3±0.060	0.5±0.2300	0.2±0.110	436
Isoptera	0.6±0.210	<0.1±0.030	0.3±0.1900	0.4±0.2700	2.6±1.1400	1.1±0.470	0.3±0.0800	0.2±0.060	363
Tricoptera	0.2±0.060	<0.1±0.020	0.2±0.1100	0.3±0.2600	3.8±0.7900	0.6±0.180	<0.1±0.0200	0.3±0.080	334
Dermaptera	0.2±0.060	<0.1±0.000	<0.1±0.0200	1.0±0.3300	<0.1±0.0300	0.5±0.280	<0.1±0.0300	<0.1±0.010	128
Thysanoptera	<0.1±0.030	0.1±0.080	0.3±0.2600	0.1±0.0700	1.0±0.4600	0.1±0.030	0.2±0.0500	<0.1±0.000	115
Thysanura	0.7±0.150	0.3±0.120	0.6±0.1500	<0.1±0.0000	<0.1±0.0000	<0.1±0.030	<0.1±0.0100	<0.1±0.010	95
Ephemeroptera		<0.1±0.000	<0.1±0.0000	<0.1±0.0400	0.5±0.2000	<0.1±0.020	<0.1±0.0100	<0.1±0.020	42
Strepsiptera	0.4±0.120	<0.1±0.040	<0.1±0.0300	<0.1±0.0200	<0.1±0.0200	<0.1±0.010	<0.1±0.0300	<0.1±0.010	36
Embioptera	<0.1±0.000	<0.1±0.000	<0.1±0.0000	0.2±0.0700	0.3±0.0700	<0.1±0.030	<0.1±0.0000	<0.1±0.010	28
Plecoptera	<0.1±0.040	<0.1±0.020	<0.1±0.0000	<0.1±0.0200	<0.1±0.0000	<0.1±0.010	<0.1±0.0100	<0.1±0.020	11
Odonata		<0.1±0.030	<0.1±0.0000	<0.1±0.0300	<0.1±0.0000	<0.1±0.030	<0.1±0.0100	<0.1±0.000	9

*Orders included in univariate analysis, Sampling locations are the stations Antonina (AN), Colombo (CO), São José dos Pinhais (SJ), Fenix (FE), Jundiaí do Sul (JU), Guarapuava (GU), Ponta Grossa (PG) and Telêmaco borba (TB) used in collections in the state of Paraná, Brazil. Last column indicates total collection over entire study

Table 2: Univariate analysis for insect abundance patterns. Numbers outside parenthesis are differences between average abundance within season and average abundance outside season. Averages are over 1986-88

	Orders								
Seasons	Coleoptera	Collembola	Diptera	Hemiptera	Homoptera	Hymenoptera	Lepidoptera	Orthoptera	Psocoptera
Winter									
AN	-12.08 (0.02)	43.50 (0.00)	-48.14 (0.73)	1.57 (0.06)	-16.77 (0.00)	-37.26 (0.01)	-12.47 (0.01)	1.77 (0.03)	1.73 (0.23)
SJ	-10.44 (0.07)	-1.54 (0.46)	94.14 (0.35)	-0.43 (0.14)	-4.75 (0.09)	-26.26 (0.09)	-20.29 (0.05)	-2.58 (0.02)	3.34 (0.37)
CO	-12.58 (0.09)	5.98 (0.58)	-154.12 (0.15)	1.96 (0.14)	55.08 (0.00)	-84.14 (0.06)	10.27 (0.03)	-1.57 (0.00)	-2.90 (0.02)
PG	-11.80 (0.00)	-16.05 (0.33)	-87.89 (0.00)	0.62 (0.00)	-9.93 (0.00)	-25.12 (0.00)	-39.11 (0.00)	-2.82 (0.00)	-1.25 (0.16)
GU	-50.33 (0.01)	24.38 (0.00)	-1 563.78 (0.42)	22.11 (0.26)	-34.78 (0.00)	-139.60 (0.03)	-313.15 (0.00)	-8.75 (0.00)	11.54 (0.40)
TB	-78.36 (0.00)	-4.29 (0.23)	-2 198.68 (0.28)	-2.13 (0.03)	-42.23 (0.00)	-120.23 (0.00)	-59.01 (0.06)	-4.87 (0.01)	-5.03 (0.80)
JU	-18.87 (0.07)	-18.46 (0.35)	-247.14 (0.03)	-0.61 (0.07)	-14.22 (0.55)	-20.98 (0.02)	-20.13 (0.00)	-7.12 (0.00)	0.67 (0.00)
FE	-37.43 (0.29)	-76.03 (0.36)	-212.41 (0.57)	-1.66 (0.15)	-24.80 (0.16)	-100.28 (0.00)	-14.08 (0.69)	-1.85 (0.09)	-0.57 (0.31)
Spring									
AN	16.52 (0.00)	-18.62 (0.12)	-272.27 (0.02)	-0.67 (0.34)	-3.43 (0.51)	3.84 (0.54)	4.60 (0.37)	-0.80 (0.30)	1.04 (0.45)
SJ	18.44 (0.01)	0.54 (0.92)	147.69 (0.00)	0.26 (0.83)	7.31 (0.00)	43.95 (0.00)	27.23 (0.00)	1.72 (0.37)	1.74 (0.12)
CO	61.31 (0.01)	15.18 (0.83)	1 184.03 (0.03)	2.23 (0.98)	70.67 (0.00)	68.72 (0.01)	56.28 (0.01)	1.87 (0.05)	6.00 (0.23)
PG	34.28 (0.00)	11.73 (0.01)	421.51 (0.03)	0.74 (0.69)	13.95 (0.00)	64.95 (0.02)	45.49 (0.07)	3.76 (0.17)	8.78 (0.00)
GU	153.10 (0.00)	98.62 (0.00)	3 238.69 (0.00)	0.26 (0.20)	200.72 (0.00)	318.72 (0.00)	486.00 (0.00)	16.77 (0.00)	-1.87 (0.00)
TB	77.69 (0.00)	-9.94 (0.00)	1 230.50 (0.00)	0.26 (0.00)	89.26 (0.00)	90.10 (0.00)	40.72 (0.00)	1.58 (0.00)	12.45 (0.00)
JU	34.94 (0.00)	-4.00 (0.00)	754.06 (0.00)	-0.13 (0.51)	39.09 (0.00)	45.05 (0.00)	47.58 (0.00)	7.18 (0.00)	1.23 (0.62)
FE	73.28 (0.00)	210.07 (0.03)	780.89 (0.00)	3.64 (0.10)	39.29 (0.09)	155.19 (0.03)	33.80 (0.03)	2.67 (0.11)	8.91 (0.05)
Summer									
AN	6.91 (0.23)	-41.21 (0.00)	19.67 (0.83)	-1.03 (0.07)	7.46 (0.18)	-13.16 (0.87)	-1.14 (0.85)	-0.45 (0.58)	-2.32 (0.02)
SJ	15.20 (0.33)	3.82 (0.05)	35.85 (0.52)	0.64 (0.50)	1.42 (0.49)	32.36 (0.64)	15.34 (0.87)	2.80 (0.31)	-1.21 (0.04)
CO	-18.08 (0.03)	-11.83 (0.20)	-368.42 (0.60)	-1.90 (0.12)	-7.85 (0.50)	75.17 (0.07)	21.28 (0.15)	1.03 (0.00)	-2.53 (0.39)
PG	1.20 (0.00)	7.20 (0.04)	176.49 (0.00)	-0.13 (0.00)	9.80 (0.94)	8.59 (0.00)	41.20 (0.00)	1.81 (0.00)	-1.49 (0.56)
GU	-15.56 (0.79)	-29.18 (0.09)	939.59 (0.12)	-13.62 (0.80)	-13.34 (0.01)	-31.93 (0.50)	98.45 (0.00)	1.25 (0.03)	-9.48 (0.35)
TB	83.20 (0.39)	9.72 (0.54)	3 434.88 (0.78)	1.90 (0.31)	-1.35 (0.81)	183.83 (0.32)	116.42 (0.84)	7.52 (0.77)	-2.38 (0.00)
JU	13.33 (0.59)	54.60 (0.28)	169.12 (0.25)	0.38 (0.00)	-6.68 (0.86)	6.53 (0.64)	1.30 (0.43)	8.00 (0.73)	-1.32 (0.00)
FE	-15.20 (0.14)	-51.65 (0.00)	-74.19 (0.17)	-1.03 (0.13)	1.69 (0.89)	41.08 (0.02)	-2.15 (0.40)	0.27 (0.37)	-7.76 (0.41)
Fall									
AN	-10.57 (0.04)	11.07 (0.42)	321.90 (0.02)	-0.66 (0.92)	15.13 (0.00)	49.51 (0.18)	10.00 (0.05)	-0.69 (0.41)	-0.82 (0.54)
SJ	-21.87 (0.00)	-2.54 (0.10)	-280.41 (0.00)	-0.18 (0.51)	-3.67 (0.03)	-47.03 (0.00)	-20.46 (0.00)	-1.67 (0.01)	-4.10 (0.38)
CO	-31.00 (0.00)	-10.26 (0.37)	-673.51 (0.00)	-2.49 (0.55)	-121.03 (0.05)	-51.59 (0.00)	-87.21 (0.04)	-1.21 (0.01)	-0.56 (0.00)
PG	-22.75 (0.00)	-2.04 (0.26)	-486.28 (0.00)	-1.23 (0.84)	-12.73 (0.00)	-46.18 (0.00)	-43.31 (0.00)	-2.52 (0.00)	-5.95 (0.18)
GU	-85.56 (0.00)	-96.56 (0.59)	-2 487.36 (0.00)	-10.33 (0.01)	-151.59 (0.00)	-142.00 (0.00)	-250.62 (0.00)	-8.77 (0.00)	-1.26 (0.00)
TB	-74.26 (0.00)	5.01 (0.02)	-2 173.82 (0.00)	0.12 (0.02)	-43.58 (0.01)	-137.43 (0.00)	-88.23 (0.00)	-3.61 (0.07)	-4.92 (0.04)
JU	-28.46 (0.00)	-31.22 (0.00)	-663.69 (0.00)	0.38 (0.12)	-17.48 (0.00)	-29.55 (0.02)	-27.74 (0.01)	-7.70 (0.00)	-0.61 (0.74)
FE	-39.28 (0.00)	-149.59 (0.02)	-766.80 (0.00)	-1.99 (0.03)	-23.55 (0.00)	-122.08 (0.06)	-27.22 (0.00)	-1.52 (0.23)	-4.91 (0.86)

Numbers in parenthesis are p-values. Sampling locations are Antonina (AN), Colombo (CO), São José dos Pinhais (SJ), Fenix (FE), Jundiaí do Sul (JU), Guarapuava (GU), Ponta Grossa (PG) and Telêmaco borba (TB)

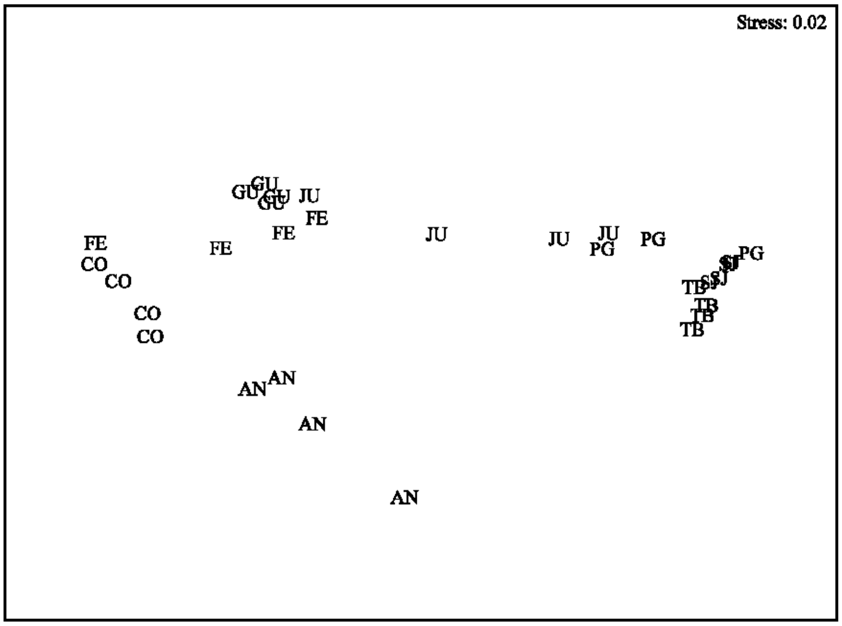

Fig. 2: Multidimensional scaling 2-D projections of stations on insect abundance patterns by seasons. Stations are AN-Antonina, SJ-São José dos Pinhais, CO-Colombo, PG-Ponta Grossa, TB -Telêmaco Borba, JU-Jundiaí do Sul, GU-Guarapuava and FE-Fênix

DISCUSSION

Overall results of this study indicate a strong seasonality for the dominant insect orders. Most insects were abundant in the spring and summer and were in reduced numbers in the winter. Diptera was the only order that indicated a retracted period of high abundance, namely only in the spring. Seasonality was also a strong function of location. These results indicate that patterns in population dynamics of insects in the sub-tropical region of Brazil may be more localized. Another strong indication of localized patterns of population dynamics are the results for the analysis including all orders. The good separation of MDS plots and the highly significant ANOSIM analysis further strengthens the support for localized patterns of insect abundance dynamics.

Analytical techniques based on higher taxonomic levels have the potential to mask important ecological dynamics, but also have the advantage of facilitating identification of organisms. Misidentifications at the genus or species level may be a source of misleading results and be counter-effective for conservation practices or provide baseline data conducive to misinterpretations of historical ecological patterns. Use of multiple taxonomic groups in ecological pattern assessment may be preferred, but the logistical hindrance of sorting through the vast number of organisms may make the task impractical and error prone. Alternatively, identification to higher taxonomic levels may require less training and make datasets based on them more readily obtained. Due to the inherent bias from insect sampling gears (Liburd *et al*., 2001; Leather, 2005), use of multiple gears and methods may provide a more faithful representation of the insect community. The justification for using multiple gears is further supported by the advantage in speed and accuracy of identification when using higher taxonomic levels and the minimization from sampling gear selectivity biases.

Most sampling gears used in ecological experiments are selective (Leather, 2005). Malaise traps are no exception (Krcmar and Durbesic, 2000), in that they select for flying insects and against ground dwellers (Kerr *et al*., 2000; Campbell and Hanula, 2007). To obtain a representative sample of community structure within a habitat, one may use multiple sampling gears or estimate gear selectivity factors for a particular gear by engaging in some sort of destructive sampling. The goal of this study was not to produce absolute estimates of abundance or describe the entire community present at stations, but provide a relative comparison among habitats and an indication of patterns in abundance, especially for flying insects.

Insect abundance dynamics may be driven by genetic factors, food availability, or biotic and abiotic environmental factors (Tauber *et al*., 1986; Samways, 1994). Present analysis of the influence of temperature did not explain the patterns of fluctuation in abundance. Humidity, however, correlated well with abundance by station averaged over seasons, indicating that seasonality may be strongly influenced by environmental factors related with precipitation. Moreover, the MDS results show that the coastal station separated most from all others. The coastal region did not rank the highest in humidity, indicating that other factors may be additional drivers of insect abundance dynamics.

Humidity was an important component in this study in explaining insect abundance seasonality and may have key implications for insect conservation and maintenance of biodiversity. Global climate change predicts that precipitation patterns will be affected differently in different areas of the globe (Wang, 2005; Burke *et al*., 2006). Mean precipitation is expected to decrease in the subtropics (Wang, 2005; Solomon *et al*., 2007) suggesting that the study area will become less humid. Climate models also predict that precipitation intensity (amount of rain per event) will also increase (Kharin and Zwiers, 2005; Meehl *et al*., 2005; Barnett *et al*., 2006). Additionally, precipitation extremes are projected to increase more rapidly than the increase in the mean (Kharin and Zwiers, 2005) indicating that more erratic precipitation patterns will be common. If predictions come to fruition, insect patterns of abundance and biodiversity would be drastically affected. Insect abundance may more strongly respond to the extremes, rather than to mean changes of precipitation, placing a stronger importance on the description of currently prevailing conditions for assessing and possibly predicting changes in insect abundance. Knowledge of current conditions of insect abundance dynamics coupled with continued monitoring of shifting patterns in habitat will allow for more effective remedial conservation practices.

Insects have been extensively used as sentinels for habitat degradation and faunal diversity changes (Kerr *et al*., 2000; Rainio and Niemela, 2003; Andersen *et al*., 2002, 2004; Hodkinson, 2005; Nelson, 2007), because they usually have short life cycles, are abundant and ubiquitous and are many times critical in ecological processes (Samways, 1994). Due to its widespread and ubiquitous occurrence, insects may also be used to infer changes in aquatic environments (Harper and Everard, 1998; Hodkinson, 2005). Aquatic insects have narrow thermal tolerances that vary by species and developmental stage (Samways, 1994). Insects, therefore, are good candidates for detecting short-term changes in environmental conditions and enable resource managers and conservationist to take proactive actions toward mitigating conservation practices for a suite of habitats.

CONCLUSIONS

Insects were analyzed at an intermediate taxonomic level and the existence of a site-specific seasonality pattern related with an environmental component was identified. The results indicate that major environmental factors have an effect through taxonomic levels beyond genus and species. With the increasing need for data to assess habitat degradation, especially for acquiring baseline information, study programs such as this may become more widespread and contribute critical ecological information in an increasingly changing habitat. The establishment of monitoring programs that use a variety of complementary gears and involve multiple agencies, non-governmental organizations and academia will produce spatially wide and temporally broad datasets that provide critical information on insect dynamics. This is vital information for regions of the globe where data is lacking, but habitat changes are commonly the most dramatic and costly.

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