Dynamics of soil Oribatids (Acari) in a tropical regeneration ecosystem of Costa Rica

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Abstract

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Population dynamics of four Oribatid mites species are analyzed for further purposes of soil health on three different restoration habitat regime in the Lankester Botanical Garden, Costa Rica. A logarithmic Poisson regression and an alternative Negative Binomial Model were used to estimate statistical interactions between species presence on each habitat. Highest proportions found were constituted by *Zetomimus naias* and *Nothrus willmanni* in the latest restored habitat. Besides, a very high proportion of *N. willmanni* was found in the low disrupted habitat (oldest habitat restored) at the end of the rainy season. This is evidence of successful establishment of *N. willmanni* in spite of the constantly low organic-matter-recycling-rate, in other words, the low impact on the site. *N. willmanni* kept high population even when impact had occurred long time ago.

Additional key words: mesofauna, Oribatida, soil health, Soil mites, tropical ecosystem.

Resumen

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Se analiza la dinámica poblacional de cuatro especies de ácaros oribátidos del Jardín Botánico Lankester en Costa Rica. A lo largo de un año se realizaron muestreos con el fin de recopilar información para futuras aplicaciones de indicadores en la salud del suelo. Se usó como metodología analítica una regresión logarítmica Poisson y en contraste se aplica un Modelo Binomial Negativo para estimar la presencia de las especies en cada hábitat. Se encontraron altas proporciones de *Zetomimus naias* y *Nothrus willmanni* en el hábitat que ha permanecido con menor tiempo de regeneración. *N. willmanni* también mantiene alta abundancia en el hábitat menos alterado (mayor tiempo en estado de regeneración), principalmente al final de la época lluviosa. Esto evidencia el éxito de las poblaciones de *N. willmanni* a pesar de las bajas tasas de reciclaje, es decir, a pesar del menor impacto sobre el hábitat. Esta especie mantiene altas poblaciones inclusive mucho tiempo después de que el impacto ha ocurrido.

Palabras claves adicionales: ecosistema tropical, mesofauna, Oribatida, salud del suelo, Ácaros de suelo.

Introduction

Oribatida is the most widely distributed mite group of tropical soil mesofauna (Balogh and Balogh 1988, Balogh and Balogh 1990, Subías 2004). In Costa Rica, Oribatida has been

reported as a dominant component of fauna (41%) in soils (Heneghan et al. 1999).

Although little information concerning the ecology of different Oribatida subgroups is available in Central America, with the exception of researches on its role in nutrient recycling (Beare et al. 1992, Heneghan et al. 1999, González and Seastedt 2001, Franklin 2004, Illig et al. 2005). Curry (1986) explained that the composition of biotic soil communities is highly disturbed in regenerating ecosystems. Evaluations of natural forest soils and grassland soils showed patterns of low peaks for the total amount of individuals as well as overall richness.

Several authors, in search of a possible edaphic stress bioindicator, directed their attention to meso and microfauna, as they are the most environmentally sensitive fauna, detecting changes even better than some physicochemical parameters (Paoletti and Bressan 1996, Stork and Eggleton 1992, Lebrun and van Straalen 1995, Behan-Pelletier 1999), (i.e. oribatid mite groups). Since then, the elaboration of models and analysis has intensified in order to discover which faunistic functional groups can rapidly assess soil health. Çilgi (1994) proposed that any possible bioindicator should be distributed on whole habitat and abundant on ecosystem. In addition sampling and identification should be easy. Another postulate from this author is that bioindicators should be permanent or be common species even when impact occurred.

In this paper fluctuation of most common soil oribatids sampled are analyzed. These included *Nothrus willmanni* (Mahunka) as well as *Euryacarus pilosus* (Mahunka), *Nanhermannia nana* (Nicolet) and *Zetomimus naias* (Behan-Pelletier), species of which adults are easy to identify. However, at date their population dynamics are unknown in Central America. Theoretical studies have predicted, that oribatids fluctuation depends on habitat restoration. We were testing this hypothesis in two restored sites of Cartago, Costa Rica.

Methods

The study was carried out at Lankester Botanical Garden (lat 9° 50', long -83° 50') located in Dulce Nombre of Cartago (1 400 m), Costa Rica. It has an area of 10.7 ha with an annual average temperature of 18-22 °C. The annual rainfall varies from 900 to 1 200 mm. The rainiest months are September and October, while the driest months are March and April (Rivas-Rossi 1996).

Sampling was completed in one year, starting on September 2006 and ending August 2007. During this period, 10 plots were defined in two different habitats located within the Botanical Garden (20 plots totally). The habitats were: High Leaf Litter Forest (HLLF), a tropical secondary forest with 25 years of regeneration and plants with high rate of increase; Low Leaf Litter Forest (LLLF), a tropical secondary forest with 40 years of regeneration and low rate of leaf interchange. The control habitat was a Grassland site (GL) that kept a monthly pruning treatment (10 plots sampled).

Monthly samples were taken randomly from plots in each habitat. The area of each plot was 1 m². Five replicates were obtained per plot and samples consisted of 250 g of soil (organic matter and 5 cm deep approximately). Each sample was packed in a plastic bag and transported to the laboratory where samples were put on the Berlese funnels for at least 48 hours or until the soil got dried. The oribatid specimens were collected in 70 % alcohol and mounted in Hoyer medium for their identification using a stereoscope Motic SMZ 168 with external illumination Motic MLC-150c. They were identified using the Balogh and Balogh (1990) key, the list of Costa Rican species provided by Schatz (2006).

After an exploratory data analysis, the count of collected individuals was analyzed considering both habitat and sampled months via Generalized Linear Model (McCullagh

and Nelder 1989), with a Poisson regression distribution (Prob χ^2 in base to likelihood ratio test). Over-dispersion (Φ) was obtained in the Poisson Regression Model (Sileshi 2006, 2008). To correct this over-dispersion, a second alternative Negative Binomial Model has been evaluated, using also a logarithmic function crossing. This model takes into account part of the variance that the Poisson regression does not identify (Lawless 1987). The interaction between species levels and habitat was estimated using SPSS 17.0 software (SPSS Inc 2007).

Results

A total of 6 367 individuals belonging to *N. willmanni*, *E. pilosus*, *N. nana* and *Z. naias* were identified (Table 1). The highest proportions were presented by *Z. naias* and *N. willmanni* in HLLF (Figure 1), these were even higher than proportions of species in LLLF (Figure 2). The proportion of *N. willmanni* increases stridently in GL with respect to the other species (Figure 3). Species differences per habitat were evident (χ^2= 443.9, *df*= 3, P= 0.0001), (χ^2= 1 836.8, *df*= 2; P= 0.0001) for the Poisson Regression Model (Φ= 0.77). The variance of species according to habitat is related to statistically significant interactions between habitat+species (χ^2= 518.2, *df* = 6, P= 0.0001). The species' yearly distribution also shows differences (χ^2= 165.6, *df*= 10, P= 0.0001) in the Poisson Regression Model, but no so in the Negative Binomial Model (χ^2= 4.4, *df*= 10, P= 0.927), the rest of the variables (species, habitat and species+habitat) maintain a similar significance for the Negative Binomial Model and the Poisson Regression Model.

Different temporary patterns are shown between months in HLLF, LLLF and GL. In spite of this, *N. willmanni* always occurred with a higher number of individuals in comparison with other species (this is particularly true in GL), for every sampled month. This is contrary to the conditions shown by *E. pilosus*. This

species summed the lowest counts collected in the three habitats, and particularly evident in HLLF.

Only the HLLF habitat presented clear seasonal trends for the species. This explains why the Poisson Regression Model, which presents an excess of zeros in data concerning LLLF and GL, presented large and significant abundance differences for species in habitats. This also accounts for the lack of significant variance in monthly distribution when using the Negative Binomial. The proportions of individuals in HLLF are characterized by population peaks at the end of rainy season, during November and December, with lowest proportions present at the end of the dry season and in the beginning of the rainy season (April to June). LLLF revealed a highly irregular dynamic for the species' presence during the sampling year. The trend is unclear in this habitat due to the low number of mites registered (Figure 2).

Also GL showed low abundances of *Z. naias* and *E. pilosus*, contrasting with stable *N. willmanni* abundances (Figure 3). This does not hold true for *N. nana*. It must be taken into consideration that only two individuals for this species were recorded in GL.

Discussion

For a long time it has been known that the high diversity of tropical oribatids is influenced by seasonal regeneration cycles (Staton 1979). Even though a significant difference of abundances is shown for the analyzed species, habitat is a key discriminant for temporal population behavior in all species. In all cases, the individuals revealed no differences in their abundance in HLLF, presence for each of the four species maintained similar patterns (but different overall abundance), there was an increase of population in rainy season and a falling in the driest months; increasing again in the beginning of forthcoming rainy season. From a perspective of tropical oribatid species richness, several authors have

Table 1. Species and habitat of four mites soil sampled in Lankester Botanical Garden.

Species	Habitat							
	HLLF	%	LLLF	%	GL	%	X^2	$p<$*
Zetomimus naias	1891	0.39	23	0.16	4	0.003	26.94	0.001
Nanhermannia nana	1049	0.22	26	0.18	3	0.002	27.80	0.001
Nothrus willmanni	1432	0.29	47	0.33	1313	0.97	21.94	0.001
Euryacarus pilosus	503	0.10	46	0.32	30	0.02	24.31	0.001
Total	4875	–	142	–	1350	–	–	–

*Kruskal-Wallis, *df*=2.

shown that soil mites fluctuate depending on the communities overall distribution (Stamou and Asikidis 1992, Heneghan et al. 1999, Beare et al. 1992).

González and Seastedt (2001) argued that in tropical areas some factors such as climate, soil fauna and quality of substrate, independently influence the rate of organic matter decomposition. Others have proposed that it is difficult to categorize factors affecting mite communities, such as mite habitat and access to food resources, mainly because they are the result of microclimate interactions associated to optimal conditions (Maraun and Scheu 2000). An analysis of each species in three contrasting environments allows us to clarify temporal dynamics which are sometimes difficult to describe with diversity indexes and richness. Previous collaborations on the ecology of tropical soil meso-arthropods in Brazil and southeast of Nigeria have revealed that oribatid population's peak density fluctuates during an annual cycle in sites affected half of the year by seasonal rain (Franklin et al. 2004). While some species have wide peaks throughout the whole year, others peak at the end of the rainy season (Badejo 1990, Badejo and Ola-Adams 2000). The four species evaluated in Costa Rica present high affinity to establish in HLLF, but not in LLLF. In GL *N. willmanni* is the only species present. GL is affected by high environmental impacts such as drying (during

dry season) or intermittent floods in the rainy season due to soil saturation, all of which result in soil temperature changes.

Specific interactions between *Z. naias*, N. nana and *E. pilosus* with *N. willmanni* are not clear; conclusions of Anderson's study (1978) concerning a niche competition investigation between unrelated species, *Hermaniella* sp. (little common soil oribatid) and *N. willmanni*, state that both species maintained overlapped niches as well as access to food, despite differences in layer and inability to communicate. A similar effect occurred when they used the same niche. In the case evaluated herein, *N. nana* and *E. pilosus* were present in low layers of soil with recently decomposed organic matter rather than *N. willmanni*, and *Z. naias* increased its population sizes in layers with high rates of fermentation (high leaf litter forest, the youngest restored habitat). No data was found about niche interaction of species *Z. naias* and *E. pilosus*. However in habitat competition (niche translocation) any taxon could be specialized in singular kind of food (Wallwork 1976). Nevertheless, this does not explain why in HLLF species kept both low and high populations close in time, but different amount of individuals. We suggest that species sampled kept a food sources translocation, which would explain why populations ascending and descending at same time.
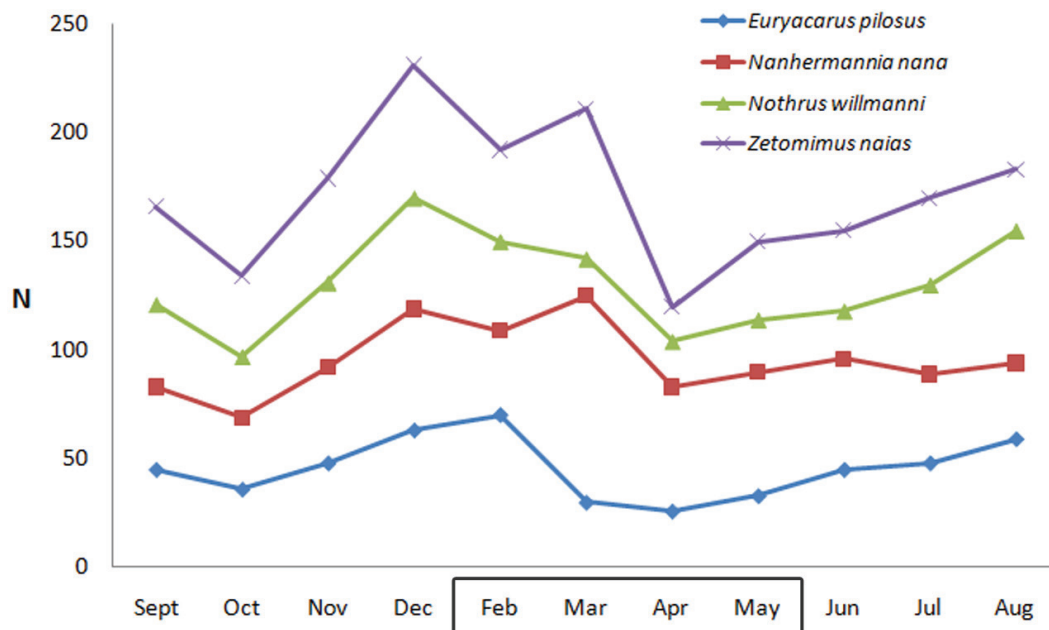
Figure 1. Monthly variation of mite populations on youngest habitat restored (HLLF), rectangular form represents dry season.
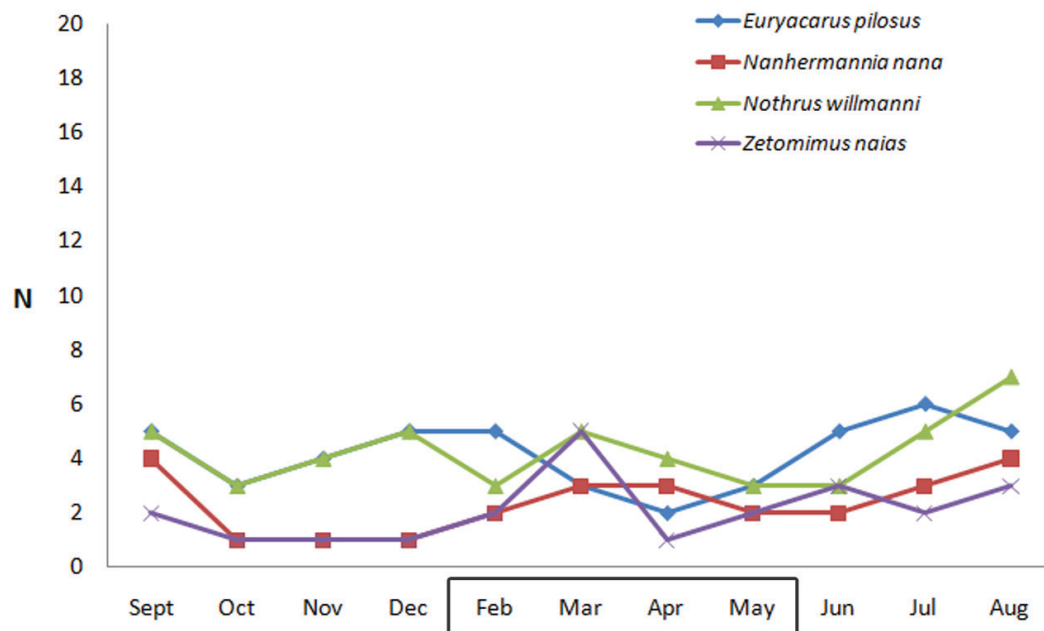

Figure 2. Species on oldest habitat restored (LLLF), the proportion pattern is similar in two different seasons (dry and rainy, rectangular form represents dry season).
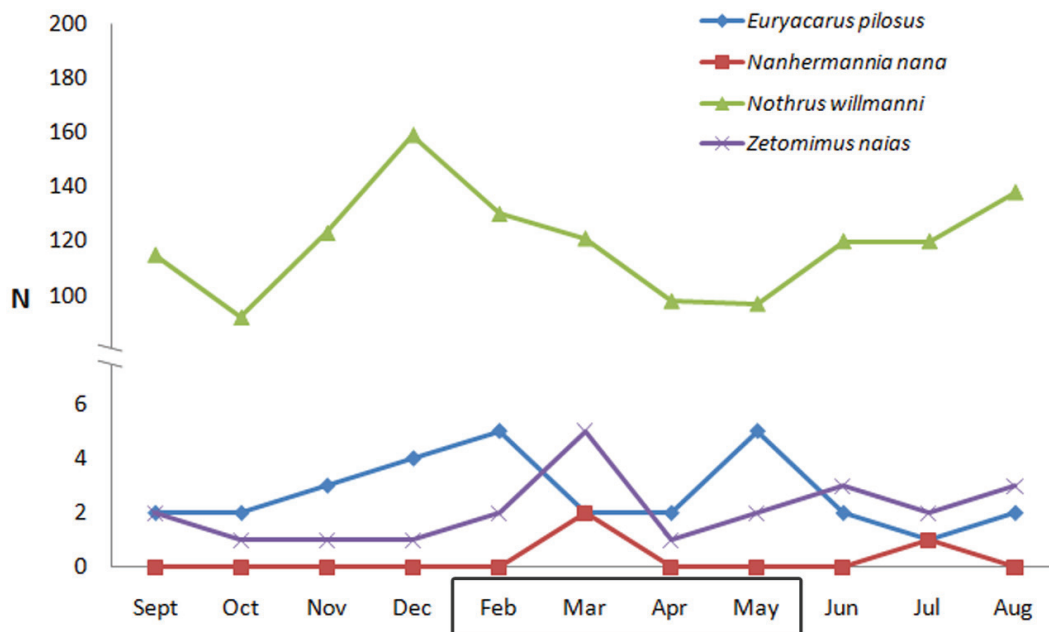
Figure 3. Grassland (GL-Control) sampled in Lankester Botanical Garden for a year, all adult mite populations are really low (rectangular form represents dry season).

There are interesting patterns in LLLF, particularly when population size fluctuations for the species are high. *E. pilosus*, for example, presents an increasing population size with peaks in the beginning and during the rainy season, the rest of the species' proportion shows peaks inside/outside of the dry and rainy seasons. A very high proportion of *N. willmanni* in GL evidences that this habitat provides ideal conditions for population growth, particularly at the end of the rainy season. Likewise, *N. willmanni* has successfully established itself in HLLF despite conditions that constantly enforce recycling of organic matter. This situation in environments where there is a continuous cycle of crops or any extractive land use, as in the case described by Badejo and Ola-Adams (2000), the growth period of soil fauna (particularly Oribatida) becomes consistently shorter in relation to lower dispersal rate (Stamou and Asikidis 1992).

In Costa Rica it is important to evaluate the food resources of *N. willmanni*, in addition to the ecological questions concerning the effect of altered environments on Nothridae frequency, as reported by pioneer studies of soil mites in tropical zones (Strickland 1945). To identify indicators of soil quality is difficult as a result of several physical, chemichal and biological factors that drive geochemistry, biochemistry and ecological space-temporal variations.

Soils analyzed reveal high organic matter concentration typical for tropical forests (high C/N proportions and acid soils). Without theoretical estimates of physical chemistry, data just show a temporary relationship of the Oribatida species found in different restored soils. Despite the fact that results do not include quantitative data on pH, or relative substrate humidity, it should be noted that low acidity levels would induce poor nutritional soil conditions, and thus, low proportions of oribatid (van Straalen and Verhoef 1997), i.e. changes in soil structure of oribatid populations is linked to changes in pH and humus formation. However, we should not dismiss valuable information that can be provided by physical

variables related to toxicological and chemical aspects of soil. Even though an indication of soil quality is nowadays possible either by pH analysis or other manual methodologies, the details of ecological mesofaunistic interactions expose important ecological effects to changes occurring in soil conditions for single habitats (van Straalen and Verhoef 1997). Proposal of any new bioindicator begins with an analysis of adult population dynamics of species sampled in order to define the focus species that complete the requirements postulated by Çilgi (1994).

Acknowledgments

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