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Monthly variation of leaf litter Collembola in the tropical rainforest of Los Tuxtlas, Veracruz, Mexico

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Abstract

In order to evaluate leaf litter Collembola at the tropical rainforest of Los Tuxtlas, Veracruz, México, fifteen pitfall traps were activated monthly for about one week, in a new experimental area during 2015. A total of 4,291 specimens were captured in the 180 samples collected. Ten families were recorded, those better represented were Paronellidae (27 %), Neanuridae (20.5 %), Entomobryidae (16.9 %), Dicyrtomidae (15 %), and Isotomidae (11.6 %). Among the 32 genera reported, most abundant were *Trogolaphysa* (18 %), *Ptenothrix* (13 %), *Isotoma* (10 %), *Neotropiella* (10 %) and *Pseudachorutes* (10 %). Results were compared with three other similar studies carried out in two different localities from Mexico: Huitepec, Chiapas, and Tlayacapan, Morelos and one other from Nicaragua: Moropotente. Each of these localities has different weather patterns and type of vegetation. Los Tuxtlas showed a moderate similarity with Huitepec, and less with Tlayacapan, and a very low similarity with Moropotente. Our study found that the abundance of individuals in the four most important families in Los Tuxtlas was much less than those reported for other similar studies.

Keywords Springtails | pitfall traps | seasonal variation | abundance

1. Introduction

Collembola, or springtails, are present in large numbers in different environments, being the second most important group of litter arthropods (after mites) and at times the foremost, with a great importance in ecosystem ecology (Hopkin 1997). Some sampling techniques, such as pitfall traps (Palacios-Vargas & Mejía-Recamier 2007a) are convenient for catching small soil arthropods like Collembola and are very efficient for epiedaphic families such as Entomobryidae, Sminthuridae, Paronellidae and Isotomidae. These families can be collected in large quantities within a short time period with this method but for others, like Odontellidae and Brachystomellidae they usually are less efficient. Moreover, in the case of euedaphic families as Onychiuridae and Tullbergiidae they are useless. On the other hand, necrotraps (pitfall traps with bait made made of decomposing animal fragments) have also been found to be efficient in the sampling of the epiedaphic fauna, but the presence or type of bait has not yet been evaluated (Terrón-Sierra & Palacios-Vargas 1991).

Therefore, pitfall traps are ideal for sampling Collembola, which due to their small size and agility are very difficult to collect. Since a large volume of specimens can be collected by this technique, several

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new species (Palacios-Vargas & Mejía-Madrid 2011, Palacios-Vargas & Montejo-Cruz 2011) have been described in recent studies in Nicaragua, as well as new genera (Dias da Silva et al. 2015) from Brazil which otherwise would have been difficult to obtain. Furthermore, some species of rare genera from the tropics have been described exclusively due to this latter methodology (Palacios-Vargas 2007). Pitfall traps also have been used in the assessment of springtail fauna found in agricultural soils (Flores-Pardavé et al. 2011) in Mexico.

Previous studies have been carried out in several localities in Mexico (Díaz Gómez 1999, Palacios-Vargas & Mejía-Recamier 2007a) and other countries (Pérez Miguel 2015) using pitfall traps to evaluate the springtails community in different landscapes. To our knowledge, this is the first study of this type in the tropical rainforest of Los Tuxtlas, Veracruz.

The first published inventory on this fauna from Veracruz was carried out by Hepburn & Ross (1964) who reported 18 species from litter samples. Recently, a comprehensive revision of this group was carried out by Palacios-Vargas (2003), which documented 48 species in Los Tuxtlas region and 150 species for the State of Veracruz, from which only 18 are from the Tropical Biology Field Station (Palacios-Vargas 2013).

The main objective of this study was to document the leaf litter Collembola assemblage using pitfall traps placed in the tropical rainforest of Los Tuxtlas for one year to determine seasonal and monthly fluctuations of abundance and to compare these results with similar studies from other localities.

This study is part of a larger project: 'Ecología de Microartrópodos de la selva de Los Tuxtlas, Veracruz' which will compare arthropods found in litter to those of soil and canopy, in order to understand their importance in the energetic flow in this ecosystem, as well as their adaptation to this type of vegetation.

2. Materials and methods

2.1 Study area (Fig. 1)

The Los Tuxtlas region is located on the coastal plain of the Gulf of Mexico in the southern portion of the State of Veracruz. The region is 80 km long in a northwest-southeast direction and 50 km wide in some parts for a total extension of nearly 3,300 km^2 (329.941 ha). A peculiarity of this region is that it is completely isolated from any other mountain range and is an area with a high annual precipitation. Regional average annual rainfall is between 1,500 and 4,500 mm and average annual temperatures range between 8°C and 36°C (Guevara et al. 2006).

This study was carried out in an area of mature high evergreen rainforest of the Los Tuxtlas Tropical Biology Field Station at 18°35'06" North latitude and 94°4'29" West longitude and 180 m above sea level, owned and operated by the Institute of Biology of the National Autonomous University of Mexico (UNAM).

2.2 Vegetation

The Los Tuxtlas region, is one of the most diverse regions in Mexico, and has an extraordinary complex mixture of vegetation covering mountainous and coastal areas. It is the northern limit of tropical rainforest in the Americas. Although the dominant ecosystem is tropical rainforest, this is mixed with other vegetation types in the surroundings of the Los Tuxtlas Tropical Biology Station. In general, the region holds high evergreen, medium or low evergreen rainforest, cloud forest, oak forest, pine forest, savannah, dunes, areas of secondary vegetation (acahual) and grassland. An important part of its flora and fauna are shared with areas to the south into Central America and South America (Álvarez et al. 2016). However, the natural vegetation in the region has been severely depleted with estimates of only 5.4% of the original vegetation remaining. Despite this, the region is still home to 3,356 species of vascular plants, half the total for the state of Veracruz, and includes over 400 species of trees (Sosa & Gómez-Pompa 1994).

2.3 Methods

A one-hectare plot (100 m × 100 m) was established in an undisturbed area of rainforest, approximately 2 km from the installations of the Los Tuxtlas Biological Field Station. The terrain has a slightly abrupt and irregular slope. The plot was divided into 25 quadrants of 20 m × 20 m. Five equidistant traps (every 20 m) were placed along three 100 m transects at the top, middle and bottom of the main study plot. Monthly, during 2015 we placed 15 pitfall traps with a 75% alcohol preservative along these transects.

The traps were operated in the field for five days each month, in order to maximize the capture of Collembola. All springtails collected were preserved in 75 ml bottles and then transported to the Laboratorio de Ecología y Sistemática de Microartrópodos of the Faculty of Sciences, UNAM for further examination.

Springtails from each trap were separated and counted.

Additionally, approximately 50% of the specimens were prepared under slide covers for identification to genus level, following the technique described by Palacios-Vargas & Mejia-Recamier (2007b). All the specimens were grouped into genera for data analysis.

Monthly temperature and rainfall data for 2015 were obtained from the database of the Los Tuxtlas Tropical Biology Station. Measurements were taken using the model Vantage Pro 2 by Davis Instruments, U.S.A.

Results were compared with three other similar studies carried out in two different localities from Mexico: Huitepec, Chiapas (with monthly collections of 9 pitfall traps, from August 1988 to July 1989, and a total of 108 samples), and Tlayacapan, Morelos (with monthly collections of 5 pitfall traps, from July 1995 to June 1996, and a 60 total samples) (Díaz Gómez 1999, Palacios-Vargas & Mejía-Recamier 2007a), and other from Nicaragua: Moropotente (90 pitfall traps in August 2007 and 90 in April, 2009) rainy and dry seasons respectively (Pérez Miguel 2015).

2.4 Data Analysis

To estimate the quality of samples, genera accumulation curves were performed, and confidence ranges at 95% were calculated. Also, the non-parametric index Chao 1 estimator was calculated to predict the maximum genera in the area. The analysis of species accumulation and Chao 1 estimator were performed using EstimateS 9.1.0. software (Colwell 2013). To determine the diversity of springtails we used the Shannon-Wiener (H´) index, species richness, and evenness, both monthly as well as the total were calculated to observe the seasonal changes. True diversity and effective genera number were also calculated. The effective number of genera (Hill 1973, Jost 2006), used to measure units of true diversity (*D*), was calculated using SpadeR program (Chao et al. 2015), where genera present the same weight to its abundance (diversity of order 1, q = 1), or higher weight to dominant genera (diversity of order 2, q = 2). The monthly effect of collection on the Collembola abundance variation was

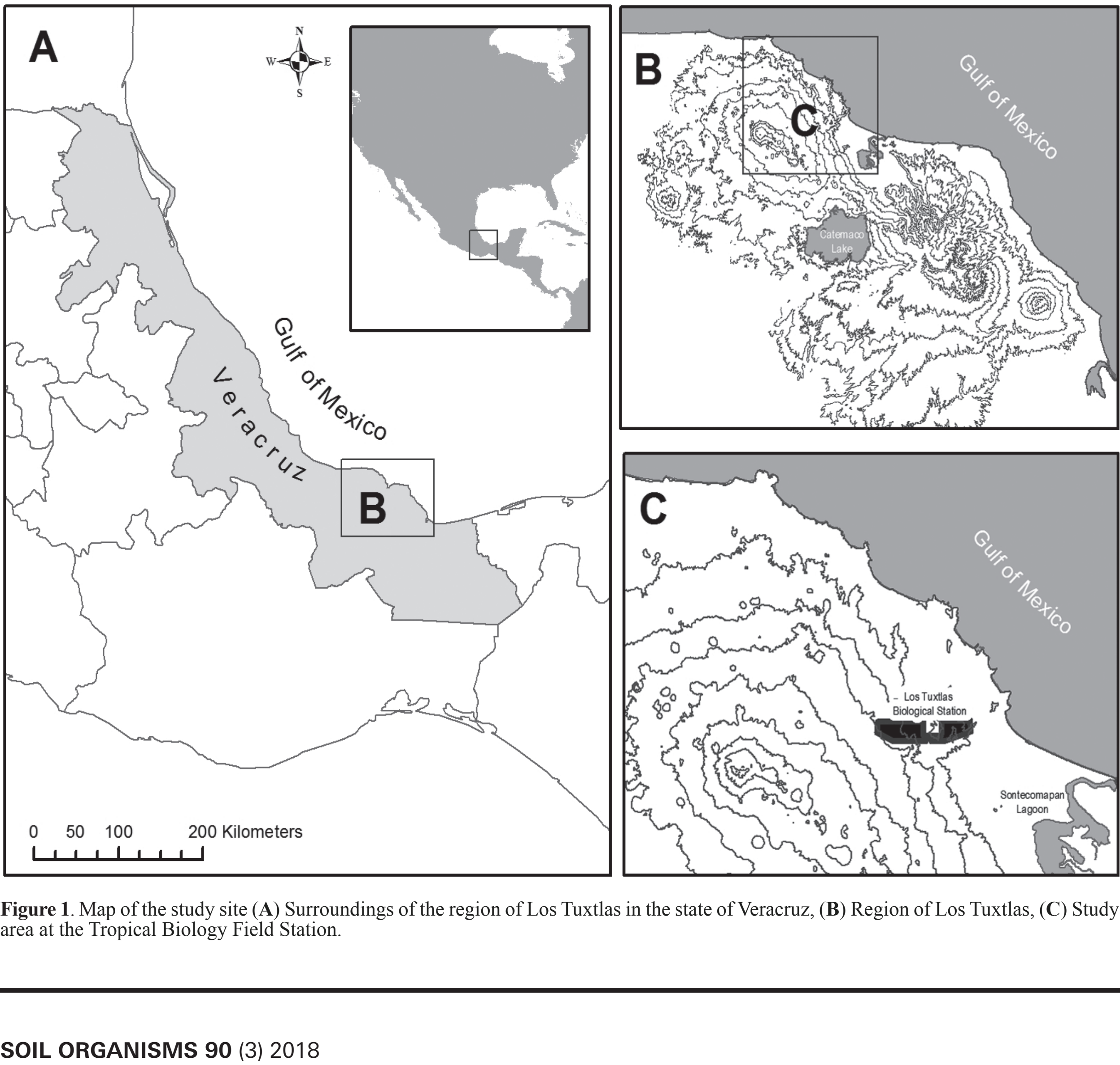

Figure 1. Map of the study site (**A**) Surroundings of the region of Los Tuxtlas in the state of Veracruz, (**B**) Region of Los Tuxtlas, (**C**) Study area at the Tropical Biology Field Station.

evaluated by the one way ANOVA test, and significant differences were analyzed by a post hoc Tukey test. Comparison of community compositions between months was performed with a cluster analysis using UPGMA as an amalgamation method and Pearson similarity as distance. Analysis was performed with Statitistica ver. 6 software (StatSoft 1995).

3. Results

A total of 4,291 springtails were collected with the 180 pitfall traps during this study. Ten families and 32 genera were represented in this sample. Five families Paronellidae (27%), Neanuridae (20%) Entomobryidae (16.9%), Dicyrtomidae (15%) and Isotomidae (11.6%) accounted for 90.5% of all captures (Fig. 2). Due to the large sample size we optimized identification to only genus level for this study. The 32 genera represent 96.87% of estimated genus richness (Fig. 3), according to the Chao 1 estimator (32 genera). Three families (Odontellidae, Sturmiidae and Sminthurididae) were very rare, and contributed with less than 1% of the total captures and were only captured toward the latter part of the year (Fig. 2).

In terms of the 32 genera represented in this study the most abundant were *Trogolaphysa* (18%) and *Ptenothrix* (13%), with *Neotropiella*, *Isotoma* and *Pseudachorutes* contributing 10% each. Combined, the abundance of these genera represented 61% of the total number of Collembola captured. The remaining 27 genera showed lower abundances which together totaled 39% (Fig. 3). In the case of genus richness, the lowest estimator was Chao 1 with an annual mean of 27.39 genera (Fig. 4).

True diversity in the study recorded 14 effective genera (Tab. 1). The total Shannon diversity index was 2.64, and Pieolou's evenness was 0.77, but monthly variations were observed, the lowest values being recorded in August and February and the highest values in December and March (Tab. 1). Nevertheless, the values of the effective number of genera show that December presented the highest value (12) and August the lowest. The difference between them shows that December presents three more times effective species than August. The diversity of order 2 (^2D), which considers only the most abundant genera, showed the same pattern in these months, with lowest values in August and highest in December, and in all cases two most abundant genera recorded were: *Trogolaphysa* sp. and *Ptenothrix* sp.

Results of a one-way ANOVA test show a significant effect of month on the Collembola abundance ($F_{1,11} = 287$, $p < 0.005$), and according to the post hoc Tukey test, differences are between April, June and August in relation with November, when the highest abundances were recorded.

Cluster analysis shows two main groups, one with the months that recorded low numbers of genera, as August, September, June and July and the other group with the remaining months (Fig. 5). In the second cluster January and February comprise one group with medium number of genera, and the other group is comprised by the months that recorded the highest number of genera, (May, April and March; October, November and December). Considering the composition of genera, we found two groups, one with genera that were found during all (or almost) the study (as *Ptenothrix*, *Lepidocyrtus*, *Trogolaphysa*, *Dicyrtoma*, *Calvatomina*), and other with genera that were found only during dry months (as *Willowsia*, *Pseudosinella* and *Salina*) or during wet months, as *Pseudanurophorus* and *Sminthurus*, further genera that were only recorded in one or two months, as *Ballistura* and *Xenylla* (Tab. 1).

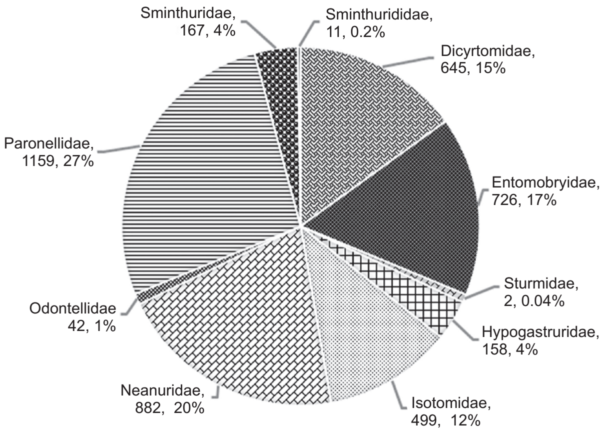

Figure 2. Abudances and percentages of Collembola families collected in pitfall traps at Los Tuxtlas Tropical Biology Station, Veracruz, Mexico.

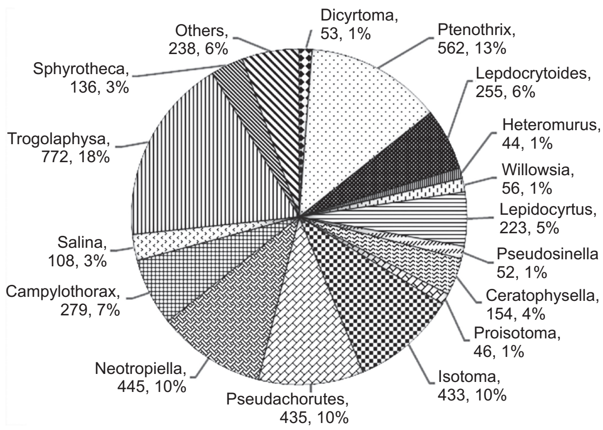

Figure 3. Abudances and percentages of different genera from Los Tuxtlas Tropical Biology Station, Veracruz, Mexico.

Table 1. Monthly and total abundance, species richness (S), Shannon diversity index (H'), Pielou's evenness (J'), effective number of genera ([1]D) and most abundant genera (2D) values in Collembola community found in pitfall traps in Los Tuxtlas, Veracruz.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Hypogastruridae													
Ceratophysella	5	18	2		1	1	2			68	54	3	**154**
Xenylla	3				1								**4**
Neanuridae													
Arlesia											1	1	**2**
Neotropiella	11	4	5	3	5	10	20		6	157	215	9	**445**
Pseudachorutes	54	19	1	2	3	25	26			38	265	2	**435**
Odontellidae			2								40		**42**
Superodontella										39		39	
Entomobryidae													
Americabrya			1	5	1								**7**
Heteromurus			11	6	25		2						**44**
Lepidocyrtoides	7	2	34	16	30	60	52	4	8	11	17	14	**286**
Lepidocyrtus	37	52	4	30	7	19	9	1	1	18	42	3	**223**
Orchesella	3	1	3	5	4	3			2	1		1	**23**
Pseudosinella		1	1	2							32	16	**52**
Seira			9	18	2	1	4	1					**35**
Willowsia	8		10	12	2					11	4	9	**56**
Heteromuridae													
Dicranocentrus			2		2					6	21		**31**
Isotomidae													
Ballistura	2		2										**4**
Isotoma	39	285	6	4	9	1	2	1	4	18	62	2	**433**
Isotomiella						2				5		5	**12**
Isotomurus						9			3	**2**	**6**		**20**
Proisotoma	1		4	2		16	2			7	10	4	**46**
Pseudanurophorus			1			1	1		1				**4**
Paronellidae													
Campylothorax	1		33	35	32	22	24	7	14	29	38	44	**279**
Salina	6	18	9	60	1						14		**108**
Trogolaphysa	18	67	116	69	97	33	54	41	44	114	86	33	**772**
Dicyrtomidae													
Calvatomina				2	6			2	2	15		3	**30**
Dicyrtoma				1	4	4	3	1	4	12	2	22	**53**
Ptenothrix	106	82	22	21	32	3	8	4	4	28	238	14	**562**
Sminthuridae													
Neosminthurus								2	1				**3**
Sminthurus			2	2		1	1					18	**24**
Sphyrotheca		5	1	4	4		3			78	8	33	**136**
Temeritas	3		1										**4**
Sminthurididae													
Sphaeridia										5	5	1	**11**
Sturmiidae													
Sturminus										2			**2**
Total	**304**	**554**	**282**	**300**	**268**	**202**	**213**	**64**	**91**	**621**	**1154**	**237**	**4291**
S	16	12	24	20	20	16	16	10	12	18	19	20	**31**
H'	2.017	1.562	2.153	2.347	2.142	2.108	2.094	1.35	1.761	2.313	2.244	2.509	**2.643**
[1]D	7.51	4.77	8.61	10.45	8.52	8.23	8.11	3.86	5.82	10.10	9.43	12.29	**14.05**
[2]D	2.24	1.99	2.20	2.38	2.26	2.31	2.30	1.76	2.06	2.37	2.34	2.45	**2.47**
J'	0.727	0.629	0.678	0.784	0.715	0.760	0.755	0.587	0.709	0.800	0.762	0.837	**0.770**

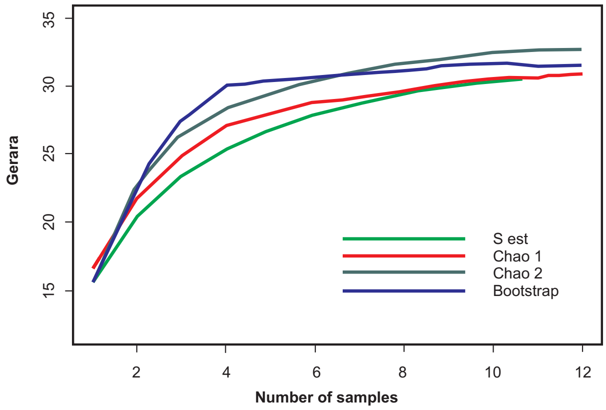

Figure 4. Curve of accumulation of collembolan genera for a 12-months period in 2015.

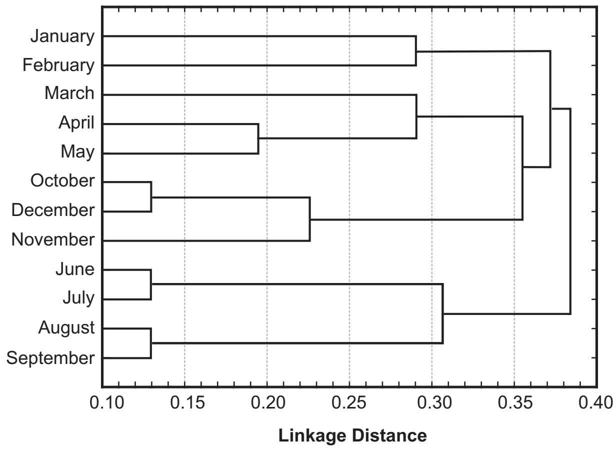

Figure 5. Dendrogram of cluster analysis.

Tab. 1 shows that the number of individuals captured monthly was relatively constant throughout the year, except August and September when the number was considerably reduced. The highest abundance was found in November. The Pearson correlation tests between the abundance, precipitation and temperature showed no correlation with any of these climatic factors. Taking into consideration the accumulation of the number of genera over time (12 months) the expected diversity indicators show that 94 % (Bootstrap) and 100 % (Chao 1) were reached. We can determine from these indicators that only one or two genera are lacking in our sample (Fig. 4).

Regarding the similarity among the four localities mentioned in Tab. 2, we found that the most similar locality with Los Tuxtlas in terms of families reported was Huitepec, Chiapas, Mexico (Lopéz Gómez 1999), and that Moropotente (Nicaragua) (Pérez Miguel 2015) was the least similar with values of 66 % and 57 % respectively.

Members of Bourletiellidae family were absent in the three Mexican localities, but they were very abundant at Moropotente, Nicaragua (Tab. 2). It is noteworthy that the number of specimens of Sminthurididae from Nicaragua was much larger than the total number collected at Los Tuxtlas by three times the amount. Two other families, Katiannidae and Tomoceridae (Tab. 2) are lacking from the pitfall traps from Los Tuxtlas but were recorded in very low numbers at Tlayacapan, Morelos (Palacios-Vargas & Mejía-Recamier 2007a).

However, it is noteworthy that the Sturmiidae family, only known previously from Panama, Colombia and Brazil canopies, was collected for the first time in

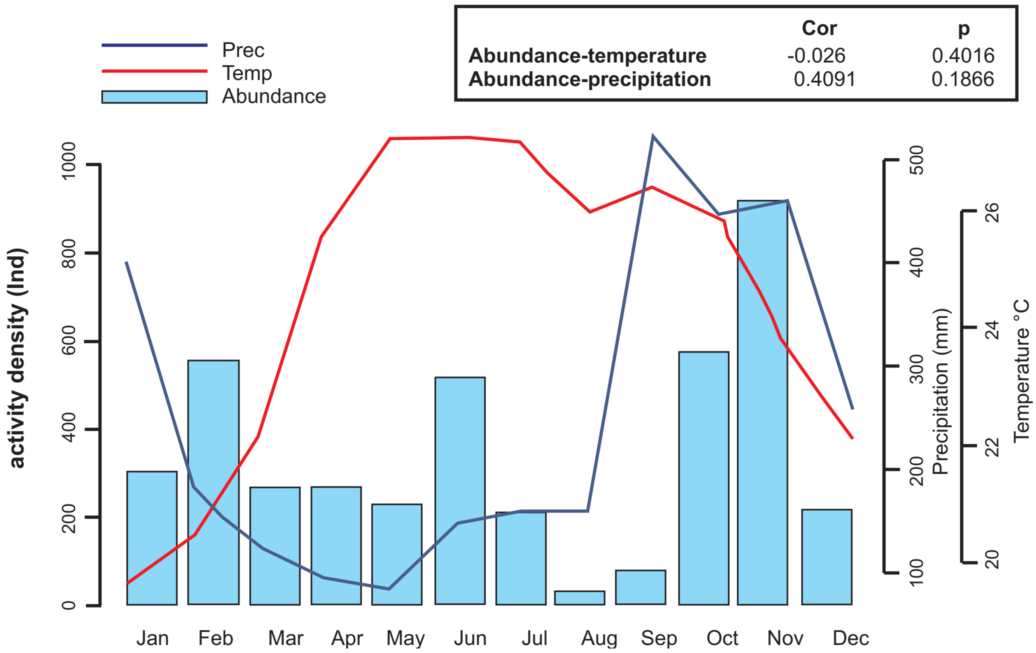

Figure 6. Relationship between precipitation, mean monthly temperature and abudance of collembola in pitfull traps for 2015.

this study using pitfall traps. Meanwhile, the family Paronellidae (27% of total captures) was very abundant in Los Tuxtlas, but showed an irrelevant abundance at the other three sites compared with (Tab. 2).

4. Discussion

We found a high diversity in the Collembola community at the genus level although many were represented with only a few individuals. Nevertheless, the total number of individuals collected in Los Tuxtlas was relatively low (4,289), compared with Moropotente in Nicaragua or Huitepec in Chiapas (18,947 and 12,473 specimens respectively). We believe that the number of epigeic genera represented in our sample almost reaches its maximum diversity for this study site. Depending on the locality, the main differences were found in the genera presented and the number of individuals for each genus. The differences in the abundances documented in the three other localities may be due to factors such as type of vegetation, climatic conditions, land use history and/or sampling methods. In each of these localities the dominant families differ, and it is notable that Collembola captures were much higher in the dry forest of Nicaragua than in the Los Tuxtlas tropical rainforest, whereas in contrast the pine-oak forest of Tlayacapan (Morelos) recorded the highest number of families (Tab. 2).

The representatives of the family Odontellidae are usually scarce in litter samples, but at Los Tuxtlas a larger abundance was recorded than in the other three localities. In a previous study by Castaño-Meneses et al. (2004) it was noted that at this same locality they were common in the basidiocarps of *Boletus* sp. and *Polyporus* sp. fungi where they feed from, so it may be difficult to evaluate their presence in litter, except for the fact that November is when the highest precipitation, temperature and abundance of individuals occurred (Fig. 6).

In the tropical rainforest of Los Tuxtlas, the genera *Trogolaphysa*, *Ptenothrix*, *Isotoma*, *Lepidocyrtoides* and *Lepidocyrtus* are well represented throughout all the months of the year (Tab. 2). A similar pattern occurs for *Pseudachorutes, Neotropiella and Campylothorax*, which are present in most months. These genera seem to dominate the sample due to the greater abundance in number of individuals. Furthermore, Bourletiellidae obtained in the tropical dry forest in Chamela, Jalisco, was found to be

Table 2. A comparison of the total number of specimens of Collembola families found in one locality in Nicaragua and three in Mexico, including the study area of Los Tuxtlas. Percentage of families in parenthesis. Mind the different numbers of traps and exposition.

	NICARAGUA	MÉXICO		
Family	**Moropotente**	**Morelos Tlayacapan**	**Chiapas Huitepec**	**Veracruz Los Tuxtlas**
Bourletiellidae	3459 (13%)	–	–	–
Brachystomellidae	747 (3%)	3 (0.09%)	–	–
Cyphoderidae	32 (0.12%)	–	–	–
Dicyrtomidae	1188 (5%)	288 (9%)	377 (3%)	645 (15 %)
Entomobryidae	1034 (4%)	**1631 (53%)**	842 (7%)	695 (16 %)
Heteromuridae	–	–	–	31 (0,6 %)
Hypogastruridae	791 (3%)	28 (1%)	**10 086 (82%)**	158 (3,68%)
Isotomidae	653 (2.5%)	318 (10%)	13 (0.1%)	499 (11,18 %)
Katiannidae	–	3 (3%)	3 (0.02%)	–
Neanuridae	1439 (5%)	98 (3%)	18 (0.2%)	882(25,68%)
Odontellidae	1 (0.004%)	3 (0.09%)	37 (0.04%)	42 (0,95%)
Paronellidae	–	27 (7%)	678 (5%)	**1159 (29,1 %)**
Sminthuridae	3648 (14%)	349 (11%)	419 (4%)	11 (0,14 %)
Sminthurididae	**13809 (52%)**	34 (1%)	–	167 (3 %)
Tomoceridae	–	2 (0.06%)	–	–
Total	18,947	2,784	12,473	4,289

very abundant in the canopy using a fogging technique (Palacios-Vargas et al. 1999, Palacios-Vargas & Gómez-Anaya 1993) and was also present in litter samples of the same locality but not in Los Tuxtlas, while in the pitfall traps from Nicaragua they totaled 13 % of the springtails.

From the data we have presented here the monthly variations in the number of individuals captured is evident, although there were no significant differences found between precipitation or average monthly temperature (Fig. 6). It could be possible that the variation in abundance of Collembola is dependent on specific life cycles rather than abiotic factors.

5. Conclusions

Ten families were collected in the tropical rainforest of Los Tuxtlas by means of pitfall traps. Highest abundances were presented by the Paronellidae (27 %) and Neanuridae (20 %), which were captured in lower numbers using the same methodology in Mexican mixed forests of pines and oaks (5 – 7 %), (5 – 2 %) in Morelos and Chiapas States, and the first family being absent in the tropical dry forest of Moropotente, Nicaragua.

When we compared the total abundance of springtails captured in pitfall traps in Los Tuxtlas (4,291) with other localities such as Tlayacapan, Morelos (2,784); Huitepec, Chiapas (12,473) and Moropotente, Nicaragua (18,947) with different types of vegetation and climate we found a low number, but the diversity of genera seems to be slightly higher. Although our locality showed a moderate similarity with Huitepec (Chiapas), two families Katiannidae and Tomoceridae were not documented in our study.

We believe that our findings using with pitfall traps give a good scenario of the springtails wandering in the litter, their abundance and taxonomic importance. A more complete understanding of the behavior of the Collembola community at Los Tuxtlas could be enhanced by the study of other biotopes in the region utilizing different techniques such as canopy fogging and the use of Berlese funnels for both soil and leaf litter samples.

6. Acknowledgments

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