PAN-PACIFIC ENTOMOLOGIST
74(1): 47–54, (1998)

COLLEMBOLA FROM THE CANOPY OF A MEXICAN TROPICAL DECIDUOUS FOREST[1]

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Abstract.—Sampling of the Arthropoda in a tropical deciduous forest was carried out at Chamela, Mexico. The Collembola community was emphasized because it was the most abundant arthropod group in the samples. *Salina banksi* (Paronellidae) was the most abundant and constant Collembola species. Seasonal variation of the abundance was positively correlated with precipitation and temperature. Canopy and shrub layer from Chamela shared only 12 Collembola species with the leaf litter and soil from the same study area. From reports in the literature, it was determined than Chamelan Collembola are more abundant than elsewhere.

Key Words.—Insecta, Collembola, Chamela, Canopy.

Collembola are usually associated with edaphic environments, where they constitute an important group because of their abundance and their role in nutrient cycling in the soil. Collembola can be abundant in other environments such as in the soil and litter accumulated in epiphytic plants as demonstrated by Palacios-Vargas (1981) e.g., so called suspended soils of Delamare-Debouteville (1948). The role of Collembola in the canopy can be as important as that in the soil, especially in environments where there is an accumulation of organic matter in the canopy, as occurs in the tropical deciduous forest of Chamela.

Current studies of South American epiphytic environments provided descriptions of new collembolan taxa (Bretfeld 1994), and studies using insecticidal fogging have shown that Collembola are one of the dominant groups in the canopy (Guilbert et al. 1995).

MATERIALS AND METHODS

The study was carried out in the Tropical deciduous forest at the Chamela Biological Station in the state of Jalisco, México (19°30′ N, 105°03′ W). Bullock (1988) showed that rainy season is from July to October and dry season from September to June. The vegetation was described in detail by Lott (1985).

For sampling, three watersheds, designated 1, 4 and 4A by Cervantes et al. (1988), were selected because their primary production is similar (Saharukán & Maass 1990). The tree layer sampled was 25 m tall.

Seven fumigations were carried out to include both rainy (August and September 1992, July 1993) and dry seasons (May and November 1993, and February and May 1994). We used a fogging machine (Dyna fog) and a natural pyrethum as the insecticide (Resmethrin 3% in kerosene solution) applied before sun rise (0400 to 0600 h), following the method of Erwin (1983). For every fumigation, a 100 m^2 area was delimited and 50 funnels (0.5 m of diameter) were hung randomly in the shrub layer about 50 cm above the floor forest. Specimens that

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fell on the funnels were collected by washing with alcohol (80%) some 5 h latter. In 5 fumigations, the fauna of ten funnels were quantified separately to estimate group distribution on the sampling surface.

Sampling of the shrub layer was done every two weeks from August 1991 to July 1993 using five malaise traps per watershed. In the first year, sampling was done in watersheds 1 and 4 and during the second year it was done in watersheds 1 and 4A.

The specimens were sorted and counted into orders, except the Collembola which were mounted and identified to species. Differences in the abundance of Collembola among watersheds and months were tested with ANOVA. The distribution of the Collembola on the sample surface was analyzed by standard deviation among some funnels samples in the same region and time. Simple regression analysis (Zar 1984) was performed between abiotic (temperature and precipitation) and biotic parameters, such as number of Collembola and abundance of other arthropods at all sites.

Rainy and dry seasons were compared in terms of species richness and composition, Hill Diversity Indices, Shannon-Weaver Diversity Index and Pielou's Evenness Index (Ludwig & Reynolds 1988) for the canopy and shrub layer.

RESULTS

A total of 25 species of Collembola were found in both habitats (Appendix I). Twenty-five groups of Arthropoda were represented in the canopy samples (Table 1). A total of 1,098,248 specimens were collected with a mean density of 15,986 specimens/m^2; 95% of which were Collembola (1,044,032) with nineteen species found (Table 2). *Salina banksi* MacGillivray (Paronellidae) was the most abundant species of Collembola, reaching 89.59% of the total Collembola. A remarkable seasonal behavior was noted. This species was most abundant in the rainy season (July to October) when it represented 89.9% of all Collembola trapped but in the dry season this declined to 65% of all Collembola. *Seira* spp. and *Deuterosminthurus maassius* Palacios-Vargas & Gonzalez were the next most abundant species of Collembola collected during both the rainy season (8.4% of the total abundance) and the dry season (19% of the total abundance). Mean density of Collembola from the canopy was estimated to be 15,197 specimens/m^2.

Both seasons had 19 species and similar composition, the dominant species was *Salina banksi* in rainy season according to N2 of Hill diversity, whereas the same species and *Seira dubia* were dominant in dry season (Table 3). Shannon and evenness indices were higher in dry season because of the decreased number of *S. banksi* (Table 3).

The Collembola abundance showed heterogenety among foggings (Table 4) with distribution being more homogenous in the rainy months than in dry months.

There was significant positive correlation between abundance of Collembola and monthly average of precipitation (r = 0.83, df = 5, P = 0.02). Similar results were obtained when this parameter was correlated with more abundant species, such as *Salina banksi* (r = 0.83, df = 5, P = 0.02), *Seira dubia* (r = 0.82, df = 5, P = 0.02), *S. knowltoni* (r = 0.83, df = 5, P = 0.02) and *S. bipunctata* (r = 0.83, df = 5, P = 0.02). However, there was no significant correlation between temperature and abundance of Collembola (r = 0.31, df = 5, P = 0.49). There was a significant negative correlation between temperature and abundance of Co-

Table 1. Mean density and relative abundance of Arthropoda from canopy in Chamela.

Taxa	Abundance	Percentage	Density specimens/m²
Collembola	1,044,032	95.06	15,196.97
Acari	13,691	1.25	199.29
Hymenoptera	9850	0.90	143.38
Aranea	7333	0.67	106.74
Diptera	4920	0.45	71.62
Coleoptera	3872	0.35	56.36
Homoptera	3598	0.33	52.37
Psocoptera	2314	0.21	33.68
Thysanoptera	2310	0.21	33.62
Larvae	2114	0.19	30.77
Orthoptera	919	0.08	13.38
Hemiptera	838	0.08	12.20
Isopoda	688	0.06	10.01
Dyctioptera	477	0.04	6.94
Lepidoptera	408	0.04	5.94
Pseudoscorpionidae	359	0.03	5.23
Isoptera	355	0.03	5.17
Chilopoda	69	0.01	1.00
Thysanura	35	<0.01	0.51
Neuroptera	29	<0.01	0.42
Embioptera	26	<0.01	0.38
Scorpionida	8	<0.01	0.12
Mecoptera	1	<0.01	0.01
Solifuga	1	<0.01	0.01
Odonata	1	≤0.01	0.01
Total	1,098,248	100	15,986.14

Table 2. Seasonal abundance of canopy Collembola from Chamela.

Taxa	Rainy season	Dry season	Total	Density specimens/m²
Ceratophysella gibbosa	1009	110	1119	16.29
Xenylla humicola	2236	248	2484	36.16
Brachystomella minimucronata	777	123	900	13.10
Pseudachorutes subcrassoides	319	91	410	5.97
Aethiopella sp.	953	106	1059	15.41
Neotropiella quinqueoculata	907	150	1057	15.39
Entomobrya ca. *californica*	899	221	1120	16.30
Seira bipunctata	22,073	716	22,789	331.72
S. dubia	22,700	862	23,562	342.97
S. knowtoni	32,940	716	33,656	489.90
Lepidocyrtus finus	1830	125	1955	28.48
L. gr. *lanuginosus*	3385	235	3620	52.69
Salina banksi	925,388	9933	935,321	13,614.57
Sphaeridia pumilis	798	224	1022	14.88
Sminthurinus ca. *conchyliatus*	595	215	810	11.79
S. ca. *latimaculosus*	1028	204	1232	17.93
S. (Polykatianna) ca. *radiculus*	934	279	1213	17.66
Sphyroteca ca. *mucroserrata*	1040	114	1154	16.80
Deuterosminthurus maassius	8940	609	9549	139.00
Total	1,028,751	15,281	1,044,032	15,196.97

Table 3. Parameters of Collembola communities (see text for explanation).

Parameter	Canopy		Shrub layer	
	Rainy season	Dry season	Rainy season	Dry season
S	19	19	12	14
N1	2	5	5	5
N2	1	2	4	3
H'	0.52	1.56	1.68	1.52
J'	0.18	0.53	0.68	0.58

S = Richness species; N1 = Abundant species; N2 = Very abundant species; H' = Shanon-Weaver diversity index; J' = Pielou evenness index.

leoptera ($r = -0.91$, df = 5, $P = 0.04$), Pseudoscorpionida ($r = -0.97$, df = 5, $P = 0.02$) and Hymenoptera ($r = -0.72$, df = 5, $P = 0.03$).

Malaise traps are not suitable for sampling Collembola, nevertheless, the specimens obtained in them allowed an estimate of the general richness and composition of Collembola of the shrub layer. A total of 41,443 specimens, belonging to 24 arthropod groups were collected (Table 5) in malaise traps. Collembola were the fourth group in abundance (6.3%) after Diptera (35%), Coleoptera (13.4%) and Hymenoptera (13%).

A total of 14 species of Collembola were collected in the shrub layer; the most abundant species were *Lepidocyrtus finus* Christiansen & Bellinger, *Calvatomina rufescens* Reuter and *S. banksi*, and four are new records for the Jalisco State, *Sminthurus butcheri* Snider, *Temeritas macrocerus* Denis, *Isotoma* (*Desoria*) *hiemalis* Schött and *Calvatomina rufescens* (Table 6). Twelve species were found during the rainy season whereas 14 were collected during the dry season; however, diversity and evenness were higher in the rainy season (Table 3).

Collembola abundance in the shrub layer was significantly correlated with precipitation ($r = 0.43$, df = 438, $P = 0.03$), but not with temperature ($r = 0.09$, df = 438, $P = 0.27$). There were significant correlations only between Collembola and Acari ($r = 0.81$, df = 459, $P = 0.01$), Aranea ($r = 0.49$, df = 459, $P = 0.02$), Chilopoda ($r = 0.59$, df = 459, $P = 0.04$) and Isopoda ($r = 0.49$, df = 460, $P = 0.03$).

ANOVA tests showed significant differences between Collembolan abundance of the two watersheds (F = 6.31, df = 1,459; $P < 0.001$) as well as among months (F = 5.07, df = 11,459, $P < 0.001$) and the interaction between months and watersheds was significant (F = 3.08, df = 11,436 $P < 0.0005$) indicating spatial and temporal heterogenity of Collembolan abundance in the shrub layer.

Table 4. Simple statistics within samples of Collembola in five fumigations by funnels.

Fumigation	Mean	SD
August 1992	301.6	98.46
May 1993	1.28	1.31
November 1993	201.5	20.14
February 1994	7.7	6.03
May 1994	5.23	9.15

Table 5. Abundance and percentage of Arthropoda collected by malaise trap in Chamela.

Taxa	Abundance	Percentage
Diptera	14,600	35.23
Coleoptera	5566	13.43
Hymenoptera	5401	13.03
Collembola	2633	6.35
Lepidoptera	3863	9.32
Acari	3411	8.23
Homoptera	2144	5.17
Aranea	1162	2.80
Psocoptera	795	1.92
Orthoptera	518	1.25
Larvae	393	0.95
Hemiptera	301	0.73
Thysanoptera	139	0.34
Isoptera	129	0.31
Undetermined	93	0.22
Neuroptera	92	0.22
Dictyoptera	85	0.21
Thysanura	33	0.08
Others	25	0.06
Embioptera	20	0.05
Opilionida	12	0.03
Chilopoda	10	0.02
Solifuga	5	0.01
Isopoda	4	0.01
Mecoptera	3	0.01
Scorpionida	2	<0.01
Pseudoscorpionida	2	<0.01
Strepsiptera	2	<0.01
Total	41,443	100.00

Table 6. Seasonal abundance of malaise trap Collembola from Chamela.

Taxa	Rainy season	Dry season	Total
Ceratophysella sp.	3	2	5
Rapoportella sigwalti	4	4	8
Seira bipunctata	0	3	3
S. dubia	1	6	7
S. knowltoni	20	239	259
Lepidocyrtus finus	416	886	1302
L. gr. *lanuginosus*	24	71	95
Salina banksi	157	68	225
Isotoma (Desoria) hiemalis	0	2	2
Sminthurus ca. *butcheri*	85	115	200
Sminthurus sp.	63	10	73
Calvatomina rufescens	167	221	388
Temeritas macroceros	25	22	47
Deuterosminthurus maassius	3	16	19
Total	968	1665	2633

Discussion and Conclusions

We found more Collembola species in canopy fogging than in malaise traps (19 and 14 species respectively). Guilbert et al. (1995) reported 32 Collembola species by fogging in New Caledonia. This result is higher than our observations in Chamela.

Palacios-Vargas (1981) reported 22 genera (31 species) of Collembola living in *Tillandsia* (Bromeliaceae) on the basaltic flows of Chichinautzin (Morelos, Mexico). Of these genera, 11 are also present in Chamela canopy and, it is possible they are also living in *Tillandsia* which are abundant at the Station (Lott et al. 1987).

The greatest abundance of Collembola reported by Guilbert et al. (1995) reached 18.4% of total arthropods, but in Chamela it was 98% and with one species, *S. banksi* accounting for 89.6% of all Collembola. This means that one species of Collembola is dominant in the Arthropoda of the canopy. Density of Collembola in the canopy was estimated to be 30,438 specimens/m^2 and this figure is higher than that of: Guilbert et al. (1995) for a primary forest in New Caledonia (107 specimens/m^2); Watanabe & Ruaysoongnern (1989) for a dry evergreen forest in Northeastern Thailand (195 specimens/m^2), and Hijii (1986) for a *Cryptomeria japonica* (Linnaeus f.) D. Don forest in Japan (3754 specimens/m^2). Differences in densities might be explained by differences in height and composition plant cover, the amount of suspended soil acumulated in *Tillandsia* (and on trunks), or amount of dead plant matter in the canopy, which is 75% of the plant matter (J. M. Maass, personal communication).

Number of Collembola species in true soil and leaf litter from Chamela are 49 and 33 respectively (Palacios-Vargas & Gómez-Anaya 1993). There is greater similiarity between leaf litter and shrub layer then between shrub layer and canopy layer. *Salina banksi* is most abundant in the canopy and decreases significantly in the shrub layer and is rare in leaf litter and soil (two specimens in a year of montly sampling). Three species occur solely in shrub layer, *Isotoma* (*Desoria*) *hiemalis, Calvatomina rufescens* and *Sminthurus butcheri*.

According to Guilbert et al. (1995) most Collembolans from shrub layer and canopy are epiedaphic forms such as Entomobryomorpha and Symphypleona. We found that 85% and 68% of the shrub layer and canopy species belong to these groups. The other species may occur in the *Tillandsia* and bark.

Precipitation affects the abundance of Collembola in a determinant way both in the soil (Gómez-Anaya 1998) and in canopy. Seasonal variation of the Collembola from the canopy and the shrub layer are associated with humidity, but not temperature. There is a greater correlation with humidity in the canopy due to insolation and the exposure possibly resulting in dehydratation.

Humidity is correlated with the availability of food for the Collembola in each layer. The most abundant genera from canopy are mainly detritophagous, mycetophagous and polyphagous, but in the shrub layer the most common groups are saprophagous, mycetophagous and detriphagous (MacNamara 1924, De Bernardi & Parisi 1968, Ellis 1978). High accumulation of organic matter exists in the canopy of Chamela and this is correlated with the different feeding habits of Collembola been found there.

The abundance of juveniles of Hypogastruridae, Entomobryidae and Symphypleona founded in shrub layer suggest the possibility of vertical migrations between this layer and canopy.

Few species of Collembola live only in the canopy, *Neotropiella quinqueoculata* Denis and the three species of *Sminthurinus*, the remaninder can be found in shrub layer, soil or leaf litter. *Isotoma (Desoria) hiemalis*, *Sminthurus* ca. *butcheri*, *Sminthurus* sp., *Temeritas macrocerus* and *Calvatomina rufescens*, however, are found only in shrub layer.

Our results show that the fauna living in the canopy, particularly the Collembola, should have an important role in the cycling nutrients and energy in the deciduous forest.

ACKNOWLEDGMENT

We thank Dr. Eric Guilbert (Laboratoire d'Entomologie, Muséum National d'Histoire Naturelle) and Dr. Zenón Cano Santana (Laboratorio de Ecología, Fac. de Ciencias, UNAM) for critical review to the manuscript and Ms. Blanca E. Mejía Recamier, Ms. Alicia Palafox Rodríguez and Dr. Alfonso Pescador Rubio (Depto. de Biología, Fac. Ciencias, UNAM) for their assistence during this project.

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Received 24 Mar 1997; Accepted 21 May 1997.

Appendix I. Systematic list of Collembola from canopy and shrub layer.

HYPOGASTRURIDAE
- *Ceratophysella gibbosa* (Bagnall)
- *Xenylla humicola* (Fabricius)

BRACHYSTOMELLIDAE
- *Brachystomella minimucronata* Palacios-Vargas & Najt
- *B. sigwalti* Palacios-Vargas & Najt

ANURIDIDAE
- *Neotropiella quinqueoculata* (Denis)
- *Pseudachorutes* ca. *subcrassoides* Mills

NEANURIDAE
- *Aethiopella* sp.

ISOTOMIDAE
- *Isotoma (Desoria) hiemalis* Schött

ENTOMOBRYIDAE
- *Entomobrya (Drepanura) californica* Schött
- *Lepidocyrtus finus* Christiansen & Bellinger
- *L.* gr. *lanuginosus* (Gmelin)
- *Seira bipunctata* (Packard)
- *S. dubia* Christiansen & Bellinger
- *S. knowltoni* (Wray)

PARONELLIDAE
- *Salina banksi* MacGillivray

SMINTHURIDIDAE
- *Sphaeridia pumilis* (Krausbauer)

KATIANNIDAE
- *Sminthurinus (Polykatianna)* ca. *radiculus* Maynard
- *S.* ca. *conchyliatus* Snider
- *S.* ca. *latimaculosus* Maynard

SMINTHURIDAE
- *Sphyrotheca* ca. *mucroserrata* Snider
- *Sminthurus* ca. *butcheri* Snider
- *Sminthurus* sp.
- *Temeritas macroceros* Denis
- *Calvatomina rufescens* (Reuter)

BOURLETIELLIDAE
- *Deuterosminthurus maassius* Palacios-Vargas & González