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Edaphic mites (Acari: Mesostigmata: Gamasina) from three regions of Ecuador

Elsa Liliana Melo-Molina

Thesis presented to obtain the degree of Doctor in Science. Area: Entomology

Piracicaba
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To my Daughter Victoria Eugenia

For being, without being, allowing me to grow for her

To my husband Carlos Alberto

For being the emotional, professional and economic support since we have been together

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"When we thought we had everything and in truth we had nothing"

"When the storm passes and the roads are tamed and we are the survivors of a collective shipwreck, with a weeping heart and a blessed destiny,
we will feel happy just for being alive and we will hug the first stranger and praise the luck of not having lost a friend and then we'll remember everything we lost and all at once we will learn all we had not learned before.
We will no longer be envious because we have all suffered,
we will no longer be lazy and will be more compassionate what belongs to all will be worth more than that never achieved.
We will be more generous and much more committed;
we will understand how fragile it means to be alive. We will sweat empathy for who is and who has left"

"When the storm passes, I ask God, full of sadness to return us to be better as he had dreamed, we would be".

Translation of Alexis Valdés poem "Esperanza" (Hope) written in Spanish in March 2020 about the humanitarian crisis brought "by the Coronavirus and the "hope" of how we will feel when the "Storm Passes" ("*Cuando pase la tormenta*" - Esperanza)

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RESUMO

Ácaros edáficos (Acari: Mesostigmata: Gamasina) de três regiões do Equador

Sabe-se que o Equador é um país mega diverso, favorecido pelos biomas que possui. É de se esperar que isso também se reflita nas populações de ácaros. No que se refere aos ácaros presentes no solo e no folhedo, esse grupo possui hábitos diversos, entre os quais se destacam a regulação das condições do solo e o controle biológico de pragas. O presente estudo teve como objetivo mensurar essa diversidade, concentrando-se na ordem Mesostigmata, nas três regiões continentais: Amazônia, Litoral e Serra, em ambientes cultivados e não cultivados; em substrato de solo e folhedo, o que por sua vez possibilitou fazer descrições complementares de espécies do Equador e outras já descritas com poucos detalhes. Para isso, as coletas foram realizadas no período chuvoso entre 2018 e 2019. Os ácaros foram extraídos pelo método de Berlese-Tullgren modificado. Primeiramente, foi feita uma diferenciação das ordens dos ácaros e, posteriormente, os ácaros mesostigmatídeos foram identificados. No Capítulo 2, são apresentadas as medidas de diversidade e abundância dos ácaros mesostigmatídeos identificados nas três regiões, relacionando os ambientes onde foram coletados. Em alguns casos, foi possível identificar as espécies, mas na maioria dos casos os gêneros foram identificados, e em cada um destes, as morfoespécies, dentro das 16 famílias identificadas. O Capítulo 3 trata especificamente de espécies selecionadas da família Ologamasidae, incluindo a descrição de uma nova espécie (*Gamasiphis* n. sp.) e descrições suplementares de *G. plenosetosus* Karg e *G. salvadori* Castilho, Narita & Moraes, com novos relatos para Equador.

Palavras-chave: Amazônia, Diversidade, Litoral, Serra, Taxonomia

ABSTRACT

Edaphic mites (Acari: Mesostigmata) from three regions of Ecuador

It is known that Ecuador is a megadiverse country, favored by the ecosystems it has. It is to be expected that this is also reflected in the mite populations. In what refers to those present in the soil and litter, this group has different habits, among which are the regulation of soil conditions and their role as biological controllers of pests. The current study aimed at measuring this diversity, concentrating on the Mesostigmata order, in the three continental Ecuadorian regions: Amazon, Coast and Highland, in cultivated and non-cultivated environments, in soil substrate and litter, which in turn made it possible to make supplementary descriptions of species from Ecuador and others already described with little detail. For this, samples were taken in the wet season between 2018 and 2019. The mites were extracted using the modified Berlese-Tullgren method. First, a differentiation of the mite orders was made and later mesostigmatid mites were identified. In Chapter 2, the diversity and abundance of the mesostigmatid mites collected from the three regions are shown, relating to the environments where they were collected. In some cases, identification of species was possible. But in in most cases the mites were identified to morphospecies, within the 16 families identified. Chapter 3 refers specifically to selected species of the family Ologamasidae, including the description of a new species (*Gamasiphis* n. sp.) and supplementary descriptions of *G. plenosetosus* Karg and *G. salvadori* Castilho, Narita & Moraes, with new reports from Ecuador.

Keywords: Amazon, Diversity, Coast, Highland, Taxonomy

RESUMEN

Ácaros edáficos (Acari: Mesostigmata) de tres regiones de Ecuador

Es conocido que Ecuador es un país megadiverso, favorecido por los ecosistemas que posee. Es de esperar que esto también se refleje en las poblaciones de ácaros. En lo que se refiere a los que habitan el suelo y la hojarasca, este grupo tiene diferentes hábitos, entre los que se encuentran la regulación de los procesos del suelo y su papel como controladores biológicos de plagas. El presente estudio tuvo como objetivo medir esta diversidad, concentrándose en el orden Mesostigmata, en las tres regiones continentales del Ecuador: Amazonía, Costa y Sierra, en ambientes cultivados y no cultivados; en sustrato de suelo y hojarasca, lo que a su vez permitió realizar descripciones complementarias de especies de Ecuador y otras ya descritas con poco detalle. Para ello, se hicieron muestreos en la temporada de lluvias entre 2018 y 2019. Los ácaros se extrajeron mediante el método Berlese-Tullgren modificado. Primero se realizó una diferenciación de los órdenes de ácaros y posteriormente se identificaron ácaros mesostigmátidos. En el Capítulo 2, se muestra la diversidad y abundancia de los ácaros mesostigmátidos recolectados de las tres regiones, relacionándolos con los ambientes donde fueron recolectados. En algunos casos, fue posible la identificación de especies. Pero en la mayoría de los casos, los ácaros se identificaron como morfoespecies, dentro de las 16 familias identificadas. El Capítulo 3 se refiere específicamente a especies seleccionadas de la familia Ologamasidae, incluida la descripción de una nueva especie (*Gamasiphis* n. sp.), y descripciones complementarias de *G. plenosetosus* Karg y *G. salvadori* Castilho, Narita & Moraes, con nuevos reportes para Ecuador.

Palabras clave: Amazonía, Diversidad, Costa, Sierra, Taxonomía

1. INTRODUCTION

Ecuador is a mega diverse country, possessing seven ecosystems, which are reflected in the edaphoclimatic diversity, which greatly and differently influences the species that comprise it. In addition to its division into regions (Amazon, Coast, Highland and Insular), each one with its characteristics that make its biological and edaphoclimatic composition so variable. This adds to the seasonal variations that occur in the year, which are not always well defined (dry season and rainy seasons).

Diversity is also observed in the population of edaphic mites, these of importance in the dynamics of soils, both as regulators of the soil, as predators, the latter function of great importance in the regulation of pests that live or spend part of their lives in the soil.

In the present work, species of mites are reported that may be related to the edaphoclimatic characteristics, as determined by environmental characteristics (non-cultivated and cultivated) and types of substrates (soil and litter) from which the samples were collected.

1.1. Regions of Ecuador

Ecuador has a territorial area of 256,370 km^2. Of this total, the continental area corresponds to 251,755.34 km^2 (Dávila *et al.* 2013; Navarrete 2005; Vallejo 2010). This country has four climatic regions, comprising the Coast, Coast Plane or Western Region (24.6 % of the area), the Highland or Central Andean Region (24.8 %), the Ecuadorian Amazon or the Eastern Region (47.8 %) and the Insular region or Galapagos Archipelago (2.8 %) (FAO 2006; MAE 2016; Vallejo 2010). These regions are divided by the Andes, which is why they differ due to the influence of height, equatorial position and winds (Espinosa *et al.* 2008).

The Amazon extends to the east of the Andes, with altitudes below 600 m, forming alluvial soils and terraces used for agriculture. The Amazon ecosystem, particularly its rainforest, is considered one of the richest and most complex habitats of plants and animals in the world. This region is divided into two areas, one is characterized by alluvial or volcanic soils, being suitable for agriculture, located near the cordillera; the other with poor ferralitic soils, being a fragile area, with agricultural limitations (Espinosa *et al.* 2018). The most important feature of the region is the existence of a prolific flora and fauna with extraordinary variations of macro and micro-habitat, temperature varying between 23 and 36 °C, more than 2,000 mm of annual rainfall, which determines the absence of dry formations. The rainy and humid season runs from January to September and the dry season runs from October to December. About 18 commercial crops are extensively grown in this region, with a predominance of itinerant agriculture (burning followed by deforestation and sowing), extensive livestock, forestry and tropical crops (Sierra 1999).

The Coast is located to the west of the Andes and is traversed from north to south by a lower mountain range, with many extensive floodplains and beaches. This region has a flat area with fertile soils with slopes around the Andes that limit agricultural production, the other area is more humid with poor soils (Espinosa *et al.* 2008). In this region, the maximum heights are found in the North, reaching 800 m. The prevailing average temperature is 24.0 °C. Rainfall decreases from south to north. There, about 23 commercial crops are found, including export crops, as rice and corn (Sierra 1999).

The Highland corresponds to the Andean region, crossing the country from north to south, comprising the Eastern Cordillera, the Inter Andean Cordillera (with numerous valleys and basins) and the Western Cordillera. This region has steep slopes as the main limiting factor for agriculture; with a northern area with rich soils of volcanic origin, another central area with non-volcanic soils, with a variety of soils, but there are many areas dominated by poor soils. In some places, it reaches 5,500 m in height, being permanently covered by snow. The rainy and coldest period runs from November to April, while the dry and least cold period runs from May to October. In most of this region, the temperature is between 13.0 and 18.0 °C. Agricultural aptitude is strongly influenced by altitude, with about 22 commercial crops grown there. In the higher areas (above 3,000 m) the cultivation of tubers and cereals predominates; in intermediate areas (2,200-3,000 m) cereals, legumes, vegetables, fruits and pasture predominate; in the lower areas (below 2,200 m) export crops, cereals, vegetables, fruits and vegetables predominate (Sierra 1999).

Additionally, and as a result of this variety of environments in the regions, in Ecuador 70 % of the plants and animals on the planet have been identified; 17,058 species of vascular plants, 382 of mammals, 1,655 of birds, 404 of reptiles, 464 of amphibians, 1,539 of fish and 30 families of mollusks (MAE 2010; Vallejo, 2010; Troya *et al.* 2012; Troya *et al.* 2016) .

As for arthropods, it is not known exactly how many and which species of insects are found in the country. A survey by the Pontifical Catholic University of Ecuador (PUCE) reported in the Amazon (Estación Experimental Yasuní) approximately 60,000 species of insects in one hectare (MAE 2010). This University has a collection of insects with about 2 million specimens, of which only 30.0 % have been identified, due to a lack of resources and specialists, which limits their knowledge to catalog the diversity and endemism of this group in the country (MAE 2010; Sáenz & Onofa 2005). According to personal communication from Álvaro Barragán (2017), curator of invertebrates at the PUCE Museum, this collection has no mites and no specialist in this area.

1.2. Generalities about Mites

The word 'mite' comes from Old English and means a very small creature and, unlike other arachnids, they have evolved a lot. Some feed on plants, bacteria or fungi, while others have developed mandatory symbiotic relationships with vertebrate and invertebrate animals. Thanks to their remarkable evolutionary plasticity and relatively small size, typically around 0.5 to 1.0 mm in length, the mites have managed to colonize a number of terrestrial, marine, and aquatic habitats, but due to their small size, knowledge of their anatomy is still incomplete (Lindquist *et al.* 2009; Moraes & Flechtmann 2008; Walter & Proctor 2013).

These have considerable variation in the internal and external structures, with body shapes ranging from ovoid to flattened or vermiform. The life cycle depends on the mite group (Hoy 2011; Moraes & Flechtmann 2008). Most mites have both sexes, and many species are dimorphic, most lay eggs. The life cycle can comprise six post-embryonic stages: prelarva, larva, protonymph, deutonymph, tritonymph and adults, which are delimited by the occurrence of ecdysis, to allow the growth of the mite.

1.3. Classification

Mites are classified within the phylum Arthropoda, Subphylum Chelicerata, class Arachnida and subclass Acari. Unlike other arachnids, mites have a wide variety of foods, some are predators, fungivores, parasites in vertebrates and invertebrates, and herbivores. Within this subclass, they are grouped into two Parasitiformes (Anactinochaeta) and Acariformes (Actinochaeta) superorders, which are composed of six orders and approximately 400 families (Hoy 2011; Lindquist *et al.* 2009a).

In the superorder Parasitiformes, the orders are classified as: Opilioacaridida (or Notostigmata), Holothyrida (or Tetrastigmata), Ixodida (or Metastigmata) and Mesostigmata (or Gamasida). The latter includes predatory and parasitic mites. One of the main mesostigmatid family is Phytoseiidae, of great importance as predators. In Mesostigmata there are also many soil mites, including Ascidae, Ameroseiidae, Blattisociidae, Laelapidae, Macrochelidae, Melicaridae, Ologamasidae and Uropodidae (Krantz & Walter 2009; Moraes & Flectchmann 2008). Some examples, in Laelapidae, genera as *Gaeolaelaps* and *Stratiolaelaps* have been used as biological control agents (Walter & Proctor, 2013). For the control of edaphic pests, four predatory mites of the family Laelapidae have also been used, namely *Androlaelaps casalis* (Berlese), *Gaeolaelaps aculeifer* (Canestrini), *S. miles* (Berlese) and *S. scimitus* (Womersley) (Moreira & Moraes 2015). *Gamasiphis*, one of the most abundant genera of ologamasids, also reported the apparent consumption of eggs of the moth *Sitotroga* sp. (Gelechiidae) (Beaulieu & Walter 2007); *G. fornicatus* Lee on *Tyrophagus putrescentiae*; *G. saccus* Lee on *Nanorchestes* sp. (Nanorchestidae) (Lee 1974).

The superorder Acariformes includes the order Sarcoptiformes, which contains species commonly found in stored products and parasitic mites. This order includes the suborder Oribatida (or Cryptostigmata), which feed mainly on dead organic matter, and the suborder Endeostigmata, less important. This superorder also includes the order Thrombidiformes. In this, the main group is the suborder Prostigmata, to which approximately 36 superfamilies belong, with the families Eriophyidae, Tarsonemidae, Tenipalpidae and Tetranychidae standing out, for being phytophagous mites of interest to agriculture. To this order also belongs the less important suborder Sphaerolichida (Hoy 2011; Lindquist *et al.* 2009a; Moraes & Flechtmann 2008).

1.4. Measure of diversity of edaphic mites

"Biological diversity or biodiversity, refers to the quantity and variety of living organisms in a place or environment. This term has been used more widely since the 1960s, being used more recently with the term "Biodiversity", which apparently was proposed by Walter G. Rosen in 1985 in the National Forum on BioDiversity, however the two terms are used interchangeably; its meaning is associated with variability between living organisms and the ecological complexes of which they are part, this includes diversity within species, between species and ecosystems" (Magurran 2004).

"It is defined in terms of genes, species and ecosystems that are the result of more than 3,000 million years of evolution. These species depend for their survival on the delicate balance of the ecosystems they form. Thus, when one or more species decreases or dies, the fate of other species, including humans, is threatened" (Villarreal *et al.* 2004).

Biodiversity measurement is an imprecise and misleading concept, there is no universal unit to measure it or a single attribute, so it cannot be said that there is a better method. Biodiversity has different facets and for each one the most appropriate approach must be sought, for which the level of biodiversity to be analyzed must be considered (Moreno 2001).

Traditionally, to interpret the data from the collections of different organisms, biological diversity has been divided into three components: *alpha* (α: species richness of a particular community that we consider homogeneous), *beta* (β: degree of change or replacement in species composition between different communities in a landscape), and *gamma* (ɣ: species richness of the set of communities that make up a landscape) (Whittaker 2009).

According to Moreno (2001), this way of analyzing biodiversity is very convenient in the current context given the accelerated transformation of natural ecosystems, since a simple list of species for a given region is not enough. To monitor the effect of changes in the environment, it is necessary to have information on these three components (*alpha, beta* and *gamma*) and to be able to design conservation strategies and carry out concrete actions at the local scale.

In addition to biodiversity measures, edaphic invertebrates, which include mites, have been used as environmental bioindicators in various investigations of environmental assessments, for the functions that operate in various processes that occur, and for the characteristics of these (ease of sampling and collection, abundance and diversity). Study of these populations can facilitate the recognition of the physical-chemical composition of the soil characteristics and the type of vegetation it supports (Barrios 2007).

1.5. Edaphic mites

Soil mites are very diverse. In forest areas, this fauna becomes much more abundant and diversified mainly in the first layers of the soil (Duarte 2013; Silva 2002), added to this the humidity, temperature, type of soil and the presence, type and diversity of leaf in a given soil environment are directly related to the distribution, abundance and diversity of arthropods (Belfield 1956; Grill 1969; Rueda 2012).

Mesostigmatid mites can be found in association with the soil, in decaying wood, nests, fungi, on plants, animals. They are commonly present in the soil and comprise the main families of predatory mites (Freire 2007; Lindquist *et al.* 2009b; Moraes & Flechtmann 2008; Rueda 2012). Among the important families, we have the Phytoseiidae (mainly on plants, but also in the soil) (Gerson *et al.* 2003; Hoy 2011; Moraes & Flechtmann 2008), Ascidae (predominantly in the soil) (Britto 2011; Gerson *et al.* 2003; Moraes *et al.* 2015), Laelapidae (live freely in the soil) (Castilho *et al.* 2009; Freire 2007; Moreira & Moraes 2015), Blattisociidae (Rueda 2012), Macrochelidae (Azevedo *et al.* 2017), Melicaridae, Ologamasidae, Parasitidae, Rhodacaridae, Uropodidae and Veigaiidae (Rueda 2012).

It is important to note the role of these families in controlling other arthropods, with which they share the substrate, or which in turn can be adapted to others, among which stand out some that are currently commercialized: Laelapidae: *Gaeolaelaps aculeifer* (Canestrini), *Stratiolaelaps miles* (Berlese) and *S. scimitus* (Womersley), Macrochelidae: *Macrocheles robustulus* (Berlese) used to control larvae of Sciaridae flies ("*fungus gnat*") and other fly groups, *Lyprauta* spp. (Diptera: Keroplatidae). In Brazil, *S. scimitus* is commercialized for the control of Sciaridae flies (Castilho *et al.* 2009; Knapp *et al.* 2018; Rueda-Ramírez *et al.* 2020). Ascidae *sensu lato*, Parasitidae, Rhodacaroidea families are reported to prey of fly eggs and larvae, phytophagous mites, thrips, nematodes, eggs and larvae of *Diabrotica* spp. (Coleoptera: Chrysomelidae) (Azevedo *et al.* 2017; Castilho *et al.* 2015; Hoy 2011; Moreira & Moraes 2015).

1.6. Ecuadorian edaphic mites

Information on invertebrate genetic resources in Ecuador is scarce. Few studies emphasize some aspects of diversity or endemism; and, in relation to soil mites, the information generated in the country is almost zero, which does not allow having a reference collection. Holotypes and paratypes of the described species of this country are deposited in museums in Germany (Arachnologische Sammlung des Museums für Naturkunde, Berlin), Canada (Canadian National Collection of Insects, Arachnids and Nematodes, Bastern Cereal, Oilseed Research Center, Agriculture and Agri-Food Ottawa, Ontario), Poland (Department of Animal Taxonomy and Ecology, Adam Mickiewicz University, Posnan), Hungary (Natural History Museum Geneva and Soil Zoology Collections Hungarian, Budapest), Netherlands (Rijksmuseum van Natuurlijke Historie, Leiden), among other countries. Few are deposited in Ecuador (Museum of Zoology of the Pontifical Catholic University of Quito and the Ecuadorian Museum of Natural Sciences, Entomology Section) (Castilho *et al.* 2015; Castilho *et al.* 2016; Freire 2007; Moraes *et al.* 2016; Santos *et al.* 2017a, b, c).

Considerable numbers of mite species have already been described in the country. The approximate numbers of species are: Ameroseiidae, two species (Faraji & Karg 2006; Karg & Schorlemmer 2009); Ascidae, 17 species (Karg 1979, 1994b, 2006, 1998b; Moraes *et al.* 2016); Blattisociidae, 49 species (Christian & Karg 2006; Karg 1994c, 1998b; Moraes *et al.* 2016; Santos *et al.* 2017b); Digamasellidae, one species (Karg & Schorlemmer 2009); Laelapidae, 27 species (Karg 2000, 2003, 2006; Moreira 2014); Macrochelidae, 1 species (Karg 1994b); Melicaridae, 22 species (Karg 1994a, 2006; Naskrecki & Colwell 1998; Santos *et al.* 2017c); Ologamasidae, 43 species (Karg 1998c, 2003, 2006, 2007; Karg & Schorlemmer 2009, 2011; Castilho *et al.* 2016); Pachylaelapidae, one species (Karg & Schorlemmer 2009); Parasitidae, seven species (Karg 1998c, 2006); Parholaspididae, three species (Karg 1994b, 2006); Rhodacaridae, 10 species (Karg 1994a, 1998c, 2000, 2003; Karg & Schorlemmer 2009; Castilho *et al,* 2012), *Zygoseius*, eight species (Karg 1998a; Karg & Schorlemmer 2009); cohort Uropodina, 70 species (Hirschmann 1973; Kontschán 2008, 2010, 2012, 2016); Veigaiidae, one specie (Karg 2006) and Oribatida, approximately 43 species (Illig *et al.* 2010; Lochynska 2008; Niedbala & Roszkowska 2017).

1.7. Context of the research

Although the number of works dedicated to the study of soil mites in Ecuador is not negligible, it is assumed that many other species are yet to be found in this country, and at the moment there is no one in Ecuador qualified to carry out taxonomic studies. In addition, many of the descriptions of Ecuadorian species have been made inappropriately, and these need to be redescribed, so that they can be reliably identified. This is the first step towards the future conduction of applied studies, in search of the detection of species with the potential to be used to control harmful organisms, especially mites and small insects.

In this context, the following objective was raised: to characterize the diversity of edaphic mites in three agroecological areas of Ecuador. Considering the following activities: 1) Identify the species found, with an emphasis on Mesostigmata; 2) Analyze the relationship between population density and soil richness of Mesostigmata mites by environments and substrate; 3) Supplementary descriptions of species, previously described, with little detail; 4) Describe a new species found, publishing the description in a high-quality international magazine.

1.8. Research strategy

The present work is divided into 3 chapters. The first deals with general and introductory aspects of edaphic mites in three continental regions of Ecuador. The second refers to aspects of the diversity of mesostigmatid mites in these regions, their distribution at the different points sampled, associations with edaphoclimatic conditions, and in turn, how the mite families are distributed under these conditions. This chapter also shows the diversity of the mesostigmatid mites of Ecuador, influenced by the substrate, and the conditions of the environment. This chapter also included new species and new reports for Ecuador. In the third and last chapter, a new ologamasid species is described and complementary descriptions of two described species as well as new reports of species for Ecuador are presented.

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2. DIVERSITY OF EDAPHIC MITES (ACARI: MESOSTIGMATA) FROM NORTHERN CONTINENTAL ECUADOR WITH NEW REPORTS

Abstract

Ecuador is a small but megadiverse country consisting of four regions, each with a different ecosystem, namely the Coastal, Highland, Amazon, and Galapagos Islands. Edaphic predatory mites have been scarcely reported from these regions. The objectives of this study were to identify the species of edaphic mites northern continental Ecuador, with emphasis on the order Mesostigmata, and to evaluate their densities and species richness in three regions, in different environments and substrates. For this, samplings were conducted in the three regions of continental Ecuador, in the cultivated and natural ecosystems (environments), in the superficial 5 cm thick soil layer and in the overlaying litter layer (substrates). Collected mites were extracted using modified Berlese-Tullgren funnels. In total 27,361 mites were obtained, with the following frequency: Oribatida, including Astigmatina (67.0 %), Mesostigmata- non-Uropodina (18.6 %), Mesostigmata-Uropodina (4.9 %), Trombidiformes-Prostigmata-Eupodides (3.1 %), among others. The highest number of mites was found in the Highland (42.2 %) with a predominance of mesostigmatids. Within the mesostigmatids, 4,716 were immatures (52.7 %), the remaining consisting of 36.0 % adult females and 11.3 % adult males. In this order, 16 families, 53 genera and 192 morpho-species were identified. The most abundant families were Ologamasidae (22.3 %), Ascidae (16.2 %) and Laelapidae (15.8 %). Additionally, 732 Uropodina mites were identified, 500 specimens in the Coast, 141 in the Amazon and 91 in the Highland regions. Five families and 17 species consisted of new reports for Ecuador. Twelve new species were identified. The most diverse families were Laelapidae, Phytoseiidae, Blattisociidae and Macrochelidae, with 44, 26, 19 and 19 morpho-species, respectively. The most diverse genus was *Gaeolaelaps* Evans & Till (Laelapidae) with 17 morpho-species. The most abundant morpho-species was *Asca* aff. *garmani* (Ascidae). A non-parametric analysis was carried out with the Wilcoxon method, showing that the Coast presented the lowest mesostigmatids abundance compared to the other regions. The numbers of mites per family, with paired comparison, were different for regions, environments and substrates. When comparing mite abundance between environments and substrates, no differences were founded within each region. The *alfa* diversity indices showed that species richness was highest in the Highland region; no dominant species were observed in any of the three regions, all presenting high diversities. When calculating the *beta* diversity for the regions, it was found that the Amazon and the Highland had more species in common than other comparisons. The *gamma* diversity indices showed that *alpha* diversity contributes a higher percentage (99.96 %) to the region diversity. Comparisons between environments showed that the Coast and the Amazon have higher richness indexes in cultivated environment for the two substrates, and the Highland in the non-cultivated environment, for the two substrates, with no dominant species for environments or substrates; the lower morphospecies diversity was found in the Coast in contrast to the other regions. The Sorensen's coefficient of species similarity was highest in the Amazon between environment (56.9 %), and in the Highland between substrate (56.2 %). Finally, diversity and richness indexes for sampling sites (SS) were high for the Amazon region, while in the Coast (CP2: 2.515 *vs.* CP2: 1.189) and Highland (HP3: 3.271 *vs.* HP1: 1.295), they presented contrasting values between high and low diversity. For all SS in the three regions no dominant species were determined. Sorensen's coefficient showed low percentages in the interactions of the SS for the regions, values less than 44.0 %, except in the interaction SS CP1 *vs*. CP4 in the Coast (60.0 %).

Keywords: Diversity indices, Predator, Taxonomy

2.1. Introduction

Ecuador is a country of great diversity, probably due to the diversity of its ecosystems, representing the three regions into which it is divided (Amazon, Coastal and Highland). According to parameters such as the latitudinal, attitudinal, climatic, topographical or physiognomic, Ecuador is characterized by seven biomes (more general category of the ecosystem): tropical forests, dry tropical forests, savannahs, xerophytic savannahs, highland forests, swamps and mangroves (MAE 2010, 2013b). As a result of such diversity in ecosystems and their species of flora and fauna, Ecuador is worldwide recognized as a country of high biological diversity (MAE 2013a).

Regarding the soil mesofauna, especially mites, it has been reported in different countries that the suborder Oribatida may account for up to 80.0 % of the edaphic mites, followed by the order Mesostigmata (18.0 %), the suborder Prostigmata and the cohort Astigmatina (2.0 %). The Mesostigmata constitute a large and relevant group because they comprise the main families of predatory mites (Lindquist *et al.* 2009b; Mineiro & Moraes 2001; Silva *et al.* 2004; Silva 2002; Vásquez *et al.* 2007).

Within the Mesostigmata, 15 non-Uropodina families with approximately 202 species have been reported from Ecuador (Karg 1988, 1979, 1994a; 1994b, 2006; Karg & Schorlemmer 2009; Castilho *et al.* 2012a, 2016; Moreira 2014; Moraes *et al.* 2016; Santos *et al.* 2017a, b, c). As to the Mesostigmata-Uropodina, approximately 14 families, 24 genera and 70 species have been reported from the same country (Hirschmann 1973; Kontschán 2008, 2010, 2012, 2016), while in relation to the Oribatida, about 43 species have been reported (Illig *et al.* 2010; Lochynska 2008; Niedbala & Roszkowska 2017).

In addition to these reports, other works have been carried out on soil mites of neighboring countries, such as Colombia and Brazil, where environmental conditions affect the diversity and abundance of edaphic mesostigmatids. Research carried out in soils from natural vegetation and agroecosystems in savannah areas of the northern Brazilian state of Tocantins reports that in natural areas more mites were collected than in cultivated areas, and that Rhodacaridae was more abundant in non-cultivated areas compared to Ascidae in cultivated areas (Azevedo *et al*. 2021).

In Barretos, north of São Paulo state, more mites were found in pasture than in areas of sugarcane or natural vegetation, but the mites were more diverse in natural vegetation (Silva 2019). It was also reported that the season had no effect on the abundance of soil mites, in natural environment as opposed to coffee cultivation areas in southern Minas Gerais, Brazil (Carvalho 2013). Additionally, a greater abundance of mesostigmatids was observed in patches of secondary vegetation and Andean forest in the Bogota plateau than in flower fields (Rueda-Ramirez 2018).

In what concerns methodology, in the search to interpret the number and type of specimens obtained in the samplings, the use of indexes has been proposed. Usually, the diversity of species is estimated by the use of the *alpha* component, measuring the diversity within the communities. The *alpha* diversity, is measured taking into account two methods: 1) Methods based on the quantification of the number of species present (Margalef's species richness); 2) Methods based on the community structure, that is, the proportional distribution of the importance value of each species (Dominance: Simpson index and Community equity: Shannon-Wiener index) (Moreno 2001).

Another component, *beta* diversity or diversity of species between habitats, is based on proportions or differences. The proportions can be evaluated based on indexes or coefficients of similarity, dissimilarity or distance between the samples from data that are qualitative (presence absence of species) or quantitative (proportional abundance of each species measured as number of individuals, ecosystems or density). To measure the *beta* diversity, some indices are used, as Jaccard, Sorenson, Morisita-Horn, among others (Magurran 1988; Moreno 2001).

Finally, the third component, *gamma* diversity, defined as the species richness of a group of habitats (a landscape, a geographic area, an island) that results of the *alpha* diversity of individual communities and the degree of differentiation between them (*beta* diversity). Its value is usually close to the total number of species recorded in all communities, and it is derived from three formulas: the first based on species richness, the second on Shannon's index and the third in the Simpson's index. These formulas divide the value of *gamma* diversity into two additive and positive components: diversity within communities (*alpha*) and diversity between communities (*beta*) (Lande 1996; Moreno 2001; Whittaker 2009).

The present research is directed to the knowledge of the diversity of mites in Ecuador, and to find species potentially helpful in the biological control of agricultural pests. Efforts in this regard have been conducted in countries such as Brazil and Colombia. In Brazil, predatory mites collected have been marketed, with successful results. That is why the following objectives were set for this research: 1) To identify the species found, with emphasis on

Mesostigmata; 2) To analyze the relationship between population density and richness of mesostigmatids edaphic mites by regions, environments and substrates. The hypotheses to be tested were: 1) The diversity of edaphic mite species in the three regions of Ecuador, in cultivated and non-cultivated areas, is much greater than known today; 2) The richness levels of the groups of mites collected in different environments show great differences.

2.2. Material and Methods

2.2.1. Localization of collection regions

Three regions were selected for sampling, all in northern Ecuador, in seven provinces: Amazon (Napo, Orellana and Sucumbios), Coast (Esmeraldas and Manabí provinces) and Highland (Cotopaxi and Pichincha) (Figure 1). The samples were taken from cultivated and non-cultivated environments, from soil and litter substrate, in the wet season of 2018.

The collection sites were georeferenced with GPS Essentials (App, Google Play Store). The meteorological data of the nearest stations, belonging to INAMHI (National Institute of Meteorology and Hydrology) were also taken into account (INAMHI 2016). Based on (Espinosa *et al*. 2018), the geoclimatic conditions of the sampled points were characterized (soil type, moisture, annual precipitation, average temperature (°C), ecosystem and land area) (Tables 1.1-1.3). The specific sites were selected for belonging to small farmers, who commonly do not use synthetics chemicals for pest control, increasing the chances to find the edaphic mites.

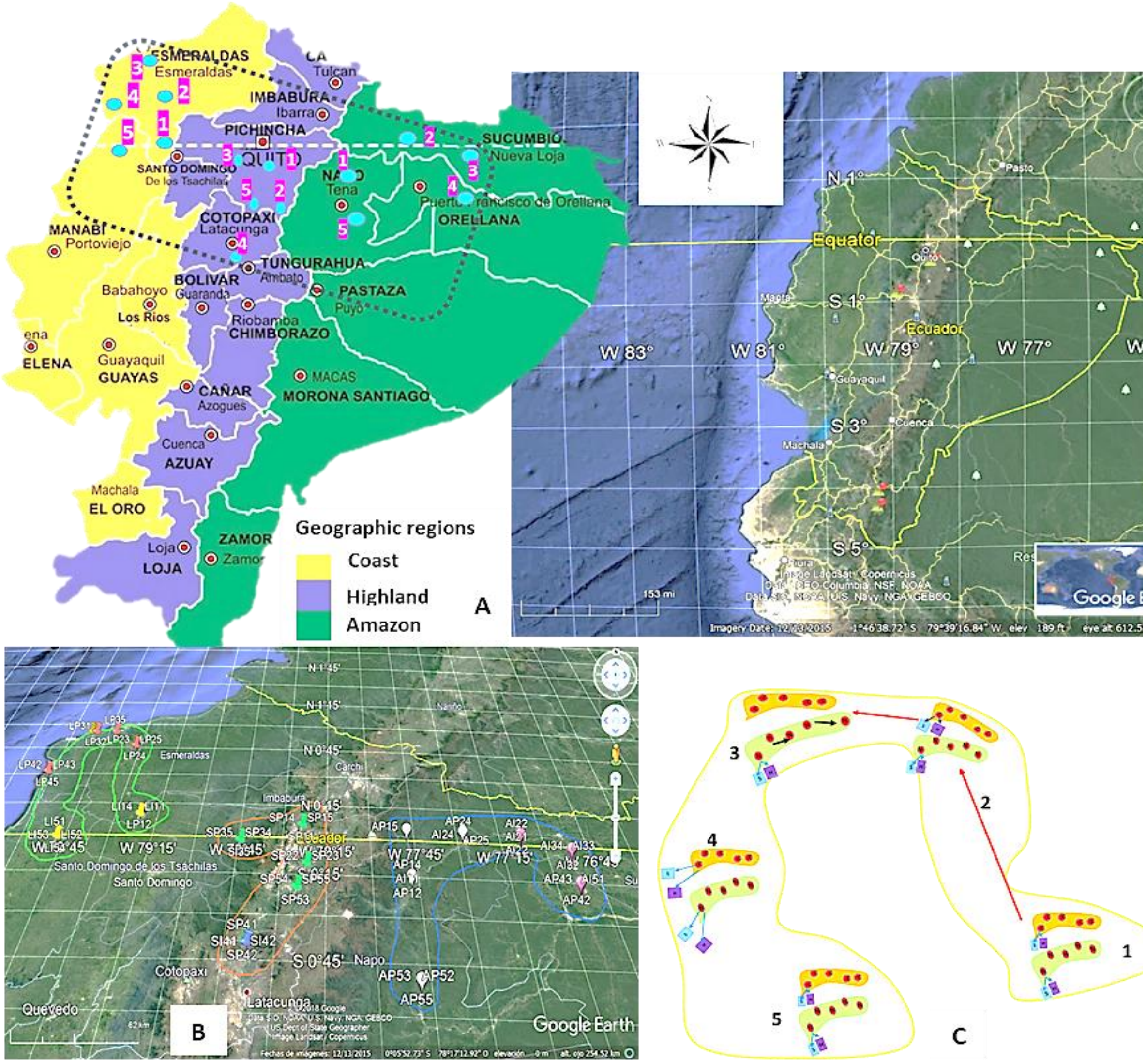

Figure 1. **A**. Regions, provinces and sites sampled in north Ecuador (blue dots 1 to 5); **B**. Location of the sampled regions (L: Coast; S: Highland; A: Amazon); **C**. Simulation of the distribution of the sampled sites (Coast region): samples sites, cultivated (Orange) and non-cultivated environment (light green); red arrows show the distances between sample sites (20 to 70 km) and black arrows show distances between subsamples sites (5 to 300 m); blue and purple squares show respectively soil and litter samples (Map from https://provinciasecuador.com/mapa-politico-del-ecuador/(A) and Google Earth (A-B)). Points are enlarged for improved visibility.

Table 1.1. Location, edaphoclimatic characteristics and vegetation of the Ecuadorian Amazon region where samples were taken in search of edaphic Mesostigmata mites, sampling in two environments (cultivated and non-cultivated plants) and in two substrates (Soil and litter) in the wet season of 2018.

Sample site	1			2			3		
Province	Napo			Sucumbíos			Sucumbíos		
Location	Between Santa Rosa de Quijos and El Chaco (SQC)			Alma Ecuatoriana (AE)			Nueva Loja (East) (NLE)		
Ecosystem	Eastern Montana Rainforest (EMR)			Amazon rainforest (AR)			Amazon rainforest (AR)		
Soil type	Colluvial, muddy, corroded andisols (2f)			Non colluvial andisols, muddy, brown, perhydrate (2d)			Ferralitic soils, desaturated clayey, aluminum toxicity (3g)		
Moisture areas	Hyper humid zone (No dry month) (HHZ)			Hyper humid zone (No dry month) (HHZ)			Hyper humid zone (No dry month) (HHZ)		
Annual precipitation	1,000-2,000			> 2,000			> 2,000		
Average temperature (°C)	9-14			14-18			>22		
Land area	Mixed			Natural			Anthropized		
Altitude (max-min)	1,537-1,514			1,161-1,189			294-312		
Subsample site				**Cultivated**					
1	Rutaceae	*Citrus limon*	S 0° 19.537 - W 77° 47.610	Rutaceae	*Citrus limon*	S 0° 0.544 - W 77° 8.342	Rutaceae	*Citrus limon*	S 0° 6.052 - W 76° 52.235
2	Verbenaceae	*Aloysia triphylla*	S 0° 19.537 - W 77° 47.610	Rubiaceae	*Borojoa patinoi*	S 0° 0.549 - W 79° 8.345	Myrtaceae	*Psidium guajava*	S 0° 6.052 - W 76° 52.235
3	Convolvulaceae	*Ipomoea batatas*	S 0° 19.534 - W 77° 47.611	Myrtaceae	*Eugenia stipitata*	S 0° 0.546 - W 77° 28.342	Musaceae	*Musa paradisiaca*	S 0° 6.045 - W 76° 52.246
4	Solanaceae	*Solanum quitoense*	S 0° 19.531 - W 77° 47.611	Piperaceae	*Piper auritum*	S 0° 0.547 - W 77° 28.339	Arecaceae	*Cocos nucifera*	S 0° 6.043 - W 76° 52.253
5	Fabaceae	*Inga feuilleei*	S 0° 19.536 - W 77° 47.602	Cucurbitaceae	*Cyclanthera pedata*	S 0° 0.543 - W 77° 28.338	Fabaceae	*Inga feuilleei*	S 0° 6.048 - W 76° 52.241
				Non-cultivated					
1	Malvaceae	*Hibiscus rosa-sinensis*	S 0° 19.539 - W 77° 47.604	Rubiaceae	*Rubus rosifolius*	S 0° 0.538 - W 77° 28.338	Sapindaceae	*Sapindus saponaria*	S 0° 6.051 - W 76° 52.237
2	Euphorbiaceae	*Ricinus communis*	S 0° 19.533 - W 77° 47.606	Acanthaceae	*Pachystachys lutea*	S 0° 0.539 - W 77° 28.338	Moraceae	*Ficus americana*	S 0° 6.048 - W 76° 52.244
3	Cyclanthaceae	*Carludovica palmata*	S 0° 19.539 - W 77° 47.606	Solanaceae	*Brunfelsia grandiflora*	S 0° 0.549 - W 77° 28.339	Malvaceae	*Urena lobata*	S 0° 6.044 - W 76° 52.239
4	Rosaceae	*Rubus rosifolius*	S 0° 19.537 - W 77° 47.601	Fabaceae	*Erytrina edulis*	S 0° 0.550 - W 77° 28.337	Campanulaceae	*Siphocampylis* sp.	S 0° 6.049 - W 76° 52.242
5	Solanaceae	*Cestrum reticulatum*	S 0° 0.538 - W 77° 47.600	Urticaceae	*Pourouma cecropiifolia*	S 0° 0.550 - W 77° 28.341	Cecropiaceae	*Cecropia obtusifolia*	S 0° 6.055 - W 76° 52.241

Continued…

Sample site	4			5		
Province	Orellana			Napo		
Location	Joya de los Sachas (JS)			Tena (TE)		
Ecosystem	Amazon rainforest (AR)			Amazon rainforest (AR)		
Soil type	Alluvial, river, muddy Andean (1d)			Non colluvial andisols, muddy, brown, perhydrate (2d)		
Moisture area	Hyper humid zone (No dry month) (HHZ)			Hyper humid zone (No dry month) (HHZ)		
Annual precipitation	> 2,000			> 2,000		
Average temperature (°C)	>22			>22		
Land area	Anthropized			Mixed		
Altitude (max-min)	271-290			604-614		
Subsample site			Cultivated			
1	Myrtaceae	*Psidium guajava*	S 0° 19.621 - W 76° 53.287	Rutaceae	*Citrus limon*	S 0° 53.827 - W 77° 48.128
2	Verbenaceae	*Aloysia triphylla*	S 0° 19.622 - W 76° 53.289	Musaceae	*Musa paradisiaca*	S 0° 53.824 - W 77° 48.133
3	Malvaceae	*Theobroma cacao*	S 0° 19.617 - W 76° 53.293	Malvaceae	*Gossypium herbaceum*	S 0° 53.813 - W 77° 48.120
4	Anacardiaceae	*Mangifera indica*	S 0° 19.614 - W 76° 53.296	Poaceae	*Saccharum officinarum*	S 0° 53.823 - W 77° 48.109
5	Caricaceae	*Carica papaya*	S 0° 19.613 - W 76° 53.295	Lauraceae	*Ocotea floribunda*	S 0° 53.816 - W 77° 48.113
			Non-cultivated			
1	Araceae	*Colocasia esculenta*	S 0° 19.626 - W 76° 53.292	Melastomataceae	*Tibouchina lepidota*	S 0° 53.830 - W 77° 48.130
2	Fabaceae	*Senna* sp.	S 0° 19.615 - W 76° 53.293	Rubiaceae	*Borojoa patinoi*	S 0° 53.830 - W 77° 48.125
3	Heliconiaceae	*Heliconia rostrata*	S 0° 19.615 - W 76° 53.294	Cecropiaceae	*Cecropia sciadophylla*	S 0° 53.828 - W 77° 48.125
4	Urticaceae	*Urera baccifera*	S 0° 19.611 - W 76° 53.298	Zingiberacea	*Renealmia sessilifolia*	S 0° 53.836 - W 77° 48.133
5	Poaceae	*Coix lacryma-jobi*	S 0° 19.612 - W 76° 53.292	Caesalpiniaceae	*Bauhinia grandiflora*	S 0° 53.811 - W 77° 48.120

Table 1.2. Location, edaphoclimatic characteristics and vegetation of the Coast region from Ecuador where samples were taken in search of edaphic Mesostigamata mites. Sampled in two environments (cultivated and non-cultivated) and in two substrates (Soil and litter) in the wet season of 2018.

Sample site		1			2			3	
Province		Esmeraldas			Esmeraldas			Esmeraldas	
Location		La Independencia (LI)			Majua (M)			Súa (SU) 3.1-3.4: Atacames 3.5: Tabiazo	
Ecosystem		Coast rainforest (CR)			Coast rainforest (CR)			Western dry forest (WDF)	
Soil type		Andisols, Clay, brown (2c*)			Undeveloped, Clay sludge pH <7 (3c)			Undeveloped, Clay sludge pH> 7 (3b)	
Moisture área		Very humid zone (1-4 dry months) (VHZ)			Humid zone (4-8 dry months) (HZ)			Dry zone (8-10 dry months) (DZ)	
Annual precipitation		>2,000			1,000-2,000			<500	
Average temperature (°C)		>22			>22			>22	
Area terretrial		Anthropized			Anthropized			Anthropized	
Altitude (max-min)		24.0-172.0			16.6-38.1			0.0-20.9	
Subsample site					Cultivated				
1	Malvaceae	*Theobroma cacao*	N 0°6.165- W 79°21.289	Malvaceae	*Theobroma cacao*	N 0°42.656- W 79°32.390	Anacardiaceae	*Mangifera indica*	N 0°50.926- W 79°51.777
2	Arecaceae	*Elaeis guinensis*	N 0°6.503- W 79°21.271	Malvaceae	*Gossypium hirsutum*	N 0°42.866- W 79°32.577	Malvaceae	*Theobroma cacao*	N 0°50.503- W 79°51.860
3	Rubiaceae	*Coffea arabica*	N 0°6.471- W 79°21.356	Rutaceae	*Citrus cinensis*	N 0°42.866- W 79°32.577	Passifloraceae	*Passiflora edulis*	N 0°50.503- W 79°51.860
4	Passifloraceae	*Passiflora edulis*	N 0°6.179- W 79°21.482	Caricaceae	*Carica papaya*	N 0°42.686- W 79°32.461	Rutaceae	*Citrus limon*	N 0°50.503- W 79°51.860
5	Caricaceae	*Carica papaya*	N 0°6.480- W 79°21.482	Malvaceae	*Theobroma cacao*	N 0°42.678- W 79°32.460	Caricaceae	*Carica papaya*	N 0°50.503- W 79°51.860
					Non-cultivate				
1	Urticaceae	*Laportea aestuans*	N 0°6.465- W 79°21.286	Verbenaceae	*Lantana camara*	N 0°42.075- W 79°31.726	Moraceae	*Morus* sp.	N 0°50.503- W 79°49.870
2	Araceae	*Phylodendron* sp.	N 0°6.468- W 79°21.282	Cyclanthaceae	*Carludovica palmata*	N 0°42.073- W 79°31.724	Fabaceae	*Phaseolus* sp.	N 0°50.508- W 79°49.863
3	Piperaceae	*Piper peltatum*	N 0°6.496- W 79°21.281	Rubiaceae	*Borreria leavis*	N 0°42.072- W 79°31.721	Solanaceae	*Solanum* sp.	N 0°50.508- W 79°49.865
4	Melatomataceae	*Clidemia hirta*	N 0°6.486- W 79°21.270	Poaceae	*Panicum maximum*	N 0°42.073- W 79°31.716	Piperaceae	*Piper umbellatum*	N 0°50.509- W 79°49.866
5	Cecropiaceae	*Cecropia peltata*	N 0°6.500- W 79°21.273	Piperaceae	*Piper aduncum*	N 0°42.073- W 79°31.713	Muntingiaceae	*Muntingia calabura*	N 0°50.492- W 79°41.881

Continued …

Sample site	4			5		
Province	Esmeraldas			Manabí		
Location	Bolivar (BL)			Estero ancho, km 48 (EA)		
Ecosystem	Coast rainforest (CR)			Coast rainforest (CR)		
Soil type	Undeveloped, Clay sludge pH <7 (3c)			Undeveloped, Clay sludge pH <7 (3c)		
Moisture área	Humid zone (4-8 dry months) (HZ)			Humid zone (4-8 dry months) (HZ)		
Annual precipitation	1,000-2,000			1,000-2,000		
Average temperature (°C)	>22			>22		
Ecosystem	Coast rainforest (CR)			Coast rainforest (CR)		
Area terretrial	Anthropized			Mixed		
Altitude (max-min)	0.0-36.5			305.0-328.0		
Subsample site			Cultivated			
1	Arecaceae	*Elaeis guinensis*	N 0°27.255- W 80°1.446	Lauraceae	*Persea americana*	S 0°4.280- W 79°47.316
2	Rutaceae	*Citrus limon*	N 0°27.248- W 80°1.423	Rutaceae	*Citrus limon*	S 0°4.269- W 79°47.309
3	Passifloraceae	*Passiflora edulis*	N 0°27.254- W 80°1.430	Myrtaceae	*Psidium guajava*	S 0°4.266- W 79°47.307
4	Cucurbitacea	*Cucurbita ficifolia*	S 0°27.254- W 86°1.420	Annonaceae	*Annona muricata*	S 0°4.268- W 79°47.314
5	Araceae	*Colocasia esculenta*	N 0°27.259- W 80°1.414	Lauraceae	*Persea americana*	S 0°4.257- W 79°47.310
			Non-cultivated			
1	Borraginaceae	*Heliotropium* sp.	N 0°27.235- W 80°1.438	Fabaceae	*Erithrina poeppigiana*	S 0°4.259- W 79°47.314
2	Borraginaceae	*Heliotropium* sp.	N 0°27.230- W 80°1.448	Boraginaceae	*Heliotropium* sp.	S 0°4.260- W 79°47.315
3	Meliaceae	*Cedrela* sp.	N 0°27.231- W 80°1.447	Solanaceae	*Solanum* sp.	S 0°4.263- W 79°47.313
4	Convolvulaceae	*Merremia aegyotia*	N 0°27.243- W 80°1.944	Piperaceae	*Piper* sp.	S 0°4.261- W 79°47.312
5	Araceae	*Philodendron* sp.	S 0°27.243- W 80°1.446	Lamiaceae	*Hiptis capitata*	S 0°4.261- W 79°47.312

Table 1.3. Location, edaphoclimatic characteristics and vegetation of the Highland region from Ecuador where samples were taken looking for edaphic Mesostigmata mites, sampling in two environments (cultivated and non-cultivated) and in two substrates (Soil and litter) in the wet season of 2018.

Sample site	1			2			3		
Province				Pichincha					
Location	Alchipichí, Puéllaro (AP)			Central University of Ecuador UCE-CADET (CADET)			El Edén, Mindo (EM)		
Ecosystem	Dry wasteland (DW)			Transition between Lower Montane Dry Forest and Lower Montane Humid Forest (TLDHF)			Inter Andean wet vegetation (IAWV)		
Soil type	Undeveloped, slightly developed (2a)			Durustolls			Colluvial, muddy, corroded andisols (2f)		
Moisture area	Dry zone (8-10 dry months) (DZ)			Humid zone (4-8 dry months) (HZ)			Very humid zone (1-4 dry months) (VHZ)		
Annual precipitation	500-1,000			1,000-2,000			>2,000		
Average temperature (°C)	9-14			<9			<9		
Land area	Anthropized			Mixed			Natural		
Altitude (max-min)	2,083.0-2,099.0			2,502.0-2,514.0			1,526.0-1,593.0		
Subsample site				**Cultivated**					
1	Rutaceae	*Citrus limon*	N 0° 2.373 - W 78° 24.079	Fabaceae	*Inga feuilleei*	N 0° 13.886 - W 78° 22.152	Myrtaceae	*Psidium guajava*	S 0° 4.787 - W 78° 44.961
2	Verbenaceae	*Aloysia citriodora*	N 0° 2.381 - W 78° 24.069	Asteraceae	*Smallanthus sonchifolius*	S 0° 13.886 - W 78° 22.155	Rutaceae	*Citrus limon*	S 0° 4.775 - W 78° 44.971
3	Lauraceae	*Persea americana*	N 0° 2.379 - W 78° 24.067	Myrtaceae	*Eucalyptus globulus*	S 0° 13.892 - W 78° 22.152	Rubiaceae	*Coffea arabica*	S 0° 4.841 - W 78° 44.770
4	Rosaceae	*Prunus salicifolia*	N 0° 2.378 - W 78° 24.068	Cucurbitaceae	*Cucurbita pepo*	S 0° 13.877 - W 78° 22.157	Poaceae	*Saccharum officinarum*	S 0° 4.840 - W 78° 44.763
5	Rosaceae	*Eriobotrya japonica*	N 0° 2.373 - W 78° 24.063	Ciruelo chino	*Prunus salicina*	S 0° 13.869 - W 78° 22.195	Musaceae	*Musa paradisiaca*	S 0° 4.849 - W 78° 44.770
				Non-Cultivated					
1	Bignoniaceae	*Tecoma stans*	N 0° 2.371 - W 78° 24.059	Euphorbiaceae	*Euphorbia laurifolia*	S 0° 13.889 - W 78° 22.164	Melastomataceae	*Leandra lacunosa*	S 0° 4.788 - W 78° 44.961
2	Euphorbiaceae	*Euphorbia laurifolia*	N 0° 2.374 - W 78° 24.062	Solanaceae	*Solanum nigrum*	S 0° 13.895 - W 78° 22.152	Acanthaceae	*Megaskepasma erythrochlamys*	S 0° 4.787 - W 78° 44.964
3	Verbenaceae	*Lantana camara*	N 0° 2.371 - W 78° 24.067	Bignoniaceae	*Tecoma stans*	S 0° 13.900 - W 78° 22.145	Rosaceae	*Rubus rosifolius*	S 0° 4.847 - W 78° 44.763
4	Solanaceae	*Datura stramonium*	N 0° 2.369 - W 78° 24.071	Verbenaceae	*Lantana camara*	S 0° 13.814 - W 78° 22.165	Solanaceae	*Acnistus arborescens*	S 0° 4.862 - W 78° 44.757
5	Asteraceae	*Taraxacum officinale*	N 0° 2.363 - W 78° 24.067	Acanthaceae	*Megaskepasma erythrochlamys*	S 0° 13.804 - W 78° 22.175	Melastomataceae	*Brachyotum coronatum*	S 0° 4.859 - W 78° 44.745

Continued…

Sample site	4			5		
Province	Cotopaxi			Pichincha		
Location	La Vaquería, Pastocalle (LVP)			University of the Armed Forces (ESPE-IASA I) (IASA)		
Ecosystem	Wet wasteland (WEW)			Wet wasteland (WEW)		
Soil type	Undeveloped, slightly developed (2a)			Brown with muddy clay minerals (2b)		
Moisture area	Dry zone (8-10 dry months) (DZ)			Very humid zone (1-4 dry months) (VHZ)		
Annual precipitation	<500			1,000-2,000		
Average temperature (°C)	<9			<9		
Land area	Anthropized			Mixed		
Altitude (max-min)	3,324.0-3,441.0			2,700.0-2,714.0		
Subsample site	**Cultivated**					
1	Poaceae	*Vicia avena*	S 0° 42.443 W 78 39.132	Rutaceae	*Citrus limon*	S 0° 23.029 - W 78° 24.889
2	Fabaceae	*Medicago sativa*	S 0° 42.436 W 78 38.944	Rosaceae	*Prunus persica*	S 0° 23.025 - W 78° 24.897
3	Solanaceae	*Solanum tuberosum*	S 0° 42.554 W 78 38.782	Solanaceae	*Solanum betaceum*	S 0° 23.024 - W 78° 24.899
4	Poaceae	*Zea mays*	S 0° 42.552 W 78 38.796	Passifloraceae	*Passiflora tacsonia*	S 0° 23.021 - W 78° 24.900
5	Fabaceae	*Lupinus mutabilis*	S 0° 42.556 W 78 39.496	Fabaceae	*Phaseolus vulgaris*	S 0° 23' 02.7 - W 78° 24' 537
	Non-Cultivated					
1	Asteraceae	*Baccharis latifolia*	S 0° 42.028 - W 78° 39.427	Malvaceae	*Hibiscusrosa-sinensis*	S 0° 23.071 - W 78° 24.937
2	Solanaceae	*Solanum nigrum*	S 0° 42.027 - W 78° 39.426	Adoxaceae	*Sambucus nigra*	S 0° 23.071 - W 78° 24.940
3	Asteraceae	*Taraxacum officinale*	S 0° 42.014 - W 78° 39.420	Lamiaceae	*Mentha piperita*	S 0° 23.078 - W 78° 24.938
4	Betulaceae	*Alnus jorullensis*	S 0° 41.983 - W 78° 39.389	Onagraceae	*Oenothera tetragona*	S 0° 23.077 - W 78° 24.941
5	Solanaceae	*Lochroma fuchsioides*	S 0° 42.088 - W 78° 39.436	Geraniaceae	*Pelargonium hortorum*	S 0° 23.090 - W 78° 24.939

2.2.2. Sampling

Priority was given to areas cultivated with small crops typical of each region, as well as in nearby undisturbed areas. In each region, five sites were selected (20 to 70 km distance between sample sites). From each site, 10 soil and 10 litter samples were taken (5 to 300 m distance between subsamples sites); each subsample was taken from the top 5 cm layer of either soil or litter (Duarte 2013; Santos 2013). Each sample was made up of four subsamples, within an area corresponding to the canopy projection of each plant, forming a total of 1 dm^3 in volume of soil and an equal volume of litter. Each sample was placed in a container and then placed in a plastic bag, which was stored in a cooled polystyrene thermal box for transport to the laboratory, keeping the temperature inside between 15 and 20 °C, with artificial ice (Figure 2).

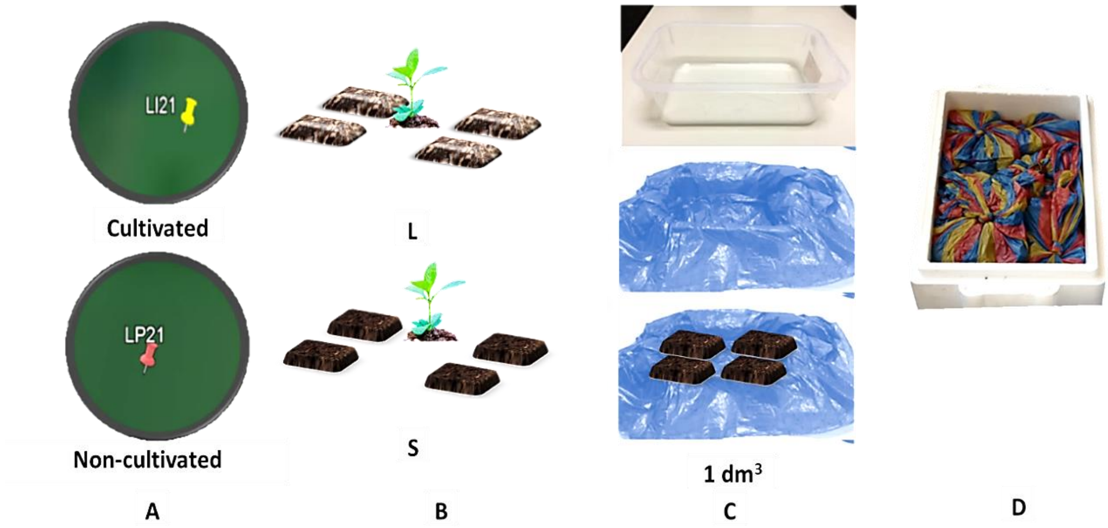

Figure 2. A. Sampling sites cultivated (C) and non-cultivated (Nc). **B**. Four subsamples, corresponding to the canopy projection of a chosen plant, litter (L) and soil (S) samples. **C**. Each sample was placed in a container and then packed in a plastic bag (1 dm^3) and placed in a polystyrene thermic box (**D**).

2.2.3. Mite extraction

The extraction of mites from the samples was carried out with modified Berlese-Tullgren funnels, placing each sample upside down in a funnel. The moving organisms moved away from the higher temperatures at the surface, to fall in a vial containing with 70.0 % ethanol solution. The samples remained in the funnel for five days; on the first day, the lamps were off, but from the second day, the temperature was gradually increased, by increasing the intensity of the light at each day, in order to allow a gradual increase in temperature (about 5.0 °C) until reaching 50.0 °C (Figure 3).

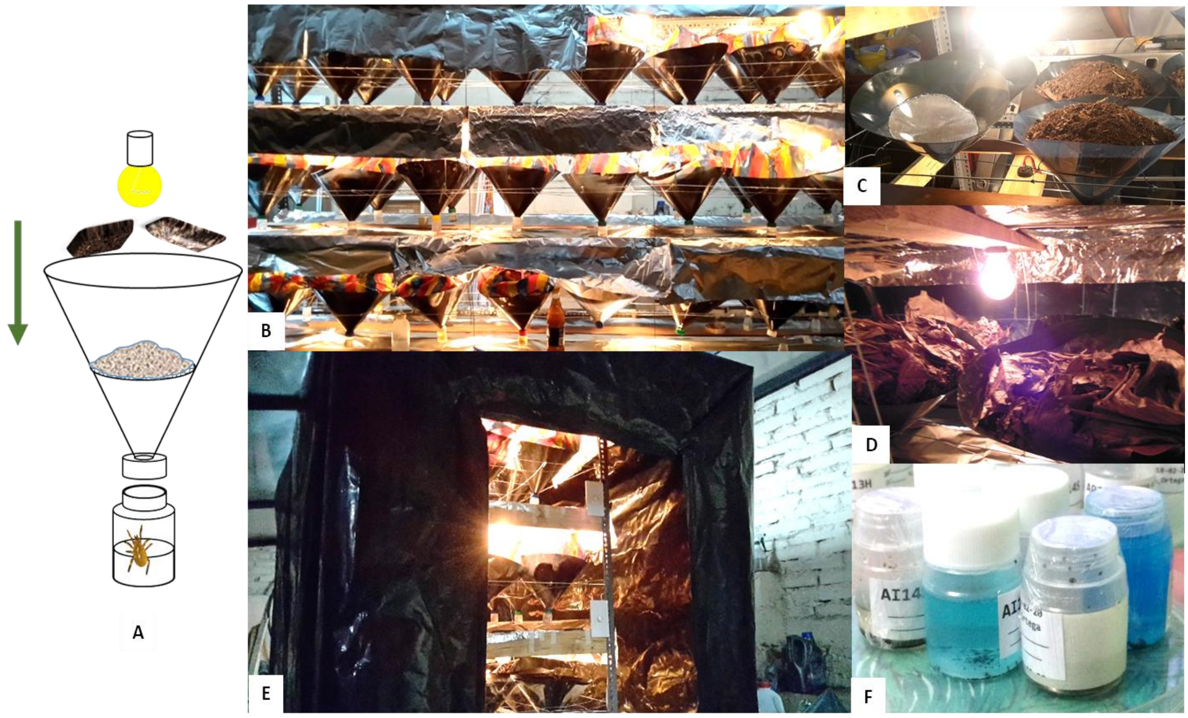

Figure 3. Extraction of mites from samples of soil and litter from three regions of Ecuador, with modified Berlese-Tullgren funnels. **A**. Funnel with light to generate heat; **B**. Arrangement of funnels in structure; **C** and **D**. Arrangement of soil and litter in funnels; **E.** External structure where the funnels were arranged to control temperature and humidity; **F.** Vial with 70.0 % ethanol where the mites were collected.

2.2.4. Screening and identification

The material collected in each vial was filtered through two 1.0 mm and 0.5 mm sieves to remove dirt, transferring the mites to Petri dishes, under a stereomicroscope at 40X magnification. The mites were then separated by orders and placed in vials with 70 % ethanol and later mounted on slides with Hoyer's medium (Moraes & Flechtmann 2008). The slides were then placed in an oven (40-50 °C) for 10 days and finally sealed with acrylic varnish, avoiding the rehydration of the mounting medium.

Identification of mite families, genera and species was done based on Krantz & Walter (2009), Krantz & Ainscough (1990), Lindquist *et al.* (2009) keys and, also in the unpublished keys of the Summer Acarology Course offered at "Ohio State University", Columbus, Ohio, USA and in the Mesostigmata Mites Recognition Training offered at the "Luiz de Queiroz" College of Agriculture (ESALQ), University of São Paulo (USP), Piracicaba, Brazil. Identification to species, whenever possible, was done by comparisons with original descriptions and redescriptions (available in the bibliographic collection of Prof. Gilberto José de Moraes) and by comparison with specimens deposited in the Mite Reference Collection of the Department of Entomology and Acarology of the University of Sao Paulo-ESALQ. Other works used in the identification process were: Britto (2011); Castilho (2008); Castilho *et al.* (2012a); Castilho *et al.* (2016); Castilho & Moraes (2010); Santos (2013); Evans (1963); Evans & Till (1965, 1979); Johnston & Moraza (1991); Lee (1970); Lindquist (1994); Lindquist & Moraza (2008); Moraes *et al.* (2016); Moreira *et al.* (2014); Santos *et al.* (2013, 2015, 2017c, b; a); Silva (2002); Silva *et al*. (2004). The identification of the Uropodina specimens was done at Ohio State University by Prof. Hans Klompen.

2.2.5. Analysis

2.2.5.1. Descriptive analysis

First, a descriptive analysis in terms of percentage was carried out to know the number of orders, families, genera and species per region, environment and substrate.

2.2.5.2. Non-parametric analysis

Second, a non-parametric analysis was made to compare the abundance of mites at the family level by region, environment and substrate. The Wilcoxon with Kruskal-Wallis and the one way with Chi-Square approximation tests were used to compare the median range of the samples and to determine whether there were significant differences among them. These tests were performed using the JMP software (SAS 2021).

2.2.5.3. Ecological analysis

To end the analyzes, richness, diversity and dominance of species of mesostigmatids mites identified in the three regions and, the effect of the environments (non-cultivated and cultivated) and the substrates (soil and litter), was measured with the *alpha* (α) component of diversity and its indexes (diversity within communities).

Initially, the method based on the quantification of the number of species present was used, referring to specific **richness** (*S*), with Margalef's index. This method takes into account the numerical distribution of the individuals of different species as a function of the total number of species in the sample. The minimum value for this index is zero, which occurs when there is only one species in the sample (Magurran 2004; Moreno 2001).

Secondly, a method based on the community structure was applied, that is, the proportional distribution of the importance value of each species. This method can in turn be classified according to whether they are based on dominance or community equity (Moreno 2001).

For **dominance**, Simpson dominance Index was calculated, which is a measure of how a species can dominate a community. Values close to 1 indicates that the species are dominant and close to 0, that they are non-dominant (Magurran 1988). In addition, **community equity**, was calculated with Shannon-Wiener index, whose values vary from 0 to 4, where values close to 0 are considered low, values close to 2.0 are intermediate and values above 2.5, high. For the analysis of biodiversity, the PAST statistical software was used (Hammer *et al.* 2013).

Additionally, to compare the diversity of morphospecies between the three regions, two environment and two substrates, ***beta*** **diversity** was calculated. *Beta* diversity allows the comparison of only two data sources at a time, for this case, as there are three regions, it is possible to compare two regions each time. For this, the coefficient of similarity of Sorense was used; the result of this data is presented as percentage. This coefficient shows how many morphospecies are similar when comparing between regions, environments and substrates sampled. The following formulas were applied for this purpose:

Beta **Diversity**:

Coefficient of similarity of Sorensen: relates the number of species in common with the arithmetic mean of the species in two data sources (two regions (each time), two environments and two substrates) (Magurran 1988).

$$I_S = \frac{2c}{a+b}$$

a = number of species present in the region A
b = number of species present in the region B
c = number of species present in both regions A and B

Last, the ***gamma*** diversity component was measured, to compare the diversity of morphospecies between the three regions. This component allows the comparison of geographical areas, in this case the three sampled regions. As previously mentioned, this can be measured with three formulas. For this case it was based on the Shannon index. The following formulas were applied for this purpose:

***Gamma* diversity**: calculation based on the Shannon index:

First, the beta diversity is calculated:

$$H'Beta = -\sum_i P_i \, LnP_i - \sum_j q_j H_j$$

Where:

$$P_i = \sum q_j \, p_{ij}$$

represents the average frequency of species *i* in the set of regions, weighted according to the importance of the communities (*qj*).

The first part of the formula is derived based on these averages by species (P_i):

$$-\sum_i P_i \, LnP_i$$

The second part of the formula uses the Shannon index calculated for each region, and the importance value for each region:

$$\sum_j q_j H_j$$

Gamma = *alfa diversity* + *beta diversity*

In this case, *alfa* = Shannon average

2.3. Results

2.3.1. Groups of mites identified

A total of 27,361 mites (adults and immatures) were collected, approximately 67.0 % of the suborder Oribatida (including Astigmatina), 18.6 % of the order Mesostigmata (non-Uropodina cohort), 4.9 % of the order Mesostigmata (Uropodina), 10.0 % of suborder Prostigmata. Within this last group, 4.3 % could be partially identified (Cunaxidae 1.1 %, Bdellidae 0.1 % and 3,1 % unidentified). Other prostigmatids mites could be separated, among which Erythraeidae, Tetranychidae, Trombidiidae and Tydeidae (5.3 %) (Table 2).

About 42.2 % of the mites were found in the Highland, 38.3 % in the Amazon and 19.6 % in the Coast (Table 2).

2.3.2. Mesostigmatid fauna

2.3.2.1. Abundance of mesostigmatid mites

In total, 5,086 non-Uropodina Mesostigmata were identified from the three regions. Considering only the number of these mesostigmatids, the greatest abundance occurred in the Highland, followed by the Amazon and last in the Coast (2,209; 2,105 and 772; respectively) (Table 2).

The third most abundant group, were the Mesostigmata- Uropodina, with 1,342 mites. Considering only this group, the greatest abundance occurred in the Amazon, followed very closely by the Coast and last by the Highland (588, 566 and 188, respectively) (Table 2).

Table 2. Groups of edaphic mites identified from three geographical regions of Ecuador, sampled in two environments (cultivated and non-cultivated) and in two substrates (soil and litter) in wet season of 2018.

Group	Amazon	%	Coast	%	Highland	%	Total	%
Oribatida (Including Astigmatina)	7,201	68.80	3,703	69.16	7,401	64.13	18,305	**66.90**
Mesostigmata-Monogynaspida-non-Uropodina	2,105	20.11	772	14.42	2,209	19.14	5,086	**18.59**
Mesostigmata-Monogynaspida-Uropodina	588	5.62	566	10.57	188	1.63	1,342	**4.91**
Mesostigmata-Trigynaspida	1	0.01			1	0.01	2	**<0.01**
Prostigmata	516	4.93	277	5.17	389	3.37	1,182	**4.32**
Cunaxidae (Eupodides)	125	1.19	127	2.37	58	0.50	310	1.13
Bdellidae (Eupodides)	9	0.09	19	0.36	2	0.02	30	0.11
Other Eupodides	382	3.65	131	2.45	329	2.85	842	3.08
Other Prostigmata	56	0.54	36	0.67	1,352	11.72	1,444	**5.28**
Total	**10,467**	**100**	**5,354**	**100**	**11,540**	**100**	**27,361**	**100**
%	**38.3**		**19.6**		**42.2**			

2.3.2.2. Developmental stages of mesostigmatids

The mesostigmatid mites (4,699 mites) were mounted and differentiated between adults (females and males) and immature stages. Considering the total number for the three regions, 52.7 % were immatures, followed by adult females (36.0 %) and last, adult males (11.3 %). This proportion was maintained within each the three regions (Table 3).

Table 3. Immature and adult edaphic mesostigmatids non-Uropodina mites identified from three geographical regions of Ecuador, sampled in two environments (cultivated and non-cultivated) and in two substrates (soil and litter) in wet season of 2018.

Region	Immature	%	Female	%	Male	%	Total	%
Highland	1,046	47.9	833	38.2	304	13.9	2,183	100.0
Amazon	1,014	53.8	670	35.5	201	10.7	1,885	100.0
Coast	417	66.1	188	29.8	26	4.1	631	100.0
Total	**2,477**		**1,691**		**531**		**4,699**	
% Total	**52.7**		**36.0**		**11.3**			

2.3.2.3. Mesostigmatid mites identified by environments and substrates

As for the identification of families of the non-Uropodina mesostigmatids, only adults were used. Thus, 2,209 mites could be identified up to family.

The Highland region had the highest percentage of mesostigmatid mites (52.7 %), with 16 families, followed by the Amazon with 13 families and the Coast with nine families identified (respectively 37.6 and 9.7 %). The families with the highest number of mites were: Ologamasidae, Ascidae, Laelapidae and Parasitidae (respectively 22.3, 16.2, 15.8 and 13.2 %) (Table 4).

Table 4. Numbers of families of edaphic mesostigmatid non-Uropodina mites collected in three regions of Ecuador (Amazon, Coast, Highland) in two environments (non-cultivated and cultivate) and two substrates (soil and litter) in wet season of 2018.

Region	**Amazon**				**Coast**				**Highland**				**Total**	**%**
Environment	**Non-cultivate**		**Cultivate**		**Non-cultivate**		**Cultivate**		**Non-cultivate**		**Cultivate**			
Substrate/Family	**Soil**	**Litter**	**Soil**	**Litter**	**Soil**	**Litter**	**Soil**	**Litter**	**Soil**	**Litter**	**Soil**	**Litter**		
Ologamasidae	34	19	35	41	6	59	8	9	207	45	11	18	**492**	**22.3**
Ascidae	10	118	11	53		5	2	40	2	62	21	34	**358**	**16.2**
Laelapidae	60	18	43	40	4	28	7	13	38	5	79	15	**350**	**15.8**
Parasitidae	80	10	34	14				1	58	21	32	41	**291**	**13.2**
Blattisociidae	27	3	13	9		6		4	56	23	5	6	**152**	**6.9**
Digamasellidae		4	1	1					11	3	57	29	**106**	**4.8**
Rhodacaridae	21	17	20	8					16		11	9	**102**	**4.6**
Macrochelidae	1	24	6	9		5	1	1	20	7	14	11	**99**	**4.5**
Phytoseiidae	2	4		11		3	2	6	1	18	9	37	**93**	**4.2**
Veigaiidae	9	1	1	1					13		7	13	**45**	**2.0**
Pachylaelapidae									2	1	13	28	**44**	**2.0**
Unknown			6						18	16	2	1	**43**	**1.9**
Amesoseiidae								1	1	12			**14**	**0.6**
Melicharidae	1			6		3		1		1			**12**	**0.5**
Parholaspididae		1	2	1					3				**7**	**0.3**
Eviphididae									1				**1**	**0.0**
Total	**245**	**219**	**172**	**194**	**10**	**109**	**20**	**76**	**447**	**214**	**261**	**242**	**2,209**	**100**

Considering all regions together, mite number was higher in non-cultivated than in cultivated sites (respectively 56.3 and 43.7 %) (Table 5). The same pattern was observed within each of the three regions.

Also, for the three regions considered together, mites were more abundant in soil than in litter samples (respectively 52.3 and 47.7 %) (Table 5). When observing the percentage of mites per substrate in each region, for the Amazon and the Highland, more mites were identified in soil than in litter (respectively 50.2 and 49.8 % and 60.8 and 39.2 %), while in the Coast it was the opposite, less mites being found in the litter than in the soil (respectively 14.0 and 86.0 %).

Table 5. Total numbers of mesostigmatid non-Uropodina mites collected in three regions of Ecuador (Amazon, Coast, Highland) in two environments (non-cultivated and cultivate) and two substrates (soil and litter) in wet season of 2018.

Region	Amazon		Coast		Highland		Total	
	Number	%	Number	%	Number	%	Number	%
Totals	830	37.6	215	9.7	1,164	52.7	2,209	
Environment								
Non-Cultivated	464	55.9	119	55.3	661	56.8	1244	56.3
Cultivated	366	44.1	96	44.7	503	43.2	965	43.7
Substrate								
Soil	417	50.2	30	14.0	708	60.8	1155	52.3
Litter	413	49.8	185	86.0	456	39.2	1054	47.7

2.3.2.4. Genera and morphospecies of mesostigmatids

In total, 53 non-Uropodina mesostigmatid genera were identified. The families with the greatest diversity were Parasitidae and Phytoseiidae, with seven genera each. Laelapidae and Macrochelidae had six and five genera, respectively (Table 6). Other families had less than five genera.

A total of 193 morphospecies was identified, Laelapidae and Phytoseiidae having the highest diversity (respectively 45 and 26 morphospecies). The remaining families had each less than 20 species.

The 732 Uropodina collected were identified in 18 genera and 20 morphospecies. In this group all stages were identified (Table 6). The most abundant families were Trematuridae, Uroactiniidae and Nenteriidae (218, 186 and 173 mites, respectively). The Urodinychidae had the highest number of genera and morphospecies (3), the others with two and one genera and morphospecies.

Table 6. Families, genera and morphospecies of edaphic Mesostigmata mites collected in three regions of Ecuador (Amazon, Coast, Highland) in two environments (non-cultivated and cultivated) and two substrates (soil and litter) in wet season of 2018.

Family	Total	%	Genus	%	Morphospecies	%
			Non-Uropodina			
Ologamasidae	468	23.9	2	3.8	18	9.3
Ascidae	351	17.9	3	5.7	18	9.3
Laelapidae	308	15.7	6	11.3	45	23.3
Parasitidae	157	8.0	7	13.2	12	6.2
Blattisociidae	149	7.6	4	7.5	19	9.8
Macrochelidae	93	4.7	5	9.4	19	9.8
Digamasellidae	92	4.7	4	7.5	7	3.6
Rhodacaridae	91	4.6	4	7.5	8	4.1
Phytoseiidae	87	4.4	7	13.2	26	13.5
Veigaiidae	45	2.3	2	3.8	6	3.1
Pachylaelapidae	43	2.2	2	3.8	2	1.0
Unknown (*Zygoseius*)	41	2.1	1	1.9	3	1.6
Amesoseiidae	14	0.7	2	3.8	3	1.6
Melicharidae	12	0.6	2	3.8	4	2.1
Parholaspididae	7	0.4	1	1.9	2	1.0
Eviphididae	1	0.1	1	1.9	1	0.5
Total	**1959**	**100**	**53**	**100**	**193**	**100**
			Uropodina			
Trematuridae	218	29.8	2	11.1	2	10.0
Uroactiniidae	186	25.4	1	5.6	1	5.0
Nenteriidae	173	23.6	1	5.6	1	5.0
Trachyuropodidae	52	7.1	1	5.6	1	5.0
Uropodidae	45	6.1	2	11.1	2	10.0
Urodinychidae	25	3.4	3	16.7	3	15.0
Trachytidae	11	1.5	1	5.6	2	10.0
Discourellidae	9	1.2	1	5.6	1	5.0
Rotundabaloghiidae	6	0.8	2	11.1	2	10.0
Clausiadinychidae	2	0.3	1	5.6	1	5.0
Oplitidae	2	0.3	1	5.6	1	5.0
Trichouropodellidae	2	0.3	1	5.6	2	10.0
Macrodinychidae	1	0.1	1	5.6	1	5.0
Total	**732**	**100.0**	**18**	**100**	**20**	**100**

It was possible to identify 1,959 non-Uropodina mesostigmatid mites up to morphospecies. Table 7 shows that the most abundant genera were *Asca*, *Gamasiphis*, *Neogamasellevans* and *Gaeolaelaps* (308, 275, 193 and 168 mites, respectively), whereas the most diverse genera were *Gaeolaelaps, Cosmolaelaps, Gamasiphis* and *Asca* (17, 16, 15 and 14 morphospecies, respectively).

In relation to the number of specimens, the highest abundance was found in the Highland with 52.8 %, followed by the Amazon with 36.7 % and finally the Coast, with 10.5 % (Table 6). Considering all Mesostigmata collected, the most abundant morphospecies were *Asca* aff. *garmani* (7.8 %), *Gamasiphis* possibly n. sp. 1 (5.5 %), *Neogamasellevans* n. sp. 2 (5.0 %), *Neogamasellevans* n. sp. 1 (4.5 %) and *Gamasiphis* possibly n. sp. 2 (3.7 %), other morphospecies had a frequency of at most 3.7 %.

Among the collected mites, 13 new species were identified, belonging to six families Ascidae (*Gamasellodes*), Blattisociidae (*Cheiroseius*), Laelapidae (*Gaeolaelaps*), Macrochelidae (two *Holostaspella* and two *Macrocheles* species) and Ologamasidae (two *Neogamasellevans* and three *Gamasiphis* species. One of the new *Gamasiphis* species is described in Chapter 3). A new species of a possibly new genus of Melicharidae was also found. (Table 7).

About the Uropodina species, 13 families, 19 genera and 20 species were identified. One of these, *Trichodinychus sellnickioides* (Trematuridae), being the most abundant species (213 mites), follow by *Uroactinia* sp. and *Ruehmnenteria* aff. *longispinosa* (186 and 173 mites, respectively) (Table 7).

Table 7. Morphospecies of edaphic Mesostigmata (including Uropodina) mites identified in three regions of Ecuador (Amazon, Coast, Highland) in two environments (non-cultivated and cultivated) and two substrates (Soil and litter) in wet season of 2018.

Family/Genus/Morphospecies	**Region**						
	Amazon	**%**	**Coast**	**%**	**Highland**	**%**	**Total**
Amesoseiidae							
Ameroseius sp. 1			1	100.0			**1**
Epicriopsis sp. 1					9	100.0	**9**
Epicriopsis sp. 2					4	100.0	**4**
Ascidae							
Asca aff. *garmani*	114	75.0			38	25.0	**152**
Asca aff. *holosternalis*	6	40.0			9	60.0	**15**
Asca aff. *longotonsoris*					4	100.0	**4**
Asca sp. 1			1	100.0			**1**
Asca sp. 2	1	100.0					**1**
Asca sp. 3	2	5.4	35	94.6			**37**
Asca sp. 5	5	100.0					**5**
Asca sp. 6	3	14.3			18	85.7	**21**

Family/Genus/Morphospecies	Region						
	Amazon	**%**	**Coast**	**%**	**Highland**	**%**	**Total**
Asca sp. 7					2	100.0	**2**
Asca sp. 8					2	100.0	**2**
Asca sp. 10	45	71.4			18	28.6	**63**
Asca sp. 11					2	100.0	**2**
Asca sp. 12					2	100.0	**2**
Asca sp. 13			1	100.0			**1**
Arctoseius sp. 1					20	100.0	**20**
Gamasellodes pos. n. sp.	15	71.4	4	19.0	2	9.5	**21**
Gamasellodes sp. 1					1	100.0	**1**
Gamasellodes sp. 2			1	100.0			**1**
Blattisociidae							
Cheiroseius granulosus Karg					2	100.0	**2**
Cheiroseius ornatus Evans & Hyatt					5	100.0	**5**
Cheiroseius n. sp. 1					1	100.0	**1**
Cheiroseius sp. 1	1	50.0	1	50.0			**2**
Cheiroseius sp. 2			1	100.0			**1**
Cheiroseius sp. 3	1	100.0					**1**
Cheiroseius sp. 4	1	33.3			2	66.7	**3**
Cheiroseius sp. 5	29	100.0					**29**
Cheiroseius sp. 6	8	44.4	2	11.1	8	44.4	**18**
Cheiroseius sp. 7					61	100.0	**61**
Lasioseius barbensiensis Faraji & Karg					4	100.0	**4**
Lasioseius floridensis Berlese	5	71.4	2	28.6			**7**
Lasioseius sp. 1	2	40.0	1	20.0	2	40.0	**5**
Lasioseius sp. 2	1	100.0				0.0	**1**
Lasioseius sp. 3					1	100.0	**1**
Lasioseius sp. 4	2	100.0					**2**
Lasioseius sp. 5					1	100.0	**1**
Platyseius parvoechinus Karg			3	75.0	1	25.0	**4**
Zercoseius spathuliger Leonardi					1	100.0	**1**
Digamasellidae							
Dendrolaelaps sp. 1					54	100.0	**54**
Dendrolaelaps sp. 2	2	100.0					**2**
Dendrolaelaps sp. 3					1	100.0	**1**
Dendrolaelaps sp. 4	2	100.0					**2**
Insectolaelaps sp. 1	2	100.0					**2**
Dendroseius sp. 1					11	100.0	**11**
Oligodentatus sp. 1					20	100.0	**20**
Eviphididae							
aff. Copriphis sp. 1					1	100.0	**1**
Laelapidae							
Cosmolaelaps barbatus Moreira, Klompen & Moraes	7	63.6	4	36.4			**11**
Cosmolaelaps bipennatus Karg					1	100.0	**1**
Cosmolaelaps bussoli Moreira, Klompen & Moraes					1	100.0	**1**

Family/Genus/Morphospecies	Region						
	Amazon	%	Coast	%	Highland	%	Total
Cosmolaelaps jaboticabalensis Moreira, Klompen & Moraes	11	52.4	10	47.6			**21**
Cosmolaelaps panniculus Karg			1	100.0			**1**
Cosmolaelaps sp. 1			1	100.0			**1**
Cosmolaelaps sp. 2					7	100.0	**7**
Cosmolaelaps sp. 3	2	100.0					**2**
Cosmolaelaps sp. 4	1	100.0					**1**
Cosmolaelaps sp. 5			6	100.0			**6**
Cosmolaelaps sp. *6*	20	100.0					**20**
Cosmolaelaps sp. 7	2	100.0					**2**
Cosmolaelaps sp. 8	1	100.0					**1**
Cosmolaelaps sp. 9	3	100.0					**3**
Cosmolaelaps sp. 10	2	100.0					**2**
Cosmolaelaps sp. 11	13	100.0					**13**
Gaeolaelaps aculeifer Canestrini					29	100.0	**29**
Gaeolaelaps brevipelis Karg	2	66.7			1	33.3	**3**
Gaeolaelaps cerrii Marticorena, Moreira & Moraes	25	100.0					**25**
Gaeolaelaps queenslandicus Womersley	24	70.6	2	5.9	8	23.5	**34**
Gaeolaelaps sp. 1					56	100.0	**56**
Gaeolaelaps sp. 2	1	100.0					**1**
Gaeolaelaps sp. 3					3	100.0	**3**
Gaeolaelaps sp. 4					2	100.0	**2**
Gaeolaelaps sp. 5					1	100.0	**1**
Gaeolaelaps sp. 6			2	100.0			**2**
Gaeolaelaps sp. 7			1	100.0			**1**
Gaeolaelaps sp. 8			1	100.0			**1**
Gaeolaelaps sp. 9	1	100.0					**1**
Gaeolaelaps sp. 10	1	100.0					**1**
Gaeolaelaps sp. 11	2	100.0					**2**
Gaeolaelaps sp. 12	1	33.3			2	66.7	**3**
Gaeolaelaps n. sp.					3	100.0	**3**
Oloopticus pinguis Karg	2	100.0					**2**
Oloopticus sp. 2	3	75.0	1	25.0			**4**
Pseudoparasitus ocularis Hunter	7	25.0	21	75.0			**28**
Pseudoparasitus sp. 1				0.0	1	100.0	**1**
Pseudoparasitus sp. 2					1	100.0	**1**
Pseudoparasitus sp. 3	3	75.0	1	25.0			**4**
Pseudoparasitus sp. 4					1	100.0	**1**
Pseudoparasitus sp. 5			1	100.0			**1**
Pseudoparasitus sp. 6	1	100.0					**1**
Pseudoparasitus sp. 7	1	100.0					**1**
Stratiolaelaps aff. *ornatissima*	2	100.0					**2**
Laelaspis aff. a*ngustiseta*					1	100.0	**1**
Macrochelidae							
Geholaspis sp. 1					1	100.0	**1**

Family/Genus/Morphospecies	Region						
	Amazon	%	Coast	%	Highland	%	Total
Glyptholaspis aff. *americana*			2	66.7	1	33.3	**3**
Glyptholaspis sp. 1	1	100.0					**1**
Holostaspella aff. *bifoliata*			2	100.0			**2**
Holostaspella aff. *polytrema*	3	100.0					**3**
Holostaspella sp. 1	2	100.0					**2**
Holostaspella pos. n. sp. 1	6	75.0			2	25.0	**8**
Holostaspella pos. n. sp. 2			3	100.0			**3**
Longicheles sp. 1					2	100.0	**2**
Macrocheles aff. *bolivares*	2	66.7			1	33.3	**3**
Macrocheles aff. *insignitus*	2	33.3			4	66.7	**6**
Macrocheles aff. *mammifer*	3	100.0					**3**
Macrocheles aff. *merdarius*	2	33.3			4	66.7	**6**
Macrocheles aff. *muscadomestica*	2	100.0					**2**
Macrocheles aff. *robustulus*	4	25.0			11	75.0	**15**
Macrocheles aff. *roquensis*	5	22.7			15	77.3	**20**
Macrocheles sp. 1	1	50.0			1	50.0	**2**
Macrocheles pos. n. sp.1	1	20.0			4	80.0	**5**
Macrocheles pos. n. sp. 2	6	100.0					**6**
Melicharidae							
Proctolaelaps sp. 1			4	100.0			**4**
Proctolaelaps sp. 2	4	80.0			1	20.0	**5**
Proctolaelaps sp. 3	1	100.0					**1**
N. g. & sp.	2	100.0					**2**
Ologamasidae							
Gamasiphis plenosetosus Karg	20	100.0					**20**
Gamasiphis salvadori Castilho, Narita & Moraes	15	57.7			11	42.3	**26**
Gamasiphis aff. *australicus*	1	12.5			7	87.5	**8**
Gamasiphis n. sp.	20	95.2	1	4.8			**21**
Gamasiphis sp. 1	2	100.0					**2**
Gamasiphis sp. 3					3	100.0	**3**
Gamasiphis sp. 4	3	100.0					**3**
Gamasiphis sp. 5	3	100.0					**3**
Gamasiphis sp. 6	1	100.0					**1**
Gamasiphis sp. 7			1	100.0			**1**
Gamasiphis sp. 8	2	66.7			1	33.3	**3**
Gamasiphis sp. 9	4	100.0					**4**
Gamasiphis sp. 10	1	100.0					**1**
Gamasiphis pos. n. sp. 1	31	29.0	51	47.7	25	23.4	**107**
Gamasiphis pos. n. sp. 2	11	15.3	26	36.1	35	48.6	**72**
Neogamasellevans sp. 1					9	100.0	**9**
Neogamasellevans n. sp. 1	7	8.0			80	92.0	**87**
Neogamasellevans n. sp. 2					97	100.0	**97**
Pachylaelapidae							
Onchodellus sp. 1					8	100.0	**8**
Pachylaelaps sp. 1					35	100.0	**35**

Family/Genus/Morphospecies	Region						
	Amazon	%	Coast	%	Highland	%	Total
Parasitidae							
Cycetogamasus sp. 1					12	100.0	**12**
Neogamasus sp. 1	48	92.3			4	7.7	**52**
Neogamasus sp. 2					6	100.0	**6**
Neogamasus sp. 3					3	100.0	**3**
Parasitus sp. 1					24	100.0	**24**
Parasitus sp. 2	2	100.0					**2**
Psilogamasus sp. 1	5	83.3			1	16.7	**6**
Phytiogamasus sp. 1	8	80.0			2	20.0	**10**
Rhabdocarpis sp. 1	1	20.0			4	80.0	**5**
Paragamasus sp. 1					7	100.0	**7**
Paragamasus sp. 2					12	100.0	**12**
Paragamasus sp. 3					18	100.0	**18**
Parholaspididae							
Gamasholaspis aff. *gamasoides*					2	100.0	**2**
Gamasholaspis aff. *lingualis*	4	80.0			1	20.0	**5**
Phytoseiidae							
Amblyseius aff. *pusillus*					1	100.0	**1**
Amblyseius sp. 1	2	40.0	1	20.0	2	40.0	**5**
Amblyseius sp. 2					2	100.0	**2**
Amblyseius sp. 3	3	100.0				0.0	**3**
Amblyseius sp. 4					1	100.0	**1**
Amblyseius sp. 5					1	100.0	**1**
Amblyseius sp. 6	1	100.0				0.0	**1**
Amblyseius sp. 7	1	20.0			4	80.0	**5**
Amblyseius sp. 8	1	100.0			0	0.0	**1**
Arrenoseius sp. 1	3	100.0			0	0.0	**3**
Arrenoseius sp. 2	1	100.0			0	0.0	**1**
Arrenoseius sp. 3					2	100.0	**2**
Neoseiulus barkeri Hughe			6	18.2	27	81.8	**33**
Neoseiulus gracilis Muma					1	100.0	**1**
Neoseiulus sp. 1					10	100.0	**10**
Neoseiulus sp. 2					1	100.0	**1**
Graminaseius sp. 1	1	100.0					**1**
Proprioseopsis sp. 1	2	66.7			1	33.3	**3**
Proprioseopsis sp. 2					1	100.0	**1**
Proprioseopsis sp. 3			1	100.0			**1**
Proprioseopsis sp. 4			1	100.0			**1**
Proprioseopsis sp. 5					2	100.0	**2**
Proprioseopsis sp. 6	1	100.0					**1**
Proprioseopsis sp. 7			1	100.0			**1**
Transeius sp. 1					1	100.0	**1**
Typhlodromips sp. 1					4	100.0	**4**
Rhodacaridae							
Multidentorhodacarus aff. *angustacuminis*	52	94.5			3	5.5	**55**

Family/Genus/Morphospecies	Region						
	Amazon	**%**	**Coast**	**%**	**Highland**	**%**	**Total**
Multidentorhodacarus aff. *diferenttis*	1	10.0			9	90.0	**10**
Multidentorhodacarus aff. *pennacornutus*	3	100.0					**3**
Multidentorhodacarus sp. 1					3	100.0	**3**
Proctogamasellopsis aff. *granulosus*					3	100.0	**3**
Proctogamasellopsis aff. *lectosomae*	2	100.0					**2**
Paragamasellevans sp. 1	2	20.0			8	80.0	**10**
Rhodacarus sp. 1	5	100.0					**5**
Veigaiidae							
Gamasolaelaps sp. 1	12	100.0					**12**
Veigaia sp. 1					10	100.0	**10**
Veigaia sp. 2					13	100.0	**13**
Veigaia sp. 3					6	100.0	**6**
Veigaia sp. 4					3	100.0	**3**
Veigaia sp. 5					1	100.0	**1**
Unknown							
Zygoseius sp. 1					7	100.0	**7**
Zygoseius sp. 2	5	100.0					**5**
Zygoseius sp. 3					29	100.0	**29**
Total	**719**	**36.7**	**205**	**10.5**	**1035**	**52.8**	**1959**
Uropodina							
Clausiadinychidae							
Clausiadinychus sp.							
Discourellidae			2	100.0			**2**
Discourella aff. *ishikawai*							
Macrodinychidae					9	100.0	**9**
Macrodinychus sp.							
Nenteriidae			1	100.0			**1**
Ruehmnenteria aff. *longispinosa*	1	0.6	130	75.1	42	24.3	**173**
Oplitidae							
Oplitis sp.			2	100.0			**2**
Rotundabaloghiidae							
Depressorotunda (*Amerorotunda*) sp.					4	100.0	**4**
Rotundabaloghia sp.	1	50.0			1	50.0	**2**
Trachytidae							
Uroseius aff. *rotundatus*					9	100.0	**9**
Uroseius sp.					2	100.0	**2**
Trachyuropodidae							
Origmatrachys aff. *peruensis/gracilis*	29	20.6	23	44.2			**52**
Trematuridae							
Trichodinychus sellnickioides Wisniewski & Hirschmann			213	100.0			**213**

Family/Genus/Morphospecies	Region						
	Amazon	%	Coast	%	Highland	%	Total
Trachycilliba sp.	5	100.0					**5**
Trichouropodellidae							
Trichouropodella baloghi Hirschmann			1	100.0			**1**
Trichouropodella sp.			1	100.0			**1**
Urodinychidae							
Caluropoda sp.	4	100.0					**4**
Prodinychus plaumanni Sellnick	1	11.1	8	88.9			**9**
Uroobovella sp.					12	100.0	**12**
Uropodidae							
*Foveolaturopoda*sp.			3	100.0			**3**
Penicillaturopoda sp. 19	42	29.8					**42**
Uroactiniidae							
Uroactinia sp.	58	31.2	116	62.4	12	6.5	**186**
Total	**141**	**19.26**	**500**	**68.3**	**91**	**12.4**	**732**

Additionally, Table 8 shows the most abundant morphospecies for each region, environments, and substrates. For this, data on the abundance of morphospecies less than 2.8 % for the Amazon and the Sierra and values less than 2.0 % for the Coast were not taken into account.

In the Amazon, with 100 identified morphospecies, *Asca* aff. *garmani* was the most abundant (15.9 %), followed by *Multidentorhodacarus* aff. *angustacuminis* (7.2 %), *Neogamasus* sp. 1 (6.7 %), *Asca* sp. 10 (6.3 %), and *Gamasiphis* possibly n. sp. 1. (4.3 %). Each of the other species accounted for less than 4,3 %. *Asca* aff. *garmani* was more abundant in the non-cultivated environment and litter substrate. In general, for morphospecies from Amazon region, abundance was higher in non-cultivated environment and in litter.

In the Coast, with 38 identified morphospecies, *Gamasiphis* possibly n. sp. 1 (24.9 %), as in the Amazon, appear among the most abundant, followed by *Asca* sp. 3 (17.1 %), *Gamasiphis* possibly n. sp. 2 (12.7 %), *Pseudoparasitus ocularis* Hunter (10.2 %) and *Cosmolaelaps jaboticabalensis* Moreira, Klompen & Moraes. Other species were less than 5.0 % in abundance. *Gamasiphis* possibly n. sp. 1, *Gamasiphis* possibly n. sp. 2, *P. ocularis*, *Cosmolaelaps* sp. 5, *C. barbatus* Moreira, Klompen & Moraes, and *Proctolaelaps* sp. 1 were more abundant in non-cultivated environment and all morphospecies were more abundant in the litter substrate. *Asca* sp. 3, as the morphospecies *Asca* sp. 10 in the Amazon were more abundant in non-cultivated environment and in the soil. In general, for morphospecies from

Coast region, higher abundance was observed in the non-cultivated environment and in the soil.

Finally in the Highland, with 111 identified morphospecies, the most abundant species was *Neogamasellevans* n. sp. 2 (9.4 %), followed by *Neogamasellevans* n. sp. 1 (7.7 %), *Cheiroseius* sp. 7 (5.9 %), *Gaeolaelaps* sp. 1 (5.4 %), *Dendrolaelaps* sp. 1 (5.2 %), *G. aculeifer* (2.8 %) and *Asca* aff. *garmani* 3.7 %). As in the Amazon, the last morphospecies appear among the most abundant. In general, for morphospecies from Highland, as in the Coast, higher abundance was observed in the non-cultivated environment and in the soil.

Within the identified morphospecies, seven were present in the three regions, ordered from highest to lowest abundance: *Gamasiphis* possibly n. sp. 1, *Gamasiphis* possibly n. sp. 2, *Gaeolaelaps queenslandicus* Womersley, *Gamasellodes* possibly n. sp., *Cheiroseius* sp. 6 and *Lasioseius* sp. 1 (Table 8).

Table 8. Most abundant morphospecies of mesostigmatid non-Uropodina mites from three regions of Ecuador (Amazon, Coast, Highland) in two environments (non-cultivated and cultivate) and two substrates (soil and litter).

Family	Morphospecies	Non-cultivated	Cultivated	Soil	Litter	N	%*
Amazon (total of 100 morphospecies)							
Ascidae	*Asca* aff. *garmani*	87	27	15	99	114	**15.9**
Rhodacaridae	*Multidentorhodacarus* aff. *angustacuminis*	29	23	28	24	52	**7.2**
Parasitidae	*Neogamasus* sp. 1	38	10	48		48	**6.7**
Ascidae	*Asca* sp. 10	15	30	43	2	45	**6.3**
Ologamasidae	*Gamasiphis* possibly n. sp. 1	15	16	19	12	31	**4.3**
Blattisociidae	*Cheiroseius* sp. 5	22	7		29	29	**4**
Laelapidae	*Gaeolaelaps cerrii* Marticorena, Moreira & Moraes	12	13	15	10	25	**3.5**
Laelapidae	*Gaeolaelaps queenslandicus* Womersley	16	8		24	24	**3.3**
Ologamasidae	*Gamasiphis* n. sp.	10	10		20	20	**2.8**
Laelapidae	*Cosmolaelaps* sp. *6*	2	18	11	9	20	**2.8**
Ologamasidae	*Gamasiphis plenosetosus* Karg	8	12	2	18	20	**2.8**
Total morphospecies**						**100**	
Coast (total of 38 morphospecies)							
Ologamasidae	*Gamasiphis* possibly n. sp. 1	43	8	46	5	51	**24.9**

Family	Morphospecies	Non-cultivated	Cultivated	Soil	Litter	N	%*
Ascidae	*Asca* sp. 3	1	34	33	2	35	**17.1**
Ologamasidae	*Gamasiphis* possibly n. sp. 2	20	6	19	7	26	**12.7**
Laelapidae	*Pseudoparasitus ocularis* Hunter	16	5	21	0	21	**10.2**
Laelapidae	*Cosmolaelaps jaboticabalensis* Moreira, Klompen & Moraes	2	8	6	4	10	**4.9**
Phytoseiidae	*Neoseiulus barkeri* Hughe	0	6	4	2	6	**2.9**
Laelapidae	*Cosmolaelaps* sp. 5	6	0	6	0	6	**2.9**
Ascidae	*Gamasellodes* possibly n. sp.	0	4	4	0	4	**2**
Laelapidae	*Cosmolaelaps barbatus* Moreira, Klompen & Moraes	4	0	3	1	4	**2**
Melicharidae	*Proctolaelaps* sp. 1	3	1	4	0	4	**2**
Total morphospecies**						**38**	
	Highland (total of 111 morphospecies)						
Ologamasidae	*Neogamasellevans* n. sp. 2	97	0	97	0	97	**9.4**
Ologamasidae	*Neogamasellevans* n. sp. 1	69	11	74	6	80	**7.7**
Blattisociidae	*Cheiroseius* sp. 7	55	6	58	3	61	**5.9**
Laelapidae	*Gaeolaelaps* sp. 1	1	55	48	8	56	**5.4**
Digamasellidae	*Dendrolaelaps* sp. 1		54	19	35	54	**5.2**
Ascidae	*Asca* aff. *Garmani*	27	11	3	35	38	**3.7**
Ologamasidae	*Gamasiphis* possibly n. sp. 2	30	5	23	12	35	**3.4**
Pachylaelapidae	*Pachylaelaps* sp. 1	1	34	13	22	35	**3.4**
Laelapidae	*Gaeolaelaps aculeifer* Canestrini	17	12	29	0	29	**2.8**
Unknown	*Zygoseius* sp. 3	28	1	17	12	29	**2.8**
Total morphospecies**						**111**	

* Percentage related to the total number of morphospecies for each region; ** Number of totals of morphospecies for each region.

2.3.2.5. Non-parametric analysis

2.3.2.5.1. Non-parametric analysis for families per region

Regarding the number of individuals per family, the results of the non-parametric analysis show that there is a significant difference with the 1-Way Test, Chi-square approximation (g.l.= 2; X^2= 28.3; p<0.0001). Nonparametric comparisons for each pair using Wilcoxon method show significant difference, when comparing the Coast with the other two regions (Highland *vs.* Coast: g.l.= 2; SED = 4.41; p<0.0001 and Amazon *vs.* Coast: g.l.= 2; SED = 4.21; p=0.0001) (Figure 4).

In the family comparison, the method makes 120 (N) combinations of pairs among families. From these combinations, only 51.0 % showed significant differences in terms of number of mites for each family with the 1-Way Test, Chi-square approximation (g.l.= 15; X^2= 85.5; p<0.0001) (Figure 5) (Appendix 1).

2.3.2.5.2. Non-parametric analysis for families per environment and substrate

There were no significant differences when comparing the abundance of specimens among families for the two environments and two substrates (Appendix 2A-B).

In addition, the number of mites per family was compared, within each region, individually. Hence, 43.3 % of the 120 combinations presented significant differences in the Amazon with the 1-Way Test, Chi-square approximation (g.l.=15; X^2= 51.8; p<0.0001), 19.2 % in the Coast, with the 1-Way Test, Chi-square approximation (g.l.=15; X^2= 43.7; p<0.0001), and 49.2 % in the Highland, with the 1-Way Test, Chi-square approximation (g.l.=15; X^2= 51.8; p<0.0001) (Figure 6A-C) (Appendix 3A-C).

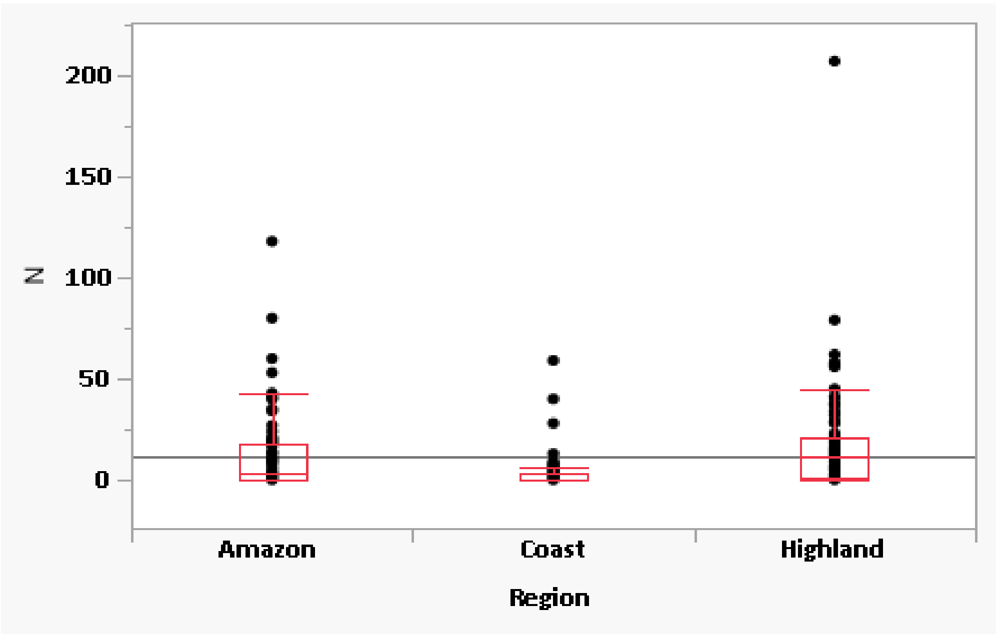

Figure 4. Non-parametric comparisons for abundance of edaphic Mesostigmatanon-Uropodina mites in three regions of Ecuador (Amazon, Coast, Highland), in two environments (non-cultivated and cultivated) and two substrates (soil and litter). N = number of mites. Each point shows the number of mites in the measured interaction (family-region-environment-substrate). The red boxes show the quartiles with the dispersion and central tendency of a data set.

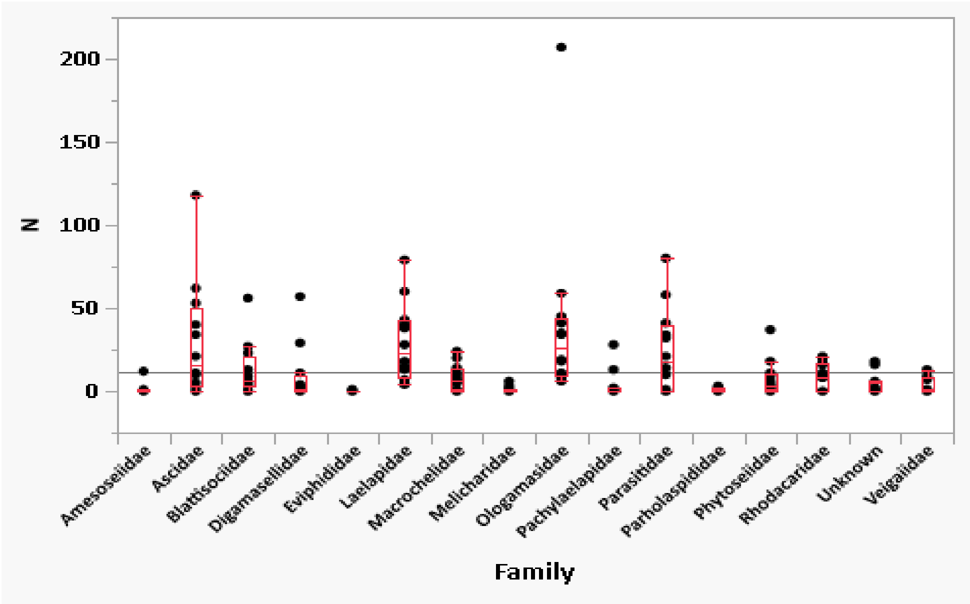

Figure 5. Non-parametric comparisons for 16 families of edaphic Mesostigmata non-Uropodina mites collected in three regions of Ecuador (Amazon, Coast, Highland), in two environments (non-cultivated and cultivated) and two substrates (soil and litter). N = number of mites. Each point shows the number of mites in the measured interaction (family-region-environment-substrate). The red boxes show the quartiles with the dispersion and central tendency of a data set.

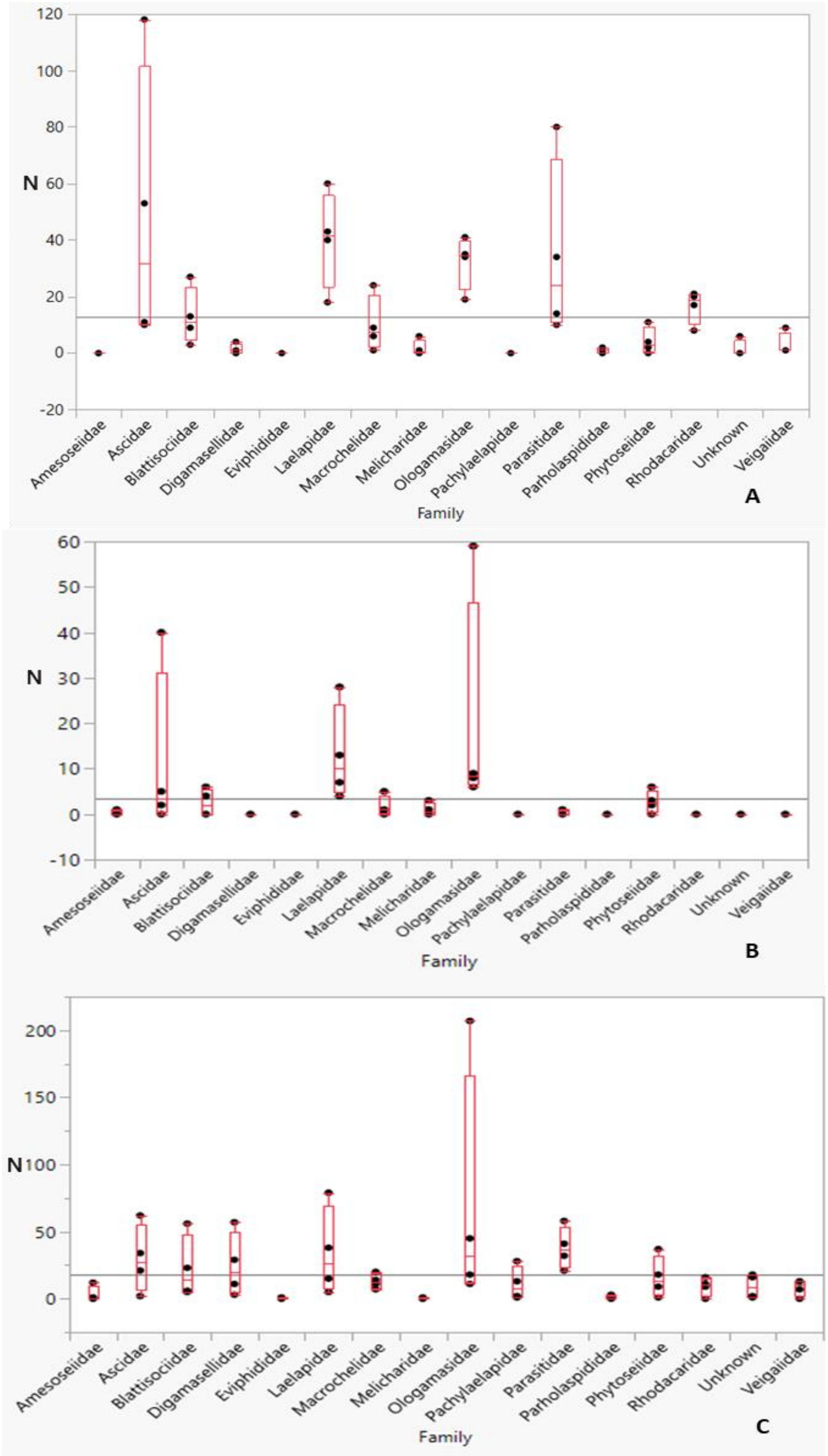

Figure 6. Non-parametric comparisons for families of edaphic Mesostigmata non-Uropodina mites collected in the **A**. Amazon, **B**. Coast, **C**. Highland region of Ecuador, in two environments (non-cultivated and cultivated) and two substrates (soil and litter). N = number of mites. Each point shows the number of mites in the measured interaction (family-region-environment-substrate). The red boxes show the quartiles with the dispersion and central tendency of a data set.

Finally, and continuing with the analysis for each region, the abundance of mites by environment and substrate was evaluated. No differences were observed in the Amazon and Highland region. For the Coast, there were differences between the number of mites between the substrates, with the 1-Way Test, Chi-square approximation (g.l.=1; X^2= 5.61; p<0.0178) (Figure 7).

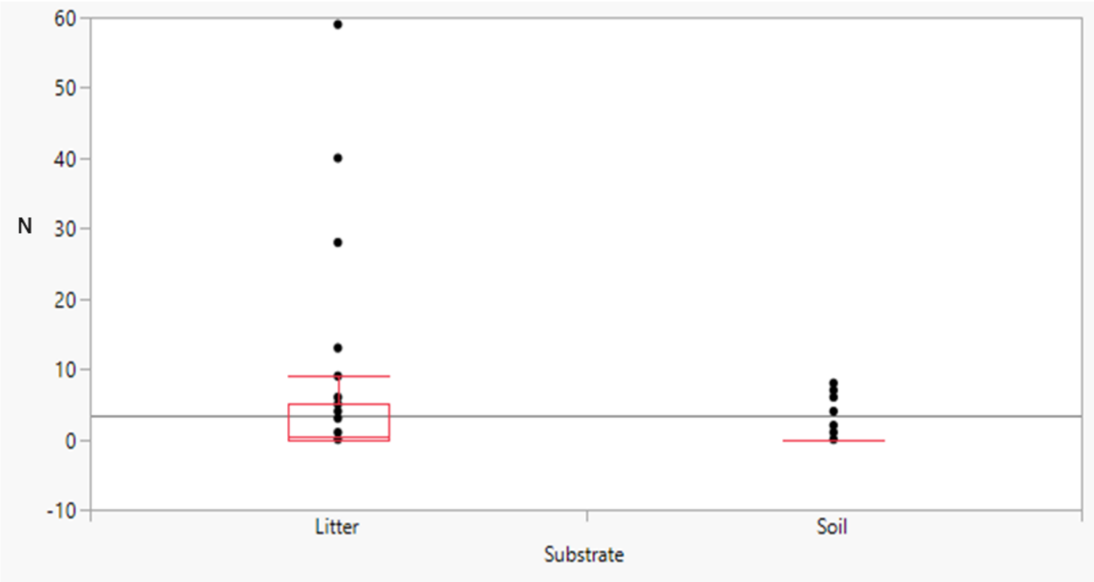

Figure 7. Non-parametric comparisons for two substrates (soil and litter) for families of edaphic Mesostigmata non-Uropodina mites collected Ecuador (Coast region) (N = number of mites). N = number of mites. Each point shows the number of mites in the measured interaction (family-region-environment-substrate). The red boxes show the quartiles with the dispersion and central tendency of a data set.

2.3.3. New reports for Ecuador

In addition to the high number of current reports for Ecuador belonging to the families identified in this study, as mentioned in Chapter 1, families, genera and species not previously reported are shown in Table 9.

That is the case of specimens of the Eviphididae family that have not previously been reported from Ecuador. In the same way, 22 new records of genera of the 16 families were identified: *Epicriopsis* (Ameroseiidae), *Zercoseius* (Blattisociidae); *Dendrolaelaps, Insectolaelaps* and *Dendroseoius* (Digamasellidae); *Coprophis* (Eviphididae); *Laelaspis* (Laelapidae); *Geholaspis, Glyptolaspis* and *Longicheles* (Macrochelidae); *Neogamasellevans* (Ologamasidae); *Onchodellus* (Pachylaelapidae); *Cycetogamasus, Neogamasus, Psilogamasus, Phytiogamasus, Rhabdocarpis, Paragamasus* (Parasitidae); *Graminaseius* and *Transeius* (Phytoseiidae) and *Paragamasellevans* and *Rhodacarus* (Rhodacaridae).

Likewise, 16 new records of species are reported in this work: *Cheiroseius ornatus* Evans & Hyatt, *Lasioseius floridensis* Berlese, *L. barbensiensis* Faraji & Karg, *Zercoseius spathuliger* Leonardi (Family: Blattisociidae); *Cosmolaelaps barbatus* Moreira, Klompen & Moraes, *C. jaboticabalensis* Moreira, Klompen & Moraes, *C. bussoli* Moreira, Klompen & Moraes, *C. panniculus* Karg, *Gaeolaelaps aculeifer* Canestrini, *G. brevipelis* Karg, *G. cerrii* Marticorena, Moreira & Moraes, *G. queenslandicus* Womersley, *Pseudoparasitus ocularis* Hunter, *Laelaspis angustiseta* Khalili-Moghadam, Saboori, Nemati & Golpayegani (Laelapidae); *G. salvadori* Castilho, Narita & Moraes (Ologamasidae); *Neoseiulus barkeri* Hughe and *N. gracilis* Muma (Phytoseiidae).

Finally, four families of Uropodina (Macrodinychidae, Oplitidae, Trachyuropodidae and Trichouropodellidae), nine genera with their respective morphospecies (*Caluropoda* sp., *Depressorotunda* (*Amerorotunda*) sp., *Macrodinychus* sp., *Origmatrachys* aff. *peruensis/gracilis*, *Penicillaturopoda* sp., *Prodinychus plaumanni* Sellnick, *Ruehmnenteria* aff. *longispinosa*, *Trachycilliba* sp., *Trichouropodella baloghi* Hirschmann) are reported for the first time from Ecuador (Table 9).

Table 9. New reports of families, genera, and species of edaphic mesostigmatid mites identified from three regions of Ecuador (Amazon, Coast and Highland) in two environments (non-cultivated and cultivate) and two substrates (Soil and litter).

Family-Genus-Specie	New report		
	Family	Genus	Species
Amesoseiidae			
Epicriopsis sp. 1		X	
Blattisociidae			
Cheiroseius granulosus Karg			
Cheiroseius ornatus Evans & Hyatt			X
Lasioseius floridensis Berlese			X
Lasioseius barbensiensis Faraji & Karg			X
Platyseius parvoechinus Karg			
Zercoseius spathuliger Leonardi		X	X
Digamasellidae			
Dendrolaelaps sp. 1		X	
Insectolaelaps sp. 1		X	
Dendroseius sp. 1		X	
Eviphididae	X		
Copriphis sp. 1		X	
Laelapidae			
Cosmolaelaps barbatus Moreira, Klompen & Moraes			X
Cosmolaelaps bipennatus Karg			
Cosmolaelaps jaboticabalensis Moreira, Klompen & Moraes			X

Family-Genus-Specie	New report		
	Family	Genus	Species
Cosmolaelaps bussoli Moreira, Klompen & Moraes			X
Cosmolaelaps panniculus Karg			X
Gaeolaelaps aculeifer Canestrini			X
Gaeolaelaps brevipelis Karg			X
Gaeolaelaps cerrii Marticorena, Moreira & Moraes			X
Gaeolaelaps queenslandicus Womersley			X
Oloopticus pinguis Karg			
Pseudoparasitus ocularis Hunter			X
Laelaspis angustiseta Khalili-Moghadam, Saboori, Nemati & Golpayegani		X	
Macrochelidae			
Geholaspis sp. 1		X	
Glyptolaspis sp. 1		X	
Longicheles sp. 1		X	
Ologamasidae			
Gamasiphis plenosetosus Karg			
Gamasiphis salvadori Castilho, Narita & Moraes			X
Neogamasellevans sp. 1		X	
Pachylaelapidae			
Onchodellus sp. 1		X	
Parasitidae			
Cycetogamasus sp. 1		X	
Neogamasus sp. 2		X	
Psilogamasus sp. 1		X	
Phytiogamasus sp. 1		X	
Rhabdocarpis sp. 1		X	
Paragamasus sp. 1		X	
Phytoseiidae			
Neoseiulus barkeri Hughe			X
Neoseiulus gracilis Muma			X
Graminaseius sp. 1		X	
Transeius sp. 1		X	
Rhodacaridae			
Paragamasellevans sp. 1		X	
Rhodacarus sp. 1		X	
	1	**22**	**16**

Family-Genus-Specie	New report		
	Family	Genus	Species
Uropodina			
Clausiadinychidae			
Clausiadinychus sp.			
Discourellidae			
Discourella aff. *ishikawai*			
Macrodinychidae	X		
Macrodinychus sp.		X	
Nenteriidae			
Ruehmnenteria aff. *longispinosa*		X	
Oplitidae	X		
Oplitis sp.			

Family-Genus-Specie	New report		
	Family	Genus	Species
Rotundabaloghiidae			
Depressorotunda (*Amerorotunda*) sp.		X	
Rotundabaloghia sp.			
Trachytidae			
Uroseius aff. *rotundatus*			
Uroseius sp.			
Trachyuropodidae	X		
Origmatrachys aff. *peruensis/gracilis*		X	
Trematuridae			
Trichodinychus sellnickioides Wisniewski & Hirschmann			
Trachycilliba sp.		X	
Trichouropodellidae	X		
Trichouropodella baloghi Hirschmann		X	X
Trichouropodella sp.			
Urodinychidae			
Caluropoda sp.		X	
Prodinychus plaumanni Sellnick		X	
Uroobovella sp.			
Uropodidae			
*Foveolaturopoda*sp.			
Penicillaturopoda sp. 19		X	
Uroactiniidae			
Uroactinia sp.			
Total	**4**	**9**	**1**

2.3.4. Ecological analysis

Alpha diversity, with the Margalef richness index show that the Highland is the region with the highest species richness, and the Coast with the lowest (15.85 and 6.95, respectively) (Table 9). However, the three regions present high indices of richness. The Simpson Dominance Index (D), for which values close to 1 show the presence of dominance species, showed no dominant species were detected in the three regions. The index of Shannon-Wiener, showed a high diversity for the three regions, as all calculated indexes were higher than 2.5 (Table 10).

Table 10. Dominance and diversity indices (*Alfa* diversity) of edaphic Mesostigmata non-Uropodina mites identified in three regions of Ecuador in the wet season. N: number of mites.

Region	N	Morphospecies	Richness	Community structure	
				Dominance	Community equity
			Margalef Richness (DMg)	Simpson Index (D)	Shannon-Wiener Index (H)
Amazon	722	99	14.900	0.051	3.666
Coast	205	38	6.951	0.124	2.642
Highland	1035	111	15.850	0.035	3.865

Likewise, to compare the three regions, *beta* diversity (between two regions at a time) were measured. Table 11 shows the coefficients and indexes calculated for the relationship between the regions, where three combinations were made: 1. Amazon *vs.* Coast; 2. Amazon *vs.* Highland and 3. Coast *vs.* Highland. Sorensen coefficients showed more specimens in common between the Amazon and the Highland regions (35.2 %), followed by the Amazon and Coast and finally the Coast and the Highland (23.4 and 13.4 %, respectively).

Table 11. Proportion (%) of common morphospecies mites (Sorensen's coefficient) (*Beta* diversity) of edaphic Mesostigmatid non-Uropodina mites from three regions of Ecuador, in the wet season of 2018.

Compared regions	Sorense's coefficient of similarity
Amazon *vs.* Coast	23.4
Amazon *vs.* Highland	35.2
Coast *vs.* Highland	13.4

The result of the calculation to obtain the *gamma* diversity, based on Simpson indexes for the three regions, showed that 99.96 % of the *alpha* diversity (diversity within regions) and 0.04 % of the *beta* diversity (diversity between regions) contribute to the diversity of the three regions. Likewise, the Highland presents the greatest diversity, followed by the Amazon and finally the Coast (111, 99 and 38 morphospecies, respectively).

As a result of the measured ecological indexes to compare environments (non-cultivated and cultivated) and substrate (soil and litter) in the three regions, when measuring *alpha* diversity with the Margalef richness index for the Amazon and the Coast, show the greatest richness for the cultivated environment and for the two substrates (Cultivated, soil-litter: 7.657, 9.670 and 2.717, 4.667, respectively), in contrast to the Highland, where the greatest richness was presented in the non-cultivated environment for the two substrates (Non-cultivated, soil-litter: 8.694, 10.280), highlighting that the lowest values correspond to the Coast (Table 12).

Simpson Dominance Index (D) showed nondominant species all three regions for the two environments and two substrates. Meanwhile, Shannon-Wiener index, showed a high diversity for Amazon and Highland regions, in the two environments and two substrates (indexes higher than 2.5), however, the Coast presented intermediate to low values (2.193-1.748) (Table 12).

Table 12. *Alfa* diversity indexes of edaphic Mesostigmata non-Uropodina mites in non-cultivated and cultivated environments and soil and litter substrates of three regions of Ecuador, in the wet season. N: number of mites. N=number.

Environment	Substrate	N	Morpho-species	Richness	Community structure	
					Dominance	Community equity
				Margalef Richness (DMg)	Simpson Index (D)	Shannon-Wiener Index (H)
				Amazon		
Non-cultivated	**Soil**	189	36	6.677	0.082	2.941
Cultivated		143	39	7.657	0.049	3.290
Non-cultivated	**Litter**	214	44	8.013	0.164	2.731
Cultivated		176	51	9.670	0.059	3.333
Total		**722**				
				Coast		
Non-cultivated	**Soil**	10	7	2.606	0.220	1.748
Cultivated		19	9	2.717	0.169	1.986
Non-cultivated	**Litter**	103	19	3.884	0.209	2.041
Cultivated		73	21	4.662	0.220	2.193
Total		**205**				
				Highland		
Non-cultivated	**Soil**	396	53	8.694	0.117	2.791
Cultivated		196	39	7.200	0.093	2.930
Non-cultivated	**Litter**	191	55	10.280	0.051	3.446
Cultivated		252	46	8.138	0.055	3.293
Total		**1035**				

Likewise, to compare environments and substrates, *beta* diversity was measured by Sorensen coefficient, showing that for environments (non-cultivated *vs.* cultivated) the percentage of common species was 56.9, 48.3 and 41.0 % for the Amazon, Highland and Coast regions, respectively. For the substrate (soil *vs*. liter), the highest number of shared species was in the Highland, followed by the Amazon and finally the Coast (56.2, 44.4 and 31.1, respectively) (Table 13).

Table 13. Proportion (%) of common morphospecies of Mesostigmata non-Uropodina mites (Sorensen's coefficient) (*Beta* diversity) in non-cultivated and cultivated environments and soil and litter substrates of three regions of Ecuador, in the wet season 2018.

Compared environment/substrate	Sorensen's coefficient of similarity
Amazon	
Non-Cultivated vs. Cultivated	56.9
Soil *vs.* Litter	44.4
Coast	
Non-Cultivated vs. Cultivated	41.7
Soil *vs.* Litter	31.1
Highland	
Non-Cultivated vs. Cultivated	48.3
Soil *vs.* Litter	56.2

Finally, a comparison was made between the sampled sites, calculated by *alpha* and *beta* diversity indexes. The data from the Amazon show, by Margalef richness index, high diversity (values greater than 5) (Table 13). The Simpson index shows that there are no dominant species (values close to 0). Shannon-Wiener index shows high diversity (values greater than 2.5).

On the Coast, low diversities are observed with the Margalef index at all sites, without dominant species (Simpson index). Values of varied diversity for samples site, for example, CP1 with high diversity (2,515), CP4 and CP5 medium diversity (2,074-2,478, respectively) and others with low diversity (1,189-1,776).

in the Highland, there were contrasting data on richness, dominance, and diversity, with sample sites HP1 with lowest richness and diversity (Table 14).

Table 5. *Alfa* diversity indexes of edaphic Mesostigmata non-Uropodina mites in samples sites of three regions of Ecuador (Amazon, Coast and Highland), in the wet season. N: number of mites.

Sample site *	N	Morphospecies	Richness	Community structure	
				Dominance	Community equity
			Margalef Richness (DMg)	Simpson Index (D)	Shannon-Wiener Index (H)
			Amazon		
API	234	46	8.255	0.167	2.741
AP2	66	23	5.251	0.102	2.684
AP3	116	28	5.68	0.081	2.845
AP4	80	28	6.162	0.065	2.987
AP5	226	45	7.939	0.061	3.221
	722				
			Coast		
CP1	26	15	4.297	0.098	2.515
CP2	29	6	1.485	0.410	1.189
CP3	49	12	2.826	0.270	1.776
CP4	27	14	3.944	0.097	2.478
CP5	74	17	3.717	0.193	2.074
	205				
			Highland		
HP1	29	8	2.079	0.448	1.295
HP2	342	44	7.370	0.138	2.665
HP3	182	47	8.839	0.059	3.271
HP4	373	43	7.093	0.071	3.057
HP5	109	11	2.132	0.322	1.472
	1035				

* Origin shown in table 1.1-1.3

To interpret the relationship between the diversity of mites between the sampled sites, the *beta* diversity index was determined. For all regions, the Sorensen coefficient of similarity between sample sites, showed low proportions of common species. Highland had the lowest percentages. The highest percentages obtained were 60,0 % (CP2 *vs.* CP4), 44,4 % (AP1 *vs.* AP5) and 28,9 % (HP2 *vs.* HP4), in the Coast, Amazon and Highland, respectively (Table 15).

Table 6. Proportion (%) of common morphospecies of Mesostigmata non-Uropodina mites (Sorensen's coefficient) (*Beta* diversity) in sampled points of three regions of Ecuador (Amazon, Coast and Highland), in the wet season 2018.

Sample site's comparison	Sorensen's Similarity coefficient		
	Amazon	Coast	Highland
P1 *vs.* P2	28.99	40.00	15.38
P1 *vs.* P3	21.62	23.08	10.91
P1 *vs.* P4	27.03	41.38	3.92
P1 *vs.* P5	44.44	43.75	0.00
P2 *vs.* P3	15.69	23.53	28.57
P2 *vs.* P4	27.45	60.00	29.89
P2 *vs.* P5	32.84	34.78	7.27
P3 *vs.* P4	32.14	32.00	11.11
P3 *vs.* P5	33.33	21.43	17.24
P4 *vs.* P5	38.89	45.16	14.81

***** Origin shows in table 1.1-1.3

2.4. Discussion

2.4.1. Groups of mites identified

In the samplings carried out, a very large proportion of the Oribatida (Including Astigmatina) was found (67.0 %), as reported by other authors (Illig 2007; Illig *et al.* 2010; Krantz & Walter 2009; Maribie *et al.* 2011**;** Santos 2013; Yamada 2020). Conversely, mites of suborder Prostigmata were identified in lower abundance, as also observed by other authors for Trombidiformes (Prostigmata) and Astigmatina (Krantz & Walter 2009; Mineiro & Moraes 2001; Silva 2002; Silva *et al.* 2004; Vásquez *et al.* 2007; Yamada 2020). Mesostigmatid mites were abundant in this research, as likewise reported by other authors. Mites of this group are important because of their known predatory behavior on agricultural pests (Moraes & Flechtmann 2008; Krantz & Walter 2009; Rueda 2018; Yamada 2020).

2.4.2. Mesostigmatid fauna

2.4.2.1. According to region

The lowest abundance determined in the Coastal region was possibly due to soil conditions, which include low organic matter content, lower porosity (Espinosa, J. 2021, pers. comm.), high temperature and in some cases low humidity. The opposite was observed in the

Highland and the Amazon, where soils are rich in organic matter, have high porosity and edaphoclimatic conditions that favor the abundance of soil mites. These results are congruent with those observed by Rueda-Ramirez (2018), who found a close relationship between environment, organic matter and soil pH with the abundance of mesostigmatids in Bogotá, Colombia.

Differently, Silva (2002) reported higher abundance of mesostigmatid mites in the natural vegetation of the Brazilian coastal Atlantic Forest biome in comparison with the Cerrado (inland and less dense vegetation), but again in this case, organic matter content is much higher in the luxurious Atlantic Forest than in the savannah like Cerrado. Other research works have shown how the type of vegetation, soil, temperature and other factors can influence the abundance of those mites (Silva 2002, 2007; Bedano *et al.* 2011).

2.4.2.2. According to environment

It is evident that the environment also affected diversity and abundance of mites of Mesostigmata, abundance being higher in non-cultivated than in cultivated areas of the three regions. There is a large number of works supporting this finding in different ecosystems and associated with different types of vegetation. For example, in Brazil natural environments had the highest number of mites, followed by eucalyptus, pasture and soybean areas in a study conducted in the central part of the country (Azevedo 2017). Similar finding was reported also in central Brazil in a second study in a pasture compared with sugarcane fields (Marticorena 2017), and in a third study in an area of the Atlantic Forest compared with cultivated environment (Junqueira 2017; Silva 2019); and in a fourth study in an area of the Atlantic Forest compared with soybean cultivation and pasture (Azevedo *et al.* 2020). In Colombia, soils of rose fields had lower mite abundance than soils of secondary vegetation (Rueda-Ramírez 2018). However, in a work carried out in the Agroforestry Research Station of Embrapa Amazon, higher abundance was found in cultivated environments in comparison with areas of natural vegetation (Franklin *et al.* 2001). On the other hand, García (2014) reported higher mite abundance in conventional plots, with no differences in abundance of species in plots with different cultivation practices.

2.4.2.3. According to substrate

When comparing substrates, highest mite abundance was found in the Amazon and Highland soils, similarly to what was observed by Santos (2013) areas of the natural vegetation from three regions of Alagoas state and of Brazil in spring and summer season of Caatinga Ecosystem. However, on the Coast the greatest abundance was found in the litter samples, as determined by Santos (2014), who reported higher mite abundance in litter of the Atlantic Forest, Silva (2002) from natural vegetation from Atlantic Forest and Cerrado, Azevedo (2017) in natural vegetation at the Cerrado Ecosystem no Tocantins state and Marticorena (2017) in natural vegetation, pasture and sugarcane in Jatai-Goias-Brazil.

Considering that a single sampling was carried out in the three regions, in the wet season, the determined family diversity (16) can be considered to be high, in comparison with the finding of other works in which more extensive samplings were conducted. Santos (2013) carried out four quarterly samplings, determining the presence of 13 families. Azevedo (2017) carried out 12 samplings in cultivated and natural areas, determining the presence of nine families. Silva (2020) conducted quarterly samplings, identifying the presence of 12 families.

The high abundance determined in this study might have been in part due to the fact that it was conducted in the wet season. Castilho *et al.* (2015) reported that mesostigmatid species develop better in humid soil. Yamada (2020) also stated that precipitation positively affected mite abundance.

2.4.2.4. Diversity of mesostigmatid mites

The diversity of mesostigmatid mites found in this work (53 genera and 193 morphospecies) is higher than usually found in similar studies. Pérez-Velásquez *et al.* (2011) found eight families and genera and 10 morphospecies in México City. In Brazil, Santos (2013) identified 30 genera and 57 morphospecies from four quarterly samplings. Marticorena (2017), reported 52 genera and 114 morphospecies in natural vegetation, pasture and sugarcane in central Brazil, in two samplings conducted once a year in three ecosystems (one natural and two agroecosystems). Azevedo (2017) reported 24 genera and 45 species in four ecosystems, in two sampling (dry and rainy seasons) in central Brazil. These comparisons show the high edaphic mite diversity in Ecuador, in comparison with data obtained in Brazil.

2.4.2.5. Families of edaphic mesostigmatid mites from the three regions

The higher abundance of Ascidae, Laelapidae and Ologamasidae corroborates results of previous studies in Brazil, Colombia, Mexico and Venezuela, which despite being conducted under different conditions, also showed those as the most abundant families. Fuentes *et al.* (2008) identified Laelapidae as the most abundant in litter from a gallery forest in Venezuela. Pérez-Velásquez *et al.* (2011) recorded Ascidae as the most abundant in an environment with scanty vegetation, in the wet season at Pedregal Angel Ecological Reserve, in Mexico. In Brazil, Santos (2013) identified Ologamasidae and Laelapidae among the most abundant families in three environments of Alagoas state. Santos (2014) identified Ascidae, Laelapidae and Ologamasidae as the most abundant in Atlantic Forest of Alagoas state. Azevedo *et al.* (2017) and Duarte *et al.* (2020) identified the same families among the most abundant in central Brazil; Silva (2020) reported Ascidae and Laelapidae as the most abundant in the Pampas biome, southern Brazil. Yamada (2020) reported the same families as the most abundant in the Pantanal biome, in western Brazil. In Colombia, Marin *et al.* (2015) identified Laelapidae and Ologamasidae as the most abundant in collections conducted in Palmira. In the same country, Rueda-Ramirez (2018) identified Ascidae, Laelapidae and Ologamasidae among the dominant families in rose fields and patches of secondary vegetation in Bogotá.

Mites of the family Laelapidae are of great interest, as species of this family are commercialized for pest control and have been reported from tropical and temperate regions (Fuentes *et al.* 2008; Venancio *et al.* 2016; Rueda-Ramirez 2018).

Of all families identified, the greatest diversity of genera was found in Phytoseiidae and Parasitidae, and the greatest diversity of morphospecies was reported for Laelapidae and Phytoseiidae. Santos (2013) identified Phytoseiidae among the families with the greatest diversity of genera, and Laelapidae with the greatest diversity of morphospecies. Azevedo (2017) reported highest diversities of genera in Laelapidae and Phytoseiidae, and highest diversity of species in Laelapidae. Likewise, in La Calera, Colombia, Ascidae *sensu lato*, Laelapidae and Ologamasidae were reported among the most diverse environmental conditions (Rueda 2012), as determined in this work for the Highland. Pérez-Velásquez *et al.* (2011) identified the same families as the most abundant in Mexico, while Silva (2020) found Phytoseiidae as one of the most diverse families in Brazil.

2.4.2.6. Genera and morphospecies of the three regions

The most abundant genera were *Asca*, *Gamasiphis*, *Neogamasellevans* and *Gaeolaelaps*, the latter of importance because some species are commercialized for pest control. Yamada (2020) also found *Gaeolaelaps* as the most abundant within the laelapids in the Pantanal biome in Brazil. Marticorena (2017) identified *Asca*, *Gaeolaelaps* and *Neogamasellevans* as dominant or subdominant in Atlantic Forest and Cerrado fragments; Silva (2019) also identified *Gaeolaelaps* as the dominant genus in the Atlantic Forest.

Almost 1,600 specimens were identified down to the morphospecies level, 22 were identified to species level and, 12 concluded to be new species. In tropical and subtropical regions, the diversity of mites is frequently reported as high, although in many cases the identification is done only up to the morphospecies level, at least for part of the specimens, as in the works conducted by Duarte (2014), Santos (2014), Azevedo (2017), Santos (2017) and Rueda-Ramirez (2018). The reason for this is the difficulty in naming the species, due to that high diversity and quite often the lack of adequate literature to allow their proper identification. But we consider this to be an important first step under these circumstances.

Additionally, 14 species of Uropodina were identified, which has not been common in studies conducted in South America. However, in Colombia 21 morphospecies of Mesostigmata were previously reported in forest fragment and pastures (Rueda 2012), which could show the great diversity of this mite group in tropical areas.

Likewise, the abundance of *Asca* aff. garmani, two possibly new species of *Gamasiphis* and two possibly new species of *Neogamasellevans* was shown. Similar groups have been identified in studies carried out in Brazil by Santos (2013) who reported *Neogamasellevans* n. sp. as one of the most abundant morphospecies in Alagoas; in the same way, *Neogamasellevans* sp. and *A. garmani* was identified in Jatai and Valparaiso (Brazil) as dominant species, in natural vegetation and sugarcane plantations (Marticorena 2017). In relation to *A. garmani*, it is reported from litter, and in addition it has been suggested as a useful species as biological indicator of environmental changes, because it is abundant and dominant in various environments (Marticorena 2017).

In the Atlantic Forest these same genera are identified, especially *Gamasiphis*, in natural and cultivated environments (Silva 2020). *Asca garmani* was report from different countries in the American continent, Australia, India and the South Pacific Island (Hurlbutt 1963; Bhattacharyya 1966; Wood 1966; De Leon 1967; Farrier & Hennessey 1993; Walter *et al*. 1993;

Mineiro *et al.* 2009). In the same way, Karg (1979) and Norton *et al.* (1993) reported this species to reproduce by thelytoky, because only females were found, as also observed in this investigation.

Information on environments, substrates and associated plants is expected to be useful for future searches for the species identified in this work, if necessary. Of the mites identified in this research, species with previous records were observed in different ecosystem. This is the case with mites identified from the Amazon region (*A. garmani*, *Gaeolaelaps cerrii* and *G. queenslandicus*), reported in the Atlantic Forest by Marticorena (2017) and Silva (2019). In the same way, *G. plenosetosus* was previously reported from the Galapagos Islands (Karg 1994).

In the Coast region, as in the Atlantic Forest, *Neogamasellevans* is reported as one of the most abundant genera (Silva *et al.* 2004). Similarly, some of the species reported in the Atlantic Forest (*C. barbatus*, in natural vegetation, as well as *C. jaboticabalensis*, *Gamasiphis* spp. and *N. barkeri* in sugarcane crops) (Silva 2019) have also been reported in this research. *Neoseiulus barkeri* has also been reported in Bogotá Savannah (Rueda-Ramirez 2018), a place with similar conditions as those reported for the Highland region in this research.

Under similar conditions to those of the Ecuadorian Highland region, mites of the genus *Cheiroseius* and *Gaeolaelaps* have been reported from forest fragment, and the latter also from pasture, in La Calera, Colombia (Rueda 2012). The same author reported *G. aculeifer* from rose fields and patches of secondary vegetation in that same region, and *G. garmani* from secondary vegetation. Genera as *Cheiroseius*, *Gamasiphis* and *Zygoseius*, found in this research, were also reported from Bogotá by Rueda-Ramirez (2018).

Finally, of the species identified in this study, *G. queenslandicus* was also reported for the Atlantic Forest in Brazil (Marticorena 2017; Silva 2009), a region with rather different ecological conditions from the sites of the present study.

2.4.2.7. Non-parametric analysis of the mesostigmatid families in the three regions

The non-parametric analysis carried out showed that there are statistical differences between the abundance of mites identified on the Coast compared to the other two Ecuadorian regions, as also determined in the descriptive analysis. As mentioned above, the environmental characteristics of this region can disfavor the presence of soil mites, which are greatly influenced by soil pH, organic matter, porosity, and rainfall (Silva 2002, 2007; Bedano *et al.* 2011 Azevedo 2017; Rueda-Ramirez 2018).

Mesostigmatids of the cohort Uropodina were also identified in the three Ecuadorian regions, as reported in previous studies in Ecuador (Hirschmann 1973; Kontschán 2008, 2010, 2012, 2016; Rueda 2012; Santos 2013).

2.4.3. New reports for Ecuador

Previous reports of non-Uropodina mesostigmatids from Ecuador mentioned 15 families, but Eviphididae was not included (Karg 1994b; Karg 1998c; Karg 2000; Karg & Schorlemmer 2009; Castilho *et al,* 2012; Castilho *et al.* 2016; Moraes *et al.* 2016; Santos *et al.* 2017b; Santos *et al.* 2017c).

Likewise, approximately 202 mesostigmatid species have been reported previously from Ecuador in those families (Karg 1979, 1994a; 1994b, 2006; Faraji & Karg 2006; Karg & Schorlemmer 2009; Castilho *et al,* 2012a; Moreira 2014; Castilho *et al.* 2016; Moraes *et al.* 2016; Freire 2007; Santos *et al.* 2017a, b, c). Sixteen species not previously reported from Ecuador were found in the present work. Those were previously identified in collections from Brazil and Colombia (Moreira, Klompen & Moraes 2014; Castilho, Narita & Moraes 2012b; Rueda-Ramirez 2018; Silva 2019; Marticorena, Moreira & Moraes 2020; Rueda *et al.* 2020, 2021; Yamada 2020).

Of the Uropodina Mesostigama, of the 10 families represented in this study, nine species were previously reported for this country (Hirschmann 1973; Kontschán 2008, 2010, 2012, 2016). In this work we add 14 families and 18 morphospecies from Ecuador.

2.4.4. Ecological analysis

The *alpha* diversity indexes showed, for the three regions, high richness, absence of dominant species and high diversity, with the Coast always presenting the lowest indexes. The *beta* diversity analyses for the three regions showed great diversity among the three regions, reflecting the few mite species common to the regions. This could be related to the fact that sampled sites were always in small farms, with crops not subjected to chemical pressure and the usual presence of associated weeds.

Similar studies have not been conducted before, in the revised literature from South America. Some particular features of the study area might have greatly influenced the results.

Ecuador is a small country but has three very distinct regions, with different edaphoclimatic conditions and ecosystems (Espinosa *et al.* 2018). Yet, those regions are rather close to each other, which facilitated the conduction of this study. These characteristics make it difficult to compare data obtained in the present study with data obtained by other authors in other countries.

Additionally, the determined *gamma* diversity was higher for the Highland, reflecting the fact that this region has soil rich in organic matter, which could favor the high diversity and abundance observed in the study (Espinosa *et al.* 2018; Rueda -Ramirez 2018).

The Equatorial zone does not have climatic extremes along the year, and does not have clearly distinct seasons. Thus, variations are mostly in terms of humidity, and are mainly influenced by height, due to the presence of the Andes mountains (Buringh 1970; Finkl 1999; Schmidt 2019).

The Amazon had the greatest richness of species in the litter, and the greatest diversity in cultivated environment. The Coast showed greater richness and diversity in litter compared to soil, for the two environments. Finally, the Highland had greatest richness in non-cultivated environment, and greatest diversity in the litter for both environments. These results are similar to that reported by Silva (2020), showing greater diversity in the natural vegetation of the Atlantic Forest than in sugarcane cultivation and pasture. Similar results were also obtained by Maribie *et al.* (2011) in Kenya, where cypress forest was shown to have greater diversity and richness of soil mites compared to horticultural crops and corn. There are also reports of higher rates of diversity in cultivated environments when dry and humid seasons were analyzed together (Azevedo *et al.* 2021). In contrast, studies conducted in the Brazilian states of São Paulo and Goias showed that the diversity and richness indexes were equal between cultivated and non-cultivated environments, with dominant species in the natural environment (Marticorena 2017). However, as in the present study, richness and diversity in that study were greater in litter.

In order to know the number of species in the five sampling sites of each region, the *alpha* and *beta* diversities were measured. Contrasting indexes were found within the regions, as follows. Differently from the Coast and the Highland, the Amazon shows the least contrasting values. Based in this information, this type of subsampling should be necessary to know the diversity and abundance of species in the Coast and Highland regions.

The *beta* diversity for sample sites showed low percentages of common species (Sorensen indexes) in the Highland, medium percentages in the Amazon and high percentages in the Coast. This could also reflect the different edaphoclimatic conditions occurring at the sampling sites within each region.

Ecuador is divided into the three northern regions by the Andes, and each region has a marked diversity mainly due to different climatic conditions, landscapes and soil types. Differences of altitude and the influence of volcanic origins, rainfall regimens and winds greatly affect the development of the soils, giving particular characteristics to each region (Espinosa *et al.* 2018). These conditions make it difficult to compare the results of this study with results of previous research, mainly in subtropical and temperate countries.

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Appendix

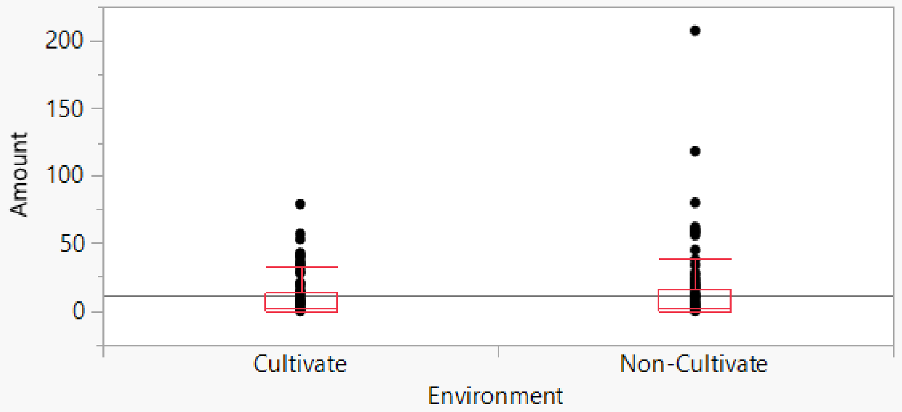
Appendix 1. Non-parametric comparisons for number of mites for each family of edaphic Mesostigmata non-Uropodina mites for three regions (Amazon, Coast, Highland) the north-central part of Ecuador, in non-cultivated and cultivated environment and soil and litter using Wilcoxon method.

Level (Family)	Level (Family)	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
Ascidae	Amesoseiidae	9.8333	2.779975	3.5372	0.0004	11	2	40
Blattisociidae	Amesoseiidae	8.4167	2.7439	3.06741	0.0022	6	3	13
Digamasellidae	Ascidae	-6.4167	2.862805	-2.24139	0.025	-10	-40	-1
Eviphididae	Digamasellidae	-6.3333	2.419726	-2.61738	0.0089	-1	-4	0
Eviphididae	Blattisociidae	-9.75	2.647805	-3.6823	0.0002	-6	-13	-3
Eviphididae	Ascidae	-10.8333	2.700644	-4.01139	<,0001	-15.5	-40	-4
Laelapidae	Eviphididae	11.9167	2.74522	4.34088	<,0001	22.5	12	40
Laelapidae	Amesoseiidae	11.4167	2.809791	4.06317	<,0001	18	7	40
Laelapidae	Digamasellidae	8.5	2.872912	2.95867	0.0031	15	4	39
Laelapidae	Blattisociidae	6.1667	2.883612	2.13852	0.0325	13	1	34
Macrochelidae	Eviphididae	10.5833	2.6946	3.92761	<,0001	6	1	11
Macrochelidae	Amesoseiidae	8.8333	2.76822	3.19098	0.0014	6	1	11
Macrochelidae	Laelapidae	-7.25	2.882984	-2.51476	0.0119	-15.5	-37	-4
Melicharidae	Blattisociidae	-8.3333	2.804629	-2.97128	0.003	-6	-13	-3
Melicharidae	Macrochelidae	-8.5	2.810436	-3.02444	0.0025	-6	-11	-1
Melicharidae	Ascidae	-9.6667	2.830348	-3.41536	0.0006	-13	-40	-2
Melicharidae	Laelapidae	-11.5833	2.848849	-4.06597	<,0001	-20	-40	-7
Ologamasidae	Eviphididae	11.9167	2.74522	4.34088	<,0001	26	10	41
Ologamasidae	Melicharidae	11.8333	2.848213	4.15465	<,0001	23.5	9	41
Ologamasidae	Amesoseiidae	11.25	2.809791	4.00386	<,0001	20.5	9	41
Ologamasidae	Digamasellidae	8.6667	2.872912	3.01668	0.0026	18	7	40
Ologamasidae	Macrochelidae	8	2.882355	2.77551	0.0055	17.5	5	35
Ologamasidae	Blattisociidae	7	2.882984	2.42804	0.0152	13.5	3	35
Pachylaelapidae	Blattisociidae	-6.6667	2.779975	-2.3981	0.0165	-5	-13	0
Pachylaelapidae	Macrochelidae	-6.6667	2.803983	-2.37757	0.0174	-5	-11	0
Pachylaelapidae	Ascidae	-8.5833	2.807856	-3.0569	0.0022	-11	-40	-2
Pachylaelapidae	Laelapidae	-10.25	2.832267	-3.61901	0.0003	-18	-40	-7
Pachylaelapidae	Ologamasidae	-10.25	2.833546	-3.61737	0.0003	-19	-41	-9
Parasitidae	Eviphididae	8.5833	2.584794	3.3207	0.0009	17	0	34
Parasitidae	Amesoseiidae	7.6667	2.698631	2.84095	0.0045	14	0	34
Parasitidae	Melicharidae	7.0833	2.774757	2.55278	0.0107	14.5	0	34
Parasitidae	Pachylaelapidae	6.6667	2.74456	2.42905	0.0151	14	0	34
Parholaspididae	Parasitidae	-7.4167	2.742579	-2.70427	0.0068	-16	-34	0
Parholaspididae	Macrochelidae	-9.0833	2.797514	-3.24693	0.0012	-6	-11	-1
Parholaspididae	Blattisociidae	-9.1667	2.779323	-3.29817	0.001	-6	-13	-3
Parholaspididae	Ascidae	-10.0833	2.807211	-3.59194	0.0003	-14.5	-40	-2
Parholaspididae	Laelapidae	-11.9167	2.832907	-4.20652	<,0001	-21.5	-40	-10
Parholaspididae	Ologamasidae	-11.9167	2.832907	-4.20652	<,0001	-25	-41	-9
Phytoseiidae	Eviphididae	9.6667	2.64712	3.65177	0.0003	3	1	9
Phytoseiidae	Parholaspididae	8.1667	2.77541	2.94251	0.0033	3	1	9
Phytoseiidae	Amesoseiidae	7.9167	2.741918	2.88727	0.0039	3	1	9
Phytoseiidae	Melicharidae	7.3333	2.802044	2.61714	0.0089	3	0	9
Phytoseiidae	Pachylaelapidae	6	2.778019	2.15981	0.0308	2	0	9
Phytoseiidae	Laelapidae	-8.4167	2.88424	-2.91816	0.0035	-15.5	-38	-4
Phytoseiidae	Ologamasidae	-8.75	2.882984	-3.03505	0.0024	-17	-38	-6
Rhodacaridae	Eviphididae	6.5	2.422719	2.68294	0.0073	8	0	16
Rhodacaridae	Parholaspididae	5.25	2.647805	1.98277	0.0474	8	0	16
Rhodacaridae	Amesoseiidae	5.1667	2.584794	1.99887	0.0456	8	0	16
Rhodacaridae	Laelapidae	-6.75	2.874173	-2.3485	0.0188	-17	-38	-4
Rhodacaridae	Ologamasidae	-7.3333	2.872281	-2.55314	0.0107	-18	-35	-6
Unknown	Macrochelidae	-6	2.826505	-2.12276	0.0338	-5	-10	0
Unknown	Blattisociidae	-6.0833	2.807856	-2.16654	0.0303	-5	-13	0
Unknown	Parasitidae	-6.25	2.780627	-2.24769	0.0246	-14	-34	0
Unknown	Ascidae	-8.1667	2.830988	-2.88474	0.0039	-11	-40	-2
Unknown	Laelapidae	-9.8333	2.850756	-3.44938	0.0006	-18	-40	-7
Unknown	Ologamasidae	-10.4167	2.850121	-3.65482	0.0003	-19	-41	-9
Veigaiidae	Eviphididae	6.25	2.414479	2.58855	0.0096	1	0	7
Veigaiidae	Parasitidae	-5.9167	2.826505	-2.09328	0.0363	-14	-34	0
Veigaiidae	Ascidae	-7.6667	2.860906	-2.6798	0.0074	-11	-40	-2
Veigaiidae	Laelapidae	-9.8333	2.868495	-3.42805	0.0006	-18	-40	-6
Veigaiidae	Ologamasidae	-10	2.870389	-3.48385	0.0005	-20	-41	-8

Appendix 2. Non-parametric comparisons for number of mites for each family of edaphic Mesostigmata non-Uropodina mite families from three regions (Amazon, Coast, Highland) the north-central part of Ecuador, for two environment (non-cultivated and cultivated) and two substrates (soil and litter), using Wilcoxon method.

A. By Environment

Oneway Analysis of Amount By Environment



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
Cultivate	0	0	0	2	13	35.6	79
Non-Cultivate	0	0	0	1.5	16	40.1	207

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Cultivate	96	9408.50	9264.00	98.0052	0.385
Non-Cultivate	96	9119.50	9264.00	94.9948	-0.385

2-Sample Test, Normal Approximation

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.1496	1	0.6989

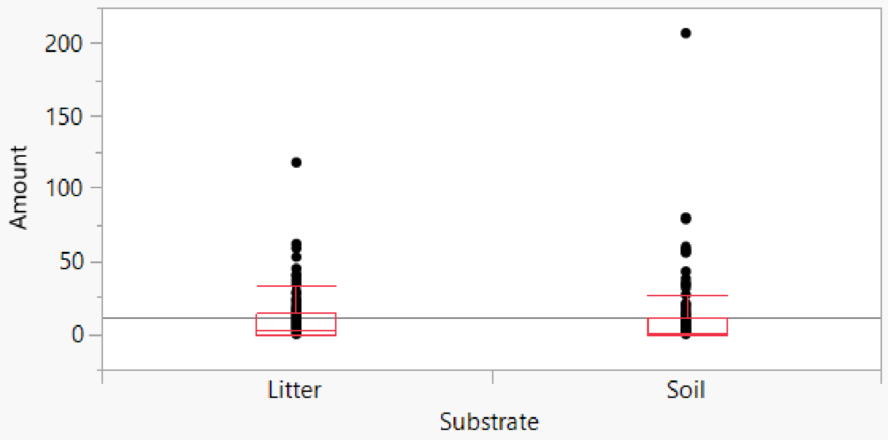
Nonparametric Comparisons For Each Pair Using Wilcoxon Method

q*	Alpha
1.95996	0.05

Level	- Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL
Non-Cultivate	Cultivate	-3.00000	7.782244	-0.385493	0.6999	0	-1.00000

B. By Substrate

Oneway Analysis of Amount By Substrate



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
Litter	0	0	0	3	14.75	37.9	118
Soil	0	0	0	1	12.5	35.9	207

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Litter	96	9598.00	9264.00	99.9792	0.893
Soil	96	8930.00	9264.00	93.0208	-0.893

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
8930	-0.89279	0.3720

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0.7995	1	0.3713

Nonparametric Comparisons For Each Pair Using Wilcoxon Method

q*	Alpha
1.95996	0.05

Level	- Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL
Soil	Litter	-6.94792	7.782244	-0.892791	0.3720	0	-1.00000	0

Appendix 3. Non-parametric comparisons for number of mites for each family of edaphic Mesostigmata non-Uropodina mite families from three regions (Amazon, Coast, Highland) the north-central part of Ecuador, in non-cultivated and cultivated environment and soil and litter, using Wilcoxon method.

A. For the Amazon

Level (Family)	Level (Family)	Score Mean Difference	Std Err Dif	Z	p-Value
Ascidae	Amesoseiidae	3.75	1.625687	2.30672	0.0211
Blattisociidae	Amesoseiidae	3.75	1.625687	2.30672	0.0211
Digamasellidae	Ascidae	-3.75	1.72171	-2.17807	0.0294
Eviphididae	Ascidae	-3.75	1.625687	-2.30672	0.0211
Eviphididae	Blattisociidae	-3.75	1.625687	-2.30672	0.0211
Laelapidae	Amesoseiidae	3.75	1.625687	2.30672	0.0211
Laelapidae	Digamasellidae	3.75	1.72171	2.17807	0.0294
Laelapidae	Eviphididae	3.75	1.625687	2.30672	0.0211
Macrochelidae	Amesoseiidae	3.75	1.625687	2.30672	0.0211
Macrochelidae	Eviphididae	3.75	1.625687	2.30672	0.0211
Melicharidae	Ascidae	-3.75	1.72171	-2.17807	0.0294
Melicharidae	Laelapidae	-3.75	1.72171	-2.17807	0.0294
Ologamasidae	Amesoseiidae	3.75	1.625687	2.30672	0.0211
Ologamasidae	Digamasellidae	3.75	1.72171	2.17807	0.0294
Ologamasidae	Eviphididae	3.75	1.625687	2.30672	0.0211
Ologamasidae	Melicharidae	3.75	1.72171	2.17807	0.0294
Pachylaelapidae	Ascidae	-3.75	1.625687	-2.30672	0.0211
Pachylaelapidae	Blattisociidae	-3.75	1.625687	-2.30672	0.0211
Pachylaelapidae	Laelapidae	-3.75	1.625687	-2.30672	0.0211
Pachylaelapidae	Macrochelidae	-3.75	1.625687	-2.30672	0.0211
Pachylaelapidae	Ologamasidae	-3.75	1.625687	-2.30672	0.0211
Parasitidae	Amesoseiidae	3.75	1.625687	2.30672	0.0211
Parasitidae	Digamasellidae	3.75	1.72171	2.17807	0.0294
Parasitidae	Eviphididae	3.75	1.625687	2.30672	0.0211
Parasitidae	Melicharidae	3.75	1.72171	2.17807	0.0294
Parasitidae	Pachylaelapidae	3.75	1.625687	2.30672	0.0211
Parholaspididae	Ascidae	-3.75	1.72171	-2.17807	0.0294
Parholaspididae	Blattisociidae	-3.75	1.72171	-2.17807	0.0294
Parholaspididae	Laelapidae	-3.75	1.72171	-2.17807	0.0294
Parholaspididae	Ologamasidae	-3.75	1.72171	-2.17807	0.0294
Parholaspididae	Parasitidae	-3.75	1.72171	-2.17807	0.0294
Phytoseiidae	Laelapidae	-3.75	1.732051	-2.16506	0.0304
Phytoseiidae	Ologamasidae	-3.75	1.732051	-2.16506	0.0304
Rhodacaridae	Amesoseiidae	3.75	1.625687	2.30672	0.0211
Rhodacaridae	Digamasellidae	3.75	1.72171	2.17807	0.0294
Rhodacaridae	Eviphididae	3.75	1.625687	2.30672	0.0211
Rhodacaridae	Melicharidae	3.75	1.72171	2.17807	0.0294
Rhodacaridae	Pachylaelapidae	3.75	1.625687	2.30672	0.0211
Rhodacaridae	Parholaspididae	3.75	1.72171	2.17807	0.0294
Unknown	Ascidae	-3.75	1.690309	-2.21853	0.0265
Unknown	Laelapidae	-3.75	1.690309	-2.21853	0.0265
Unknown	Ologamasidae	-3.75	1.690309	-2.21853	0.0265
Unknown	Parasitidae	-3.75	1.690309	-2.21853	0.0265
Unknown	Rhodacaridae	-3.75	1.690309	-2.21853	0.0265
Veigaiidae	Amesoseiidae	3.75	1.581139	2.37171	0.0177
Veigaiidae	Eviphididae	3.75	1.581139	2.37171	0.0177
Veigaiidae	Pachylaelapidae	3.75	1.581139	2.37171	0.0177
Veigaiidae	Ascidae	-3.75	1.690309	-2.21853	0.0265
Veigaiidae	Laelapidae	-3.75	1.690309	-2.21853	0.0265
Veigaiidae	Ologamasidae	-3.75	1.690309	-2.21853	0.0265
Veigaiidae	Parasitidae	-3.75	1.690309	-2.21853	0.0265

B. For the Coast

Level (Family)	Level (Family)	Score Mean Difference	Std Err Dif	Z	p-Value
Laelapidae	Amesoseiidae	3.75	1.690309	2.21853	0.0265
Laelapidae	Digamasellidae	3.75	1.625687	2.30672	0.0211
Laelapidae	Eviphididae	3.75	1.625687	2.30672	0.0211
Ologamasidae	Amesoseiidae	3.75	1.690309	2.21853	0.0265
Ologamasidae	Digamasellidae	3.75	1.625687	2.30672	0.0211
Ologamasidae	Eviphididae	3.75	1.625687	2.30672	0.0211
Ologamasidae	Macrochelidae	3.75	1.72171	2.17807	0.0294
Ologamasidae	Melicharidae	3.75	1.72171	2.17807	0.0294
Ologamasidae	Blattisociidae	3.5	1.711307	2.04522	0.0408
Phytoseiidae	Ologamasidae	-3.5	1.72171	-2.03286	0.0421
Melicharidae	Laelapidae	-3.75	1.72171	-2.17807	0.0294
Pachylaelapidae	Laelapidae	-3.75	1.625687	-2.30672	0.0211
Pachylaelapidae	Ologamasidae	-3.75	1.625687	-2.30672	0.0211
Parasitidae	Laelapidae	-3.75	1.690309	-2.21853	0.0265
Parasitidae	Ologamasidae	-3.75	1.690309	-2.21853	0.0265
Parholaspididae	Laelapidae	-3.75	1.625687	-2.30672	0.0211
Parholaspididae	Ologamasidae	-3.75	1.625687	-2.30672	0.0211
Rhodacaridae	Laelapidae	-3.75	1.625687	-2.30672	0.0211
Rhodacaridae	Ologamasidae	-3.75	1.625687	-2.30672	0.0211
Unknown	Laelapidae	-3.75	1.625687	-2.30672	0.0211
Unknown	Ologamasidae	-3.75	1.625687	-2.30672	0.0211
Veigaiidae	Laelapidae	-3.75	1.625687	-2.30672	0.0211
Veigaiidae	Ologamasidae	-3.75	1.625687	-2.30672	0.0211

C. For the Highland

Level (Family)	Level (Family)	Score Mean Difference	Std Err Dif	Z	p-Value
Laelapidae	Eviphididae	3.75	1.690309	2.21853	0.0265
Macrochelidae	Eviphididae	3.75	1.690309	2.21853	0.0265
Ologamasidae	Eviphididae	3.75	1.690309	2.21853	0.0265
Ologamasidae	Melicharidae	3.75	1.690309	2.21853	0.0265
Parasitidae	Amesoseiidae	3.75	1.72171	2.17807	0.0294
Parasitidae	Eviphididae	3.75	1.690309	2.21853	0.0265
Parasitidae	Macrochelidae	3.75	1.732051	2.16506	0.0304
Parasitidae	Melicharidae	3.75	1.690309	2.21853	0.0265
Pachylaelapidae	Eviphididae	3.5	1.679711	2.08369	0.0372
Pachylaelapidae	Melicharidae	3.5	1.679711	2.08369	0.0372
Phytoseiidae	Eviphididae	3.5	1.679711	2.08369	0.0372
Phytoseiidae	Melicharidae	3.5	1.679711	2.08369	0.0372
Unknown	Eviphididae	3.5	1.679711	2.08369	0.0372
Unknown	Melicharidae	3.5	1.679711	2.08369	0.0372
Macrochelidae	Laelapidae	-1.25	1.732051	-0.72169	0.4705
Pachylaelapidae	Blattisociidae	-1.25	1.732051	-0.72169	0.4705
Phytoseiidae	Ascidae	-1.25	1.732051	-0.72169	0.4705
Phytoseiidae	Laelapidae	-1.25	1.732051	-0.72169	0.4705
Veigaiidae	Digamasellidae	-1.25	1.72171	-0.72602	0.4678
Veigaiidae	Phytoseiidae	-1.25	1.72171	-0.72602	0.4678
Rhodacaridae	Digamasellidae	-1.5	1.72171	-0.87123	0.3836
Veigaiidae	Macrochelidae	-1.5	1.711307	-0.87652	0.3807
Macrochelidae	Ascidae	-1.75	1.732051	-1.01036	0.3123
Pachylaelapidae	Digamasellidae	-1.75	1.732051	-1.01036	0.3123
Rhodacaridae	Laelapidae	-1.75	1.732051	-1.01036	0.3123
Unknown	Blattisociidae	-1.75	1.732051	-1.01036	0.3123
Unknown	Digamasellidae	-1.75	1.732051	-1.01036	0.3123
Unknown	Laelapidae	-1.75	1.732051	-1.01036	0.3123
Pachylaelapidae	Ascidae	-2	1.72171	-1.16164	0.2454
Phytoseiidae	Ologamasidae	-2	1.72171	-1.16164	0.2454
Pachylaelapidae	Laelapidae	-2.25	1.732051	-1.29904	0.1939
Pachylaelapidae	Ologamasidae	-2.25	1.732051	-1.29904	0.1939
Rhodacaridae	Ascidae	-2.25	1.732051	-1.29904	0.1939
Veigaiidae	Ascidae	-2.25	1.72171	-1.30684	0.1913
Veigaiidae	Laelapidae	-2.25	1.72171	-1.30684	0.1913
Unknown	Ascidae	-2.5	1.72171	-1.45204	0.1465
Unknown	Ologamasidae	-2.5	1.72171	-1.45204	0.1465
Parholaspididae	Pachylaelapidae	-2.75	1.690309	-1.62692	0.1038
Phytoseiidae	Parasitidae	-2.75	1.732051	-1.58771	0.1124
Veigaiidae	Ologamasidae	-2.75	1.72171	-1.59725	0.1102
Rhodacaridae	Ologamasidae	-3	1.72171	-1.74245	0.0814
Parholaspididae	Ascidae	-3.25	1.690309	-1.92273	0.0545
Parholaspididae	Digamasellidae	-3.5	1.679711	-2.08369	0.0372
Eviphididae	Ascidae	-3.75	1.690309	-2.21853	0.0265
Eviphididae	Blattisociidae	-3.75	1.690309	-2.21853	0.0265
Eviphididae	Digamasellidae	-3.75	1.690309	-2.21853	0.0265
Melicharidae	Ascidae	-3.75	1.690309	-2.21853	0.0265
Melicharidae	Blattisociidae	-3.75	1.690309	-2.21853	0.0265
Melicharidae	Digamasellidae	-3.75	1.690309	-2.21853	0.0265
Melicharidae	Laelapidae	-3.75	1.690309	-2.21853	0.0265
Melicharidae	Macrochelidae	-3.75	1.690309	-2.21853	0.0265
Parholaspididae	Blattisociidae	-3.75	1.690309	-2.21853	0.0265
Parholaspididae	Laelapidae	-3.75	1.690309	-2.21853	0.0265
Parholaspididae	Macrochelidae	-3.75	1.690309	-2.21853	0.0265
Parholaspididae	Ologamasidae	-3.75	1.690309	-2.21853	0.0265
Parholaspididae	Parasitidae	-3.75	1.690309	-2.21853	0.0265
Rhodacaridae	Parasitidae	-3.75	1.732051	-2.16506	0.0304
Unknown	Parasitidae	-3.75	1.732051	-2.16506	0.0304
Veigaiidae	Parasitidae	-3.75	1.72171	-2.17807	0.0294

3. *Gamasiphis* SPECIES (ACARI: MESOSTIGMATA: OLOGAMASIDAE) FROM ECUADOR, WITH DESCRIPTION OF NEW SPECIES AND NEW RECORDS*

Abstract

Gamasiphis Berlese is the most diverse genus of Ologamasidae, with 74 described species, seven of which described from Ecuador. The main objective of this paper is to report the *Gamasiphis* species found in surveys recently conducted in Ecuador, including a new species here described, *Gamasiphis* **n. sp.** Complementary descriptions of two previously described species, also collected in this study, are presented.

Keywords: Amazon, Coast, edaphic mite, Highland, Rhodacaroidea

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3.1. Introduction

Ologamasidae Ryke (Rhodacaroidea) is a large and widely distributed mite group, with 44 genera and almost 500 species found in edaphic environments, nests of small mammals and composts (Castilho *et al.* 2016). The taxonomic status of this family has been complicated and confusing, changing considerably along time (Castilho *et al.* 2012a, 2016). Ologamasidae seems to be a diverse family of edaphic mites in Ecuador, where 22 species have so far been described (Castilho *et al*. 2016).

Gamasiphis Berlese is the most diverse ologamasid genus, with 74 described species that occur mainly in tropical and subtropical areas, feeding on nematodes, collembola and other arthropods (Lee 1970; Beaulieu & Walter 2007; Karg & Schorlemmer 2009; Castilho *et al*. 2010, 2012b, 2015, 2016). Seven *Gamasiphis* species have been described from Ecuador: *G. hamatellus* Karg, 1998; *G. mediosetosus* Karg, 2003; *G. pinnatus* Karg, 1998; *G. plenosetosus* Karg, 1994b; *G. silvestris* Karg, 2007; *G. undulatus* Karg & Schorlemmer, 2009 and *G. vinculi* Karg, 1994a.

The main objective of this paper is to report the *Gamasiphis* species found in surveys recently conducted in Ecuador, including a new species here described. Complementary descriptions of previously described species, also collected in this study, are also provided.

3.2. Materials and Methods

Soil and litter samples were collected from three regions in northern Ecuador. Mites were extracted from these with the use of Berlese-Tullgren funnels, mounted in Hoyer's medium and examined under phase (Leica, DMLB) and interference (Nikon, Eclipse 80i) contrast microscopes. Identification at the generic level was done based mostly on the key provided by Castilho *et al.* (2016), and to species level, based on the keys provided by Castilho *et al.* (2010, 2012b), as well as on the original descriptions and redescription of *Gamasiphis* species.

Pictures of taxonomically relevant structures were taken with a digital camera connected to the phase contrast microscope. These were processed with a digital tablet, using the Adobe Illustrator® program to produce the illustrations provided in this paper. Measurements were done with a graded ocular. For each character, the average measurement followed (in parentheses) by the minimum and the maximum measurements are given in micrometers. Setal nomenclature is based on Lindquist & Evans (1965), as adapted by Castilho *et al.* (2010, 2012a), and leg chaetotaxy is based on Evans (1963).

Voucher and type specimens were deposited at Instituto Nacional de Biodiversidad del Ecuador (INABIO), Quito, Ecuador; Laboratorio de Entomología y Acarología de la Universidad Central del Ecuador (LEA-UCE), Quito, Ecuador, and Departamento de Entomologia e Acarologia, Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo (ESALQ-USP), Piracicaba, Brazil.

3.3. Results

3.3.1. Genus *Gamasiphis* Berlese, 1904

Gamasiphis Berlese 1904: 261 (type species: *Gamasus pulchellus* Berlese, 1887, by original designation).

Gamasiphis. Castilho *et al.* 2010: 32; 2012b: 1970; 2016: 13.

Diagnosis (adult female)**.** The genus diagnosis of Castilho *et al.* (2016) was followed, correcting that seta *j1* can vary from shorter to longer than *J5* (instead of *Z5*), and that exopodal platelets near coxae II–III–IV (instead of II–III–III) are fused.

3.3.2. *Gamasiphis* n. sp.

Specimens examined: ECUADOR: Esmeraldas (Coast region): one female, La Independencia (0°06'29.8"N 79°21'16.9"W; 164 m), from soil at the base of *Piper peltatum* on 26 September 2019. **ECUADOR: Napo (Amazon region)**: one female, Tena (0°53'49.4"S 77°48'08.0"W; 608 m), from soil at the base of *Musa paradisiaca* on 4 August 2019; two females, Tena (0°53'49.7"S 77°48'07.5"W; 611 m), from soil at the base of *Citrus limon* on 4 August 2019; one female, Tena (0°53'49.4"S 77°48'06.5"W; 610 m) from soil at the base of *Saccharum officinarum* on 4 August 2019; one female, Tena (0°19'36.7"S 76°53'17.5"W; 607 m) from soil at the base of *Renealmia sessilifolia* on 26 February 2018. All specimens collected by C.A. Ortega-Ojeda. The specimen from Esmeraldas deposited at INABIO. Three specimens from Napo, deposited at LEA-UCE and two at ESALQ/USP.

Diagnosis (adult female). Anteromedial extension of epistome aciculate; setae *j2*, *j3*, *j4*, *j5*, *z3* and *Z1* at least as long as distance to the base of the respective subsequent setae; with two pairs of presternal platelets; seta *Zv2* as long as distance to base of *Zv3*; seta *Jv5* about in level with anterior margin of anal opening and about four times as long as para-anal seta; post-anal seta about 4.5 times as long as para-anal setae.

Description.

Adult female (n = 6) (Figs. 1-8).

Gnathosoma. Fixed cheliceral digit 44 (42–47) long, with 7–8 teeth in addition to the apical hook and the aciculate *pilus dentilis* (Fig. 1); movable cheliceral digit 47 (44–49) long, with four teeth in addition to the apical hook; chelicera with antiaxial and dorsal lyrifissures as well as dorsal setae distinct; arthrodial process shaped as a short coronet-shaped fringe. Palp apotele 3-tined. Epistome 3-tined, with an anteromedian extension longer than others, all three aciculate (Fig. 2). Deutosternum with indistinct margins, with seven transverse denticulate lines (Fig. 3); anterior-most shaped as an inverted "V", first to fourth lines with very small teeth, and fifth to seventh multidenticulate; lines fourth to sixth U-shaped. Internal malae fimbriate laterally. Corniculi horn-shaped 26 (25–27) long, 16 (15–16) wide at the widest point; seta *h3* directly posterior to *h1* and slightly anterior and medial to *h2*. Measurements of setae: *h1* 21 (20–22), *h2* 18 (17–20), *h3* 21 (18–22), *sc* 18 (17–20); all setae aciculate.

Dorsal idiosoma (Fig. 4). Dorsal shield 437 (419–455) long, 269 (265–276) wide (between *s6* and *r6*), covering totally the idiosoma. Podonotal region smooth anteriad of *z4*, imbricate behind; with 22 pairs of setae (*r1* and *r2* absent; other *r* setae visible in ventral view); with seven pairs of lyrifissures and four pairs of pores. Opisthonotal region imbricate anteriad of *J4*, smooth behind; with 14 pairs of setae (*J1* and all *R* setae absent); *S2* and *S*5 visible in ventral view; with nine pairs of distinguishable lyrifissures and two pairs of distinguishable pores. Measurements of setae: *j1* 13 (12–14), *j2* 34 (33–35), *j3* 33 (30–36), *j4* 34 (31–35), *j5* 34 (32–35), *j6* 34 (33–35), *z1* 15 (14–15), *z2* 30 (28–32), *z3* 34 (33–35), *z4* 35 (34–36), *z5* 28 (28–30), *z6* 37 (35–40), *s1* 14 (12–15), *s2* 14 (13–15), *s3* 33 (30–35), *s4* 36 (35–37), *s5* 36 (35–37), *s6* 33 (32–35), *r3* 23 (20–25), *r4* 12 (10–15), *r5* 11 (8–13), *r6* 28 (25–31), *J2* 20 (16–24), *J3* 19 (16–21), *J4* 11 (10–11), *J5* 7 (6–7), *Z1* 37 (36–40), *Z2* 19 (17–21), *Z3* 21 (20–21), *Z4* 10, *Z5* 69 (66–71), *S1* 7, *S2* 8 (7–9), *S3* 7, *S4* 11 (10–11), *S5* 17 (16–19); all setae aciculate.

Ventral idiosoma (Fig. 5). Base of tritosternum 19 (18–21) long and approximately 13 wide basally (Fig. 6); laciniae 65 (58–73) long, pilose, separated for about 95% of their total length. With two pairs of presternal platelets. Sternal shield reticulate; 73 (70–75) long at midline and 69 (65–75) wide at median level of coxae II; with four pairs of setae (*st1*–*st4*), *st3* inserted in line and medial to *st2*, and four pairs of lyrifissures. Genital shield scantly reticulate, 70 (68–73) long and 70 (68–72) wide at the widest level; bearing *st*5, distance *st5–st5* 47 (46–49), anterior margin convex and posterior margin truncate. Ventrianal shield imbricate anteriorly to *Zv3* and apparently smooth posteriorly; 205 (182–221) long at midline (from anterior margin to postanal seta), 176 (148–192) wide at widest point (between *Jv2* and *Zv2*); with eight pairs of setae (*Jv1–Jv5*, *Zv1–Zv3*) in addition to circumanal setae and with four pairs of distinguishable lyrifissures. Peritreme extending to region between coxae I and II. Measurements of setae: *st1* 24 (23–25), *st2* 24 (23–27), *st3* 13 (13–14), *st4* 20 (20–21), *st5* 19 (18–20), *Jv1* 25, *Jv2* 25 (23–27), *Jv3* 26 (25–26), *Jv4* 33 (31–36), *Jv5* 46 (44–48), *Zv1* 32 (29–34), *Zv2* 35 (34–36), *Zv3* 25 (24–25), para-anal 13 (12–14), post-anal 53 (50–54); all setae aciculate.

Spermatheca (Fig. 7). Phytoseiid-type. Spermathecal apparatus distinguishable as a membranous tubular structure, extending medially from base of coxa IV.

Legs. Lengths: I: 352 (330–364); II: 277 (250–296); III: 242 (230–247); IV: 339 (320–351). Numbers of setae on segments of legs I–IV: coxa: 2, 2, 2, 1; trochanter: 6, 5, 5, 5; femur: 13, 11, 6, 6; genu: 13, 11, 9, 8; tibia: 14, 10, 8, 9; tarsus II–IV: 18, 18, 17. Leg IV with four macrosetae: two on genu [*ad2* 42 (41–42) and *pd1* 39 (38–39)], one on tibia [*pd1* 42 (40–42)] and one on basitarsus [*pd3* 46 (44–46)] (Figure 8). All legs with pretarsi, with elongate ambulacral stalk and a pair of strongly sclerotized claws.

Remarks. *Gamasiphis* **n. sp.** is most similar to *G. adanalis* Karg, 1990, but the latter has 20 pairs of setae on the podonotal region (*s1* absent and only three pairs of *r* setae); 12 pairs of setae on the opisthonotal region; the dorsal setae ranging between 15-20 long; setae *j2*, *j3*, *j4*, *j5*, *z3* and *Z1* at most 0.6 times as long as distance to the base of the respective subsequent setae.

Regarding the key to *Gamasiphis* species provided by Castilho *et al.* (2012b), couplet 52 (page 1993) would require the following adjustment for inclusion of this new species:

52. Dorsal and ventrianal shields mostly imbricate 52a

– Dorsal shield smooth and ventrianal shield smooth or transversely striate anteriorly to *Zv2* and smooth elsewhere 53

52a. Podonotal region with 20 pairs of setae (*s1* absent and three pairs of *r* setae); opisthonotal region with 12 pairs of setae; setae *j2*, *j3*, *j4*, *j5*, *z3* and *Z1* at most 0.6 times as long as the distance to base of the respective subsequent setae ………………………………………. .... ***Gamasiphis adanalis*** Karg, Lesser Antilles (Karg 1990)

– Podonotal region with 22 pairs of setae (*s1* present and four pairs of *r* setae); opisthonotal region with 14 pairs of setae; setae *j2*, *j3*, *j4*, *j5*, *z3* and *Z1* at least as long as the distance to base of the respective subsequent setae ....***Gamasiphis* n. sp.**, Ecuador

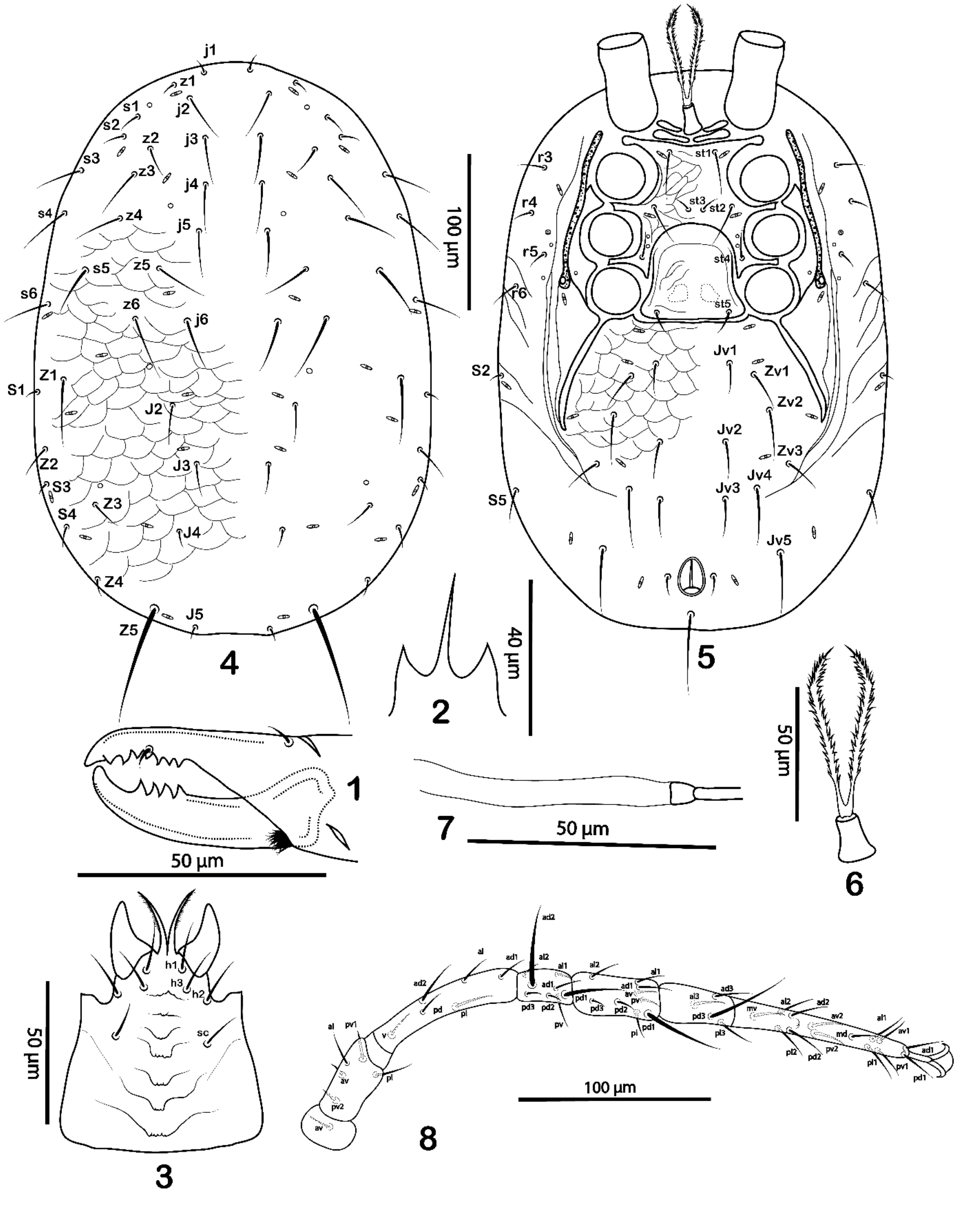
3.3.3. *Gamasiphis plenosetosus* Karg, 1994

Gamasiphis plenosetosus Karg 1994b: 210.

Gamasiphis plenosetosus. — Castilho *et al.* 2012b: 1985.

Material examined. ECUADOR: **Napo (Amazon region)**: one female, between Santa Rosa de Quijos and El Chaco (0°19'31.9"S 77°47'36.7"W; 1531 m), from soil at the base of *Solanum quitoense* on 4 August 2019; one female, Tena (0°53'49.4"S 77°48'06.5"W; 608 m) from soil at the base of *Saccharum officinarum* on 4 August 2019; **ECUADOR**: **Orellana (Amazon region)**: one female, Joya de los Sachas (0°19'36.7"S 76°53'17.9"W; 278 m) from soil at the base of *Urera baccifera* on 26 February 2018; one female. Joya de los Sachas (0°19'36.7"S 76°53'17.5"W; 274 m) from soil at the base of *Coix lacryma-jobi* on 26 February 2018; **ECUADOR**: **Sucumbios (Amazon region)**: one female, Nueva Loja (East) (0°06'02.7"S 76°52'14.8"W; 300 m) from soil at the base of *Musa paradisiaca* on 21 February 2018; one female, Nueva Loja (East) (0°06'03.1"S 76°52'14.1"W; 294 m) from soil at the base of *Citrus limon* on 21 February 2018; three females, Joya de los Sachas (0°19'36.8"S 76°53'17.8"W; 284 m) from soil at the base of *Mangifera indica* on 26 February 2018; one female, Alma Ecuatoriana (0°00'32.6"S 77°28'20.3"W; 1187 m) from soil at the base of *Rubus rosifolius* on 21 February 2018; two females, Nueva Loja (East) (0°06'03.1"S 76°52'14.2"W; 309 m) from soil at the base of *Sapindus saponaria* on 21 February 2018; two females Nueva Loja (East) (0°06'02.9"S 76°52'14.6"W; 312 m) from soil at the base of *Ficus americana* on 21 February

2018; one female, Nueva Loja (East) (0°06'02.9"S 76°52'14.5"W; 298 m) from litter at the base of *Siphocampylus* sp. on 21 February 2018. All specimens collected by C.A. Ortega-Ojeda.



Figures 1–8. *Gamasiphis* **n. sp.,** adult female. 1. Lateral (antiaxial) view of chelicera; 2. Epistome; 3. Hypostome; 4. Dorsal idiosoma; 5. Ventral idiosoma; 6. Tritosternum; 7. Spermatheca; 8. Leg IV: Macrosetae on genu, tibia, basitarsus. Lyrifissures and pores enlarged for improved visibility.

Complementary description.

Adult female (n = 15) (Figs. 9–16).

Gnathosoma. Fixed cheliceral digit 42 (39–47) long, with six teeth in addition to the apical hook and the aciculate *pilus dentilis* (Fig. 9); movable cheliceral digit 44 (43–47) long, with four teeth in addition to apical hook; chelicera with antiaxial and dorsal lyrifissures as well as dorsal setae distinct; arthrodial process of chelicera shaped as a short coronet-shaped fringe. Palp apotele 3-tined. Epistome 3-tined, with anteromedial extension club-shaped and denticulate (Fig. 10); anterolateral extensions smooth, aciculate, shorter than anteromedial extension and smooth. Deutosternum with indistinct margins, apparently with seven transverse lines (Fig. 11); first to fourth lines each with 5–6 denticles, fifth and sixth lines multidenticulate; fourth to sixth transverse lines U-shaped. Internal malae with fringed lateral margins. Corniculi horn-shaped, 22 (21–23) long, 14 (13–14) wide at the widest point. Seta *h3* posterolateral to *h1* and anteromedial to *h2.* Measurements of setae: *h1* and *h2* 13 (12–14), *h3* 14 (13–16), *sc* 15 (13–18); all setae aciculate.

Dorsal idiosoma (Fig. 12). Dorsal shield 385 (335–403) long, 240 (226–260) wide (between *s6* and *r6*), covering totally the idiosoma. Podonotal region imbricate posterolaterally to *z4*, smooth elsewhere; with 23 pairs of setae (*r1* absent); *r5* in a more ventral position than other *r* setae; with five pairs of distinguishable lyrifissures and four pairs of distinguishable pores. Opisthonotal region imbricate; with 18 pairs of setae (*R1* and *R5* absent); with eight pairs of distinguishable lyrifissures and one pair of distinguishable pores; with a slightly curved line extending diagonally from shield margin through level between *S2* and *R2* toward base of *Z1*. Measurements of setae: *j1* 11 (10–12), *j2* 30 (28–32), *j3* 27 (26–31), *j4* 27 (26–29), *j5* 27 (25–30), *j6* 31 (28–33), *z1* 7 (6–10), *z2* 25 (23–27), *z3* 29 (23–32), *z4* 29 (26–32), *z5* 28 (25–31), *z6* 31 (26–36), *s1* 24 (23–25), *s2* 26 (24–27), *s3* 31 (26–34), *s4* 34 (30–36), *s5* 35 (31–36), *s6* 36 (31–38), *r2* 27 (25–29), *r3* 24 (21–27), *r4* 25 (21–27), *r5* 14 (12–15), *r6* 33 (30–36), *J1* 28 (23–35), *J2* 33 (31–36), *J3* 34 (32–38), *J4* 30 (26–35), *J5* 20 (15–23), *Z1* 35 (31–39), *Z2* 37 (34–40), *Z3* 37 (31–42), *Z4* 28 (25–31), *Z5* 47 (43–52), *S1* 36 (30–40), *S2* 37 (35–42), *S3* 36 (34–37), *S4* 31 (29–34), *S5* 31 (29–35), *R2* 38 (35–40), *R3* 38 (36–40), *R4* 39 (36–42); all setae aciculate.

Ventral idiosoma (Fig. 13). Base of tritosternum 26 long and 14 (12–16) wide basally (Fig. 14); laciniae 41 (39–44) long, pilose, separated for about 90% of their total length. With two pairs of presternal platelets. Sternal shield with scant reticulation; 90 (88–91) long at midline and 63 (57–68) wide at median level of coxae II; with four pairs of setae (*st1*–*st4*), *st3* inserted posterior and medial to *st2*; and four pairs of distinguishable lyrifissures. Genital shield apparently smooth; 64 (60–68) long and 58 (55–62) wide at widest level; bearing *st*5, distance *st5*–*st5* 36 (34–39); anterior margin convex and posterior margin truncate. Ventrianal shield imbricate anteriorly to *Jv4* and smooth posteriorly; 189 (159–203) long at midline (from anterior margin to post-anal seta), 186 (174–203) wide at widest point (between setae *Jv2* and *Zv2*); with eight pairs of setae (*Jv1*–*Jv5*, *Zv1*–*Zv3*) in addition to circumanal setae, and three pairs of distinguishable lyrifissures. Peritreme extending to level of median region of coxa II. Measurements of setae*: st1* 20 (18–22), *st2* 17 (16–19), *st3* 10 (8–11), *st4* 17 (16–19), *st5* 16 (15–18), *Jv1* 21 (20–23), *Jv2* 25 (23–26), *Jv3* 28 (25–34), *Jv4* 37 (34–40), *Jv5* 29 (27–33), *Zv1* 33 (30–39), *Zv2* 37 (34–39), *Zv3* 38 (36–39), para-anal 11 (10–12), post-anal 12 (10–14); all setae aciculate.

Spermatheca (Fig. 15). Phytoseiid-type, clearly distinguishable as an elongate and curved scletorized structure, projecting from the posterior internal margin of the base of coxa IV, continuing in a long, membranous structure.

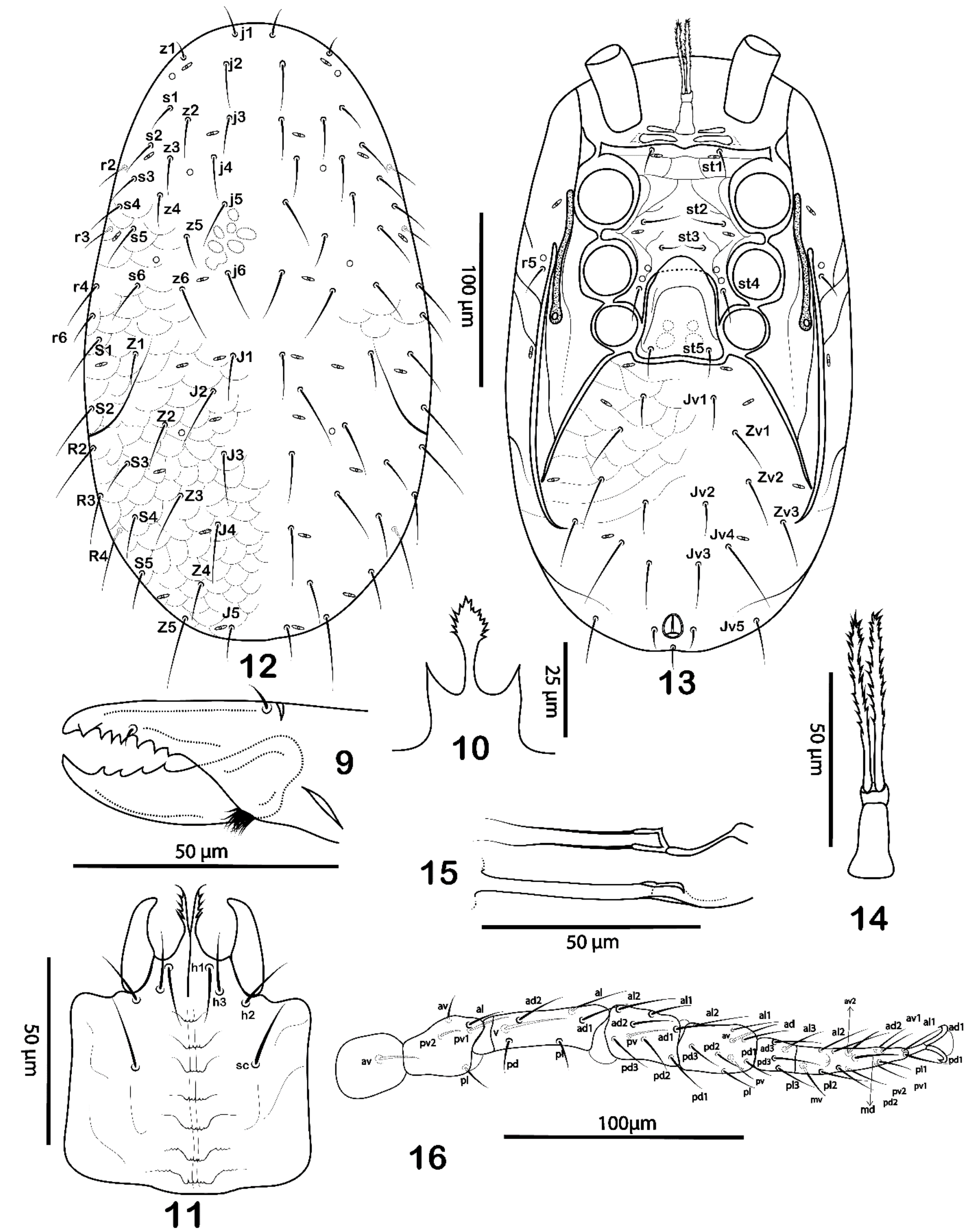
Legs. I: 329 (309–348); II: 251 (221–268); III: 214 (200–234); IV: 281 (273–286). Chaetotaxy of legs I–IV: coxa: 2, 2, 2, 1; trochanter: 6, 5, 5, 5; femur: 13, 11, 6, 6; genu: 13, 11, 9, 8; tibia: 14, 10, 8, 9; tarsus II–IV: 18, 18, 17. Without macrosetae on all legs, including leg IV (Fig. 16). All legs with pretarsi, elongate ambulacral stalk and a pair of strongly sclerotized claws.

Remarks. The redescription of this specie provided by Castilho *et al.* (2012b) complemented very well the original description, which did not provide sufficient morphological details. However, many setae of the holotype are broken, and thus their measurements could not be provided in the redescription by Castilho *et al.* (2012b). The measurements of this publication are similar to those reported by their redescription for the available setae in the holotype. Differently from what was observed in the specimens examined in this study, Castilho *et al.* (2012b) reported the presence of three teeth on the movable cheliceral digit, and the absence of *S5* and presence of *R1* in the redescription of the species based on their examination of the holotype. Also, information about the spermatheca could not be provided by Castilho *et al.* (2012b), and it is here provided for the first time.

3.3.4. *Gamasiphis salvadori* Castilho, Narita & Moraes, 2012

Gamasiphis salvadori Castilho *et al.* 2012b: 1971.

Material examined. ECUADOR: **Napo (Amazon region)**: one female from litter at the base of *Citrus limon* between Santa Rosa de Quijos and El Chaco (0°19'32.2"S 77°47'36.6"W; 1529 m) on 4 August 2019; one female from litter at the base of *Hibiscus rosa-sinensis* between Santa Rosa de Quijos and El Chaco (0°19'32.3"S 77°47'36.2"W; 1513 m) on 4 August 2019; one female from litter at the base of *Solanum quitoense* between Santa Rosa de Quijos and El Chaco (0°19'32.0"S 77°47'36.7"W; 1531 m) on 8 August 2019; one female from litter at the base of *Saccharum officinarum* at Tena (0°53'49.4"S 77°48'06.5"W; 610 m) on 4 August 2019; one female from litter at the base of *Ocotea floribunda* at Tena (0°53'49.0"S 77°48'06.8"W; 633 m) on 4 August 2019; **ECUADOR**: **Pichincha (Highland region)**: one female from litter at the base of *Citrus limon* at Puéllaro, Alchipichí (0°02'22.4"N 78°24'04.7"W; 2089 m) on 9 February 2018; two females from litter at the base of *Saccharum officinarum* at Mindo (0°04'50.4"S 78°44'45.8"W; 1546 m) on 10 February 2018; one female from litter at the base of *Musa paradisiaca* at Mindo (0°04'50.9"S 78°44'46.2"W; 1547 m) on 10 February 2018; one female from litter at the base of *Brachyotum coronatum* at Mindo (0°04'51.5"S 78°44'44.7"W; 1592 m) on 10 February 2018; one female from soil at the base of *Solanum nigrum* at UCE-CADET (Centro Académico Docente y Experimental-Tola-Universidad Central del Ecuador) (0°13'53.2"S 78°22'09.1"W; 2514 m) on 9 February 2018; one female from soil at the base of *Lantana camara* at UCE-CADET (0°13'48.8"S 78°22'09.9"W; 2509 m) on February 9, 2018. All specimens collected by C.A. Ortega-Ojeda.



Figures 9–16. *Gamasiphis plenosetosus* Karg, 1994, adult female. 9. Lateral (antiaxial) view of chelicera; 10. Epistome; 11. Hypostome; 12. Dorsal idiosoma; 13. Ventral idiosoma; 14. Tritosternum; 15. Spermatheca; 16. Leg IV. Lyrifissures and pores enlarged for improved visibility.

Complementary description.

Adult female (n = 12) (Figs. 17–18).

Gnathosoma. Fixed and movable cheliceral digits 64 (57–68) and 68 (65–70) long respectively. Corniculi 35 (34–36) long, 23 (21–23) wide at the widest point, about 1.5 as long as its basal width. Measurements of setae: *h1* 34 (34–36), *h2* 28 (28–31), *h3* 37 (37–39), *sc* 29 (29–31).

Dorsal idiosoma. Dorsal shield about 20 % shorter and narrower than reported in the original description of the species. Dorsal shield 437 (429–447) long, 262 (260–268) wide (between *s6* and *r6*), covering totally the idiosoma. Measurements of setae *j1* 13, *j2* 49 (49–55), *j3* 56 (56–60), *j4* 66 (66–68), *j5* 53 (53–55), *j6* 89 (89–91), *z1* 9 (9–10), *z2* 9 (9–10), *z3* 10 (10–12), *z4* 62 (62–65), *z5* 71 (68–75), *z6* 92 (92–96), *s2* 61 (61–65), *s3* 12 (12–13), *s4* 70 (70–75), *s5* 79 (79–81), *s6* 13 (13–16), *r2* 21 (21–23), *r3* 18, *r4* 12 (12–13), *r5* 24 (24–29), *r6* 12 (12–13), *J3* 8, *J4* 8, *J5* 10, *Z1* 11 (11–13), *Z2* 8, *Z3* 10, *Z4* 7 (7–8), *Z5* 107 (107–114), *S1* 8 (8–10), *S2–S4* 8.

Ventral idiosoma. Base of tritosternum 22 (20–26) long and 18 (16–21) wide proximally; laciniae 87 (81–94) long, separated for about 95 % of their total length. Sternal shield 83 (78–88) long at midline and 97 (91-99) wide at median level of coxae II. Genital shield 95 (91–101) long and 104 (91–117) wide at the widest level. Ventrianal shield 286 (273–299) long at midline (from anterior margin to post-anal seta) and 282 (270–294) wide at widest point (between *Zv1* and *Zv2*). Measurements of setae: *st1* 41 (39–42), *st2* 36 (34–39), *st3* 24 (23–26), *st4* 32 (31–34), *st5* 26 (23–29), *Jv1* 29 (29–31), *Jv2* 24 (23–26), *Jv3* 23, *Jv4* 33 (29–36), *Jv5* 87 (83–91), *Zv1* 29 (29–31), *Zv2* 34 (31–36), *Zv3* 30 (29–31), para-anal 16 (16–18), post-anal 100 (96–104).

Spermatheca (Figure 17)**.** Phytoseiid-type, clearly distinguishable as a sclerotized, elongated cup-shaped structure projecting from the posterior external margin of the base of the coxa IV, continuing in a membranous structure.

Legs. I: 472 (429–494); II: 410 (377–442); III: 394 (367–416); IV: 536 (507–588). Numbers of setae on segments of legs I–IV: coxa: 2, 2, 2, 1; trochanter: 6, 5, 5, 5; femur: 13, 11, 6, 6; genu: 13, 11, 9, 8; tibia: 14, 10, 8, 9; tarsus II–IV: 18, 18, 17. Leg IV with six macrosetae (Figure 18): three on genu [*ad1* 63 (60-65), *ad2* 41 (36-44) and *pd1* 55 (52-57)]; two on tibia [*ad1* 41 (34-44) and *pd1* 54 (52-57)] and on one on basitarsus [*pd3* 64 (62-65)].

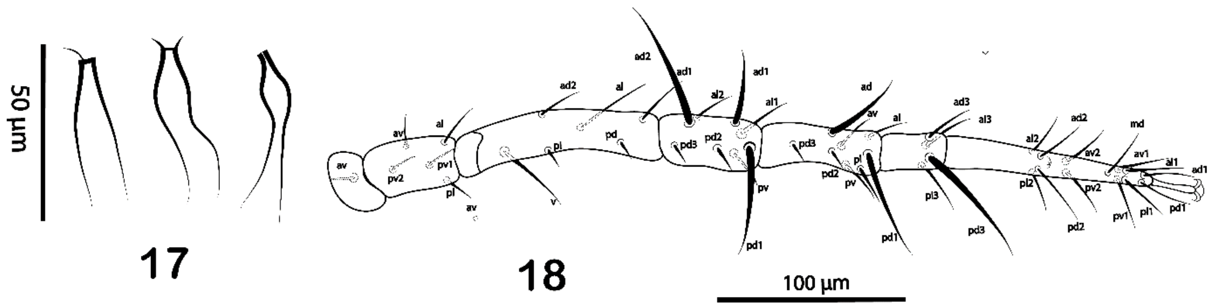


Figure 17–18. *Gamasiphis salvadori* Castilho, Narita & Moraes 2012, 17. Spermatheca; 18 Leg IV: Macrosetae on genu, tibia, basitarsus.

Remarks. This is the first record of this species outside of Brazil. The specimens collected from Ecuador fit well the description provided by Castilho *et al.* (2012b), based on females from Brazil. Given the very satisfactory original description of this species, new illustrations are not presented in this paper, except for the spermatheca and leg IV macrosetae. The presence of macrosetae on leg IV is not shown in the original description, but an examination of the type specimens showed that they are similar to what is shown herein for the Ecuadorian specimens.

3.4. Discussion

An important characteristic to be considered for the separation of species of this genus is the presence of leg macrosetae. In a diagnosis of *Gamasiphis*, Lee (1970) mentioned that setae *ad2*, *pd3* or *pd4* of tarsus IV may be distinctly longer than other setae. However, this character has apparently not received due attention in the descriptions of *Gamasiphis* species along time; for many species nothing is mentioned about the characteristics of the legs.

Of all species described in this genus, information about leg IV has only been provided for *G. angaridis* Marchenko, 2013a, *G. australicus* Womersley, 1956, *G. benoiti* Loots, 1980, *G. femoralis* (Banks, 1916), *G. fornicatus* Lee, 1970, G. *indicus* Bhattacharyya, 1978, *G. lenifornicatus* Lee, 1973, *G. maheensis* Loots, 1980, *G. ochotensis* Marchenko, 2013b, *G. setosus* Womersley, 1956 and *G. sextus* Vitzthum, 1921. Of all these, presence of macroseta has only been reported by Bhattacharyya (1978) for *G. indicus* and by Marchenko (2013a) for *G. angaridis*. In *G. indicus*, two macrosetae are mentioned on genu, one on tibia and one on tarsus of leg IV, as observed in this study for *Gamasiphis* **n. sp.** In *G. angaridis*, the illustration provided in the original description suggest the presence of two macrosetae on genu IV and one on tibia IV, although nothing in this regard is mentioned in the text of that description.

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4. FINAL REMARKS

This is the first work carried out in a systematic way for determine the diversity and abundance of soil mites in the three continental regions of North of Ecuador. The results of this work respond to the proposed objectives, revealing the great diversity of edaphic mites of the order Mesostigmata in different regions of Ecuador, with typical environmental conditions that promote the presence of distinctive biota.

Chapter 2 refers to an analysis of diversity of the mites in the soil and litter of cultivated and non-cultivated ecosystems in the three continental regions of continental Ecuador. It was shown that oribatid (mainly) and non-Uropodina mesostigmatid mites were the most abundant mite groups. Mesostigmatid mites were identified down to genus, to be separated into morphospecies or, in some cases, to species level. Most of these mites were found at the immature stages; based on adult females, they were identified in 16 families, the most abundant being the Ascidae, Laelapidae and Ologamasidae. Highest mesostigmatid abundance and diversity was found in the Highland region.

Abundance was higher in non-cultivated than in cultivated environments, while the substrate with the highest number of species was the soil in the Amazon and Highland regions, and litter in the Coast region. The mesostigmatid collected were separated into 193 morphospecies belonging to 53 genera. The most abundant morphospecies were *Asca* aff. *garmani* (Ascidae), *Gamasiphis* possibly n. sp. 1 and 2 and *Neogamasellevans* n. sp. 1 and 2 (Ologamasidae). Thirteen new species were identified, belonging to the following genera, within their respective families: Ascidae (*Gamasellodes*, 1 species), Blattisociidae (*Cheiroseius*, 1); Laelapidae (*Gaeolaelaps*, 1); Macrochelidae (*Holostaspella*, 2 and *Macrocheles*, 2); Ologamasidae (*Neogamasellevans*, 2 and *Gamasiphis*, 3). One of the new species of the latter genus was described as shown in Chapter 3. A new species of a possibly new genus of Melicharidae was also found.

Some taxa collected are new reports for Ecuador, as one family, 22 genera and 16 species. Likewise, from the Uropodina-Mesostigmata, 4 families, 9 genera and 1 species were identified.

Additionally, calculated diversity indexes showed high richness indexes, and the absence of dominant species in the three regions. Concurrently, it was shown that the Coast region always presented lower diversity values compared to the other two regions. Differences were observed between the sampling sites in each region, which would show the importance of taking samples in places with environmental differences, which occur in the regions of this country. By observing the edaphoclimatic conditions, characterized in this study, presented by the different sample sites, the Amazon region, for example, has more uniform edaphoclimatic conditions than the Coast. Despite that, some species were found in one site but not in others. So, to measure diversity it is important to take into account the existence of variability in the natural populations.

Chapter 3 concentrates on the Ologamasidae family, which was the most abundant, and presented the new species *Gamasiphis* n. sp., which was found in the Coast and Amazon regions. In this same chapter, a key to help in the separation of the world *Gamasiphis* species was presented, based on adult female morphology. In addition to this, *G. plenosetosus*, previously reported for Ecuador, a complementary description of this species was presented. This species was collected in the Amazon region, and its original description and the redescription by Castilho *et al*. (2012) were not complete. Also, *G. salvadori*, collected in the Amazon and Highland regions, is a new species record for the country; a complementary description of this species was presented.

Despite the existence of previous reports of edaphic mesostigmatid mites in Ecuador, in this study, knowledge of their diversity is enriched, including the Uropodina. The results show that the co-occurrence of certain mites' species in areas with different edaphoclimatic conditions and different plant communities confirm the versatility of certain mite species to adapt to the prevailing conditions, leaving many questions about their behavior. The taxonomic work initiated in this study will be complemented in subsequent projects to describe the new species or complement the identification of all morphospecies, which could not be completed in the present work for time limitation.

This work is expected to contribute to the knowledge on the diversity of edaphic mites in Ecuador, in addition to promoting the study of this group of arthropods of relevance to the biological management of soil pests, in addition to awakening the interest of professionals in agronomy, biology and related areas to conduct further work with this group.