

**University of São Paulo
“Luiz de Queiroz” College of Agriculture**

Plant mite (Acari) diversity in three regions of Ecuador

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

**Piracicaba
2022**

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Plant mite (Acari) diversity in three regions of Ecuador
versão revisada de acordo com a Resolução CoPGr 6018 de 2011

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To my dear family,
for supporting me with lovely motivating words,
which helped me find courage to conduct my doctoral study,
even in the most difficult circumstances

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Never mistake knowledge for wisdom.

*One helps you make a living,
the other helps you make a life.*

*People grow through experience
if they meet life honestly and courageously.*

Eleanor Roosevelt

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RESUMO

Diversidade de ácaros (Acari) plantícolas em três regiões do Equador

Como concluído por estudos recentes, ignorar os invertebrados e considerar basicamente apenas aves e mamíferos da Lista Vermelha da IUCN (União Internacional para a Conservação da Natureza) seria ignorar a aparentemente evidente sexta extinção em massa. Esta realidade é o que torna os estudos sobre biodiversidade tão importantes e úteis como "arqueologia preventiva", coletando e documentando o maior número possível de espécies, antes que desapareçam. Ignorar esta situação é como não fazer nada, negar a crise, ou aceitá-la inconvenientemente, levando o planeta inevitavelmente para a alertada nova extinção em massa, a sexta. Essa certeza e a necessidade primordial de conhecer a diversidade dos ácaros equatorianos, defendê-la e promovê-la, motivaram o presente estudo, que depois de realizado como prospecção, será a base para um estudo maior, que sistematicamente leva a determinar a diversidade de ácaros equatorianos, continentais e insulares. Com este pano de fundo, foi realizado um levantamento sistemático da diversidade da subclasse Acari na região norte do Equador, em pequenas e médias propriedades agrícolas, em hospedeiros botânicos silvestres e cultivados. Foram identificadas 2 257 espécies, correspondentes com 19 famílias, das ordens Mesostigmata e Trombidiformes, incluindo possíveis novos relatos para o país e novas espécies, uma das quais foi relatada como *Amblyseius yumbus* Ortega-Ojeda, Santos, Melo-Molina e Moraes 2021, ácaro com potencial predador de ácaros fitófagos.

Palavras-chave: Acarologia, Mesostigmata, Trombidiformes, Invertebrados, Sistemática de ácaros

ABSTRACT

Plant mite (Acari) diversity in three regions of Ecuador

As concluded by recent studies, to disregard the invertebrates and include basically just birds and mammals in the IUCN (International Union for Conservation of Nature) Red List would be ignoring the apparently evident sixth mass extinction. This reality is what makes studies about biodiversity so important and useful as "preventive archaeology", by collecting and documenting as many species as possible before they disappear. Ignoring this situation is like doing nothing, denying the crisis, or accepting it inconveniently, leading the planet inevitably towards that alerted new mass extinction, the sixth. This certainty and the primary need to know the diversity of the Ecuadorian mites, to defend and promote it, have motivated the present study, which after being carried out as a prospection, will be the basis for a larger one, which systematically leads to determine the Ecuadorian mite diversity, continental and insular. With this background, a systematic survey of the diversity of the subclass Acari was carried out in the northern region of Ecuador, in small and medium sized farms, on wild and cultivated plant species. There were identified 2,257 mites from nineteen families, corresponding to the orders Mesostigmata and Trombidiformes, including possible new records for the country and new species, one of which was published as *Amblyseius yumbus* Ortega-Ojeda, Santos, Melo-Molina and Moraes 2021, mite with potential for predation of phytophagous mites.

Keywords: Acarology, Mesostigmata, Trombidiformes, Invertebrates, Mite systematics

RESUMEN

Diversidad de ácaros (Acari) de plantas en tres regiones del Ecuador

Como concluyen estudios recientes, el hecho de no considerar un buen número de invertebrados, incluidos entre los artrópodos, insectos y ácaros, y utilizar básicamente aves y mamíferos de la Lista Roja de la UICN para los análisis, estaría ignorando la aparentemente evidente sexta extinción masiva. Es por ello que este tipo de estudios de la diversidad adquieren relevancia, por su utilidad como “arqueología preventiva”, al recolectar y documentar el mayor número posible de especies antes de que finalmente desaparezcan. Ignorar esta situación es como no hacer nada, negar la crisis, o aceptarla inconvenientemente, conduciendo inevitablemente al planeta hacia esa alertada nueva extinción masiva, la sexta. Esta certeza y la necesidad primordial de conocer la diversidad de los ácaros ecuatorianos, para defenderla y promoverla, han motivado el presente estudio, que luego de ser realizado a modo de prospección, será la base para un estudio más amplio, que lleve sistemáticamente a determinar la diversidad del ácaro ecuatoriano, continental e insular. Con ese antecedente, se realizó una prospección sistemática de la región Norte del Ecuador, en fincas de pequeños y medianos agricultores, en hospederos botánicos silvestres y cultivados, de la diversidad de la Subclase Acari. Fueron identificados 2 257 especies de ácaros, pertenecientes a 19 familias, de los órdenes Mesostigmata y Trombidiformes, incluyendo posibles nuevos reportes para el país y nuevas especies, una de las cuales fue publicada como *Amblyseius yumbus* Ortega-Ojeda, Santos, Melo-Molina y Moraes 2021, ácaro potencial predador de ácaros fitófagos.

Palabras clave: Acarología, Mesostigmata, Trombidiformes, Invertebrados, Sistemática de ácaros

1. INTRODUCTION

With 256 370 km², Ecuador is a small country (Checa & Herrera Díaz, 2013), but a country of great biodiversity. Despite the small size, this country extends over parts of the two hemispheres, bordering Colombia in the north, Peru in the south and east, and the Pacific Ocean in the east. It has four geographic regions, namely the western plains of the Coast Region, the central Highland or “Sierra”, the east Amazon, and the Galápagos Archipelago or Insular Region, 1,000 km west from the continent, in the Pacific Ocean. Ecuador’s mainland is composed of seven biomes: tropical rainforests, tropical dry forests, savannas, xerophytic shrubs, montane forests, paramos and mangroves (Sáenz & Onofa, 2005), distributed in 14 ecosystems, according to Sáenz and Onofa (2005), or 51 ecosystems, according with Cuesta-Camacho *et al.* (2007).

The Coast (24.6 % of total area of Ecuador) (Ministerio del Ambiente, 2010), goes from 0 to 1,300 m, within sub-regions north, center and south (Sáenz & Onofa, 2005). The average monthly temperature of the Coast is 27 °C; annual rainfall ranges between 2,000 and 7,000 mm from the northern bord with Colombia to approximately 10 °S of the equatorial line of the Andes, due to the influence of the warm current of the El Niño; south of it and to the Pacific Ocean two regions with deciduous forest and dry scrub, rainfall is less than 1,000 mm, from the cold stream of Humboldt.

Throughout this region, the main crops are banana, cassava, cocoa, coffee, corn, mango, melon, oil palm, papaya, pineapple, rice, soybeans, sugarcane, watermelon, and tropical grasses (pasture).

The Highland region (24.8 % of Ecuador) (Ministerio del Ambiente, 2010) has a similar vegetation in both mountains, but with a different floristic composition. Of 4,868 species of vascular plants, 1,566 shrubs and trees species grow over 2 400 m (Jørgensen *et al.*, 2006; León-Yáñez *et al.*, 2011; Ministerio del Ambiente, 2010). The rainy season in this region is from October to May (1,500 mm annually). Temperature drops from the highest altitudes, and it flutters daily above 20 °C, especially in cloudy mountains, where it drops to 0 °C.

In this region the main crops are avocado, babaco (*Carica pentagona*), beet, broccoli, bush bean, cabbage, capsicum, carnations for exportation, carrot, chard, cherimoya, citrus, fickle bean, garlic, lettuce, onion, passion fruit, peas, potato, quinoa, roses for exportation, summer flowers for exportation, sweet corn, tomato, tree tomato, wheat and cold climate pastures, among others.

In the Amazon region (47.8 % of Ecuador), the average temperature is 28 °C (Ministerio del Ambiente, 2010). It is located at an altitude of 1,300 m in the eastern foothills of the Andes, including all the mountain ranges and lowlands up to the eastern boundary with Peru. Annual rainfall exceeds 2,000 mm and there are no desert zones in this region. The main crops are cassava, cocoa, coffee, corn, naranjilla, oil palm, papaya, plantain, sugarcane, tea, and tropical grasses (pastures).

Regarding faunistic studies of invertebrates in Ecuador, most effort has been dedicated to the knowledge of those of economic importance, but little emphasis has been dedicated to the study of diversity or endemism. However, the data allow us to assume that this is a very diverse group. For example, in one hectare of tropical forest near the Yasuní Scientific Station of the Pontifical Catholic University of Ecuador-PUCE, around 60,000 species have been reported (Ministerio del Ambiente, 2010; Moncada *et al.*, 2004). According to Barragán (2009), the PUCE Museum has 2,000,000 specimens, of which only 30 % are identified. The arthropods with more information are insects, of the orders Coleoptera and Lepidoptera (Sáenz & Onofa, 2005; Mittermeier, Robles & Goettsch, 1997; Onore & Bollino, 2001; Guevara *et al.*, 2002; Estrella, 1993 and Ministerio del Ambiente, 2010).

According to the investigations carried out in entomology, most of the scientific knowledge on Ecuadorian invertebrates has been produced in other countries, due in part to the few entomologists in Ecuador and the relatively restricted time they dedicate to the production of scientific papers. To change this situation, approximately a decade ago, young entomologists were incorporated to several universities in Ecuador, to complement the work carried out by the specialists of Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP), a government entity officially responsible for all agricultural research.

The pest insects affecting crops in the three regions of mainland Ecuador belong mainly to the following groups: Hemiptera, with its suborders Auchenorrhyncha (Cicadellidae), Sternorrhyncha (Aleyrodidae, Aphididae, Coccidae and Pseudococcidae) and Prosorrhyncha (Heteroptera: Pentatomidae, Miridae and Lyridae); Lepidoptera and its suborder Glossata (Gelechiidae, Pyralidae, Tortricidae, Geometridae and Noctuidae); Diptera suborder Brachycera (Tephritidae and Agromyzidae); Coleoptera with Polyphaga (Melolonthidae, Chrysomelidae and Curculionidae); and Thysanoptera suborder Terebrantia (Thripidae).

Complementing the above, mites have been reported in several important crops in tropical environments, or cold weather, causing heavy losses in yield and commercial quality of crops. In addition to the gigantic cost to control them, there is also a serious problem with environmental pollution and intoxication, generated in the struggle to control them with synthetic biocides (Barbosa *et al.*, 2003; Bellotti *et al.*, 2012; Schoonhoven & Voysest, 1994; Knapp *et al.*, 2018; Krantz & Walter, 2009; Moraes *et al.*, 1987; Moraes *et al.*, 1991; Moraes & Flechtmann, 2008). Mites acquire relevance due to the economic costs of crops such as export flowers, of which Ecuador in 2016 exported 143 t, representing 802,461 million US dollars (Banco Central del Ecuador, 2017). Because of the attack of mites of the family Tetranychidae, Ecuador has recently almost lost the USA market as an important importer of roses, in the second semester of 2012 (Agronegocios Ecuador, 2012).

Along time, mites have been reported for Ecuadorian continental and insular regions, belonging to the families: Ameroseiidae (Karg, 1994); Ascidae (Santos, Demite & Moraes, 2021a); Blattisociidae (Santos *et al.*, 2021b); Gamasiphidae (Karg, 1998); Hypoaspidae and Laelapidae (Karg, 1994); Macrochelidae (Karg, 1994); Melicharidae (Demite, Moraes *et al.*, 2021; Santos, Demite & Moraes 2021a; Santos, Demite & Moraes 2021b; Santos, Demite & Moraes, 2021); Ologamasidae and Parholaspidae (Karg, 1993, 1994, 1998, 2006); Parasitidae and Phytoseiidae (Demite *et al.*, 2021; Schuster, 1966); Podocinidae and Rhodacaridae (Karg, 1994); Stigmaeidae (Vásquez & Dávila, 2018); Tenuipalpidae (Alcívar *et al.*, 2020); Tetranychidae (Vásquez & Dávila, 2018); and Veigaiidae (Karg, 1994).

Additionally, there are several studies on host preferences and distribution of phytophagous mites associated with crops such as vegetables and fruit trees, mainly species of Eriophyidae, Tenuipalpidae and Tetranychidae (Jeppson *et al.*, 1975) but most of these publications were done in other countries, referring to specimens collected in Ecuador.

About control of phytophagous mites, several tools have been recommended in integrated pest control programs against representatives of the family Tetranychidae, as mentioned by Bográn (2012) and Pérez (2015), including biological control with predatory mites of the family Phytoseiidae (Mesostigmata) (Melo-Molina & Ortega-Ojeda, 2012; Moraes & Flechtmann, 2008; Moraza & Balanzategui, 2015). Phytoseiidae is the most important family of predatory mites used for applied biological control of pest arthropods (Knapp, 2018). In Ecuador, the phytoseiid species *Amblydromalus limonicus* (Garman & McGregor), *Amblyseius swirskii* (Athias-Henriot), *Neoseiulus californicus* (McGregor), and

Phytoseiulus persimilis (Athias-Henriot), have been used for the control of *Tetranychus urticae* Koch (Colcha Rovalino, 2013; Hidalgo Astudillo, 2015; Koppert Biological Systems, 2021).

Currently, two companies encourage the use of predatory mites in Ecuador; one promoting the local rearing of native predatory mites (Sponagel, 2022), and the other one (Koppert Biological Systems, 2017) importing and selling the phytoseiid species: *A. limonicus*, *N. californicus*, *A. swirskii*, *P. persimilis* and *Neoseiulus cucumeris* (Oudemans).

The recent reports of a quarantine mite *Mixonychus (Bakerina) citraeus*, on Tahiti or Persian lemon, at northwest of the neighbor Colombia (Flechtmann & Mesa, 2016), and *Raoiela indica* Hirst, in the coastal province of Manabí in Ecuador (Alcívar *et al.*, 2020), makes it relevant to determine efficient predatory mites for their control.

According to some authors, preference should be given to native organism, as, in contrast to the classic biocontrol of pests, several native organisms, instead of the introduced ones, could be useful agents for biocontrol (Parker *et al.*, 2006; Guo, 2006; Miao *et al.*, 2012), by the reduced risk of unpredictable and undesirable effects on non-target species. On the other hand, as native species have co-evolved with local prey/host species, they would have a better chance of keeping pest populations below the level of economic damage, as part of the so-called "environmental resistance" (Legesse *et al.*, 2002); besides, the search for native natural enemies would further save time and money compared to the evaluation of non-native agents in foreign countries and with quarantine procedures (Miao *et al.*, 2012).

Mites used for biological control do not include only predatory plant mites but also include edaphic predators, as those parasitoid mite, a male and an immature male and a deutonymph of *Macrodirychus mahunkai* Hirschmann (Mesostigmata: Uropodidae), and the ecitonine and *Labidus coecus* (Latreille) found in Ecuador, to control leaf-cutting ants, as reported by Lachaud *et al.* (2016).

Population dynamics of herbivorous arthropods are determined by natural enemies (Bernays & Graham, 1988; Hairston *et al.*, 1960; Lawton & Strong, 1981) or by the limited resources (Ohgushi & Sawada, 1985; Schultz, 1988), in the so-called upward forces (availability of nutrients) or downward forces (predators), that is, in the little things (Wilson, 1987) and in the big ones that seem to rule the world (Terborgh, 2008). In natural

environments there is a balance between those organisms belonging to so called trophic chain.

Concurrently with the above, the greatest diversity of beneficial mites could be found, as shown by several studies, where there is a very low or no biocidal press selection, associated with wild plant, in areas with low human intervention, where the abundance of arthropods depends on the form of their interaction with the plant, and their distribution, diversity and organization patterns. They are influenced by biotic and abiotic factors such as climate, nutrient availability, competition for food such as predators, parasites and pathogens, symbionts, decomposers, competitors, etc., motivating a great population in the community (Hunter & Price, 2011).

Then the greatest diversity and abundance of biota occurs in pristine environments, instead of in intervened environments, where these parameters are significantly reduced (Jeppson *et al.*, 1975); confirmed by the fact that generalist predators and parasitoids would have to be more abundant in polycultures than in monocultures (Andow, 1991), because: **a.** they alternate and feed on a wide variety of herbivorous that become available in polycultures at different times during the growing season (Elton, 1927); **b.** It maintains breeding populations in polycultures, while in monocultures only males of some parasitoids are produced (Kulman, 1970); **c.** They can use hosts in polycultures that they could neither find nor use in monocultures (Beard, 1964; Kulman, 1970); **d.** They can exploit the widest variety of herbivores available in different polyculture microhabitats (Root, 1973); **e.** prey and hosts are more abundant or more available in polycultures (Andow & Risch, 1985; Sheehan, 1986).

For this reason, the discovery and description of many species inhabiting an environment continues to be one of the fundamental premises of biology, not only as a reason to determine the phylogeny and the history of taxonomy, but as an important aspect to face invasive species, climate change, destruction of habitats and loss of biodiversity in particular, for where the need for authorized taxonomic information is greater than ever (Zhang, 2011).

On the other hand, despite abundant evidence of a growing biodiversity extinction crisis, there are voices that deny this possibility, especially based on the IUCN Red List, arguing that the rate of species loss does not differ from the background rate. However, this list is not considered to be highly biased in considering nearly all birds and mammals, so only

a very small fraction of invertebrates has been assessed for conservation criteria. Incorporating estimates of the number of extinct invertebrates, it is possible to conclude that the rate greatly exceeds the background rate and, therefore, we are witnessing the beginning of the Sixth Mass Extinction. In the face of the growing crisis, scientists must adopt "preventive archeology" practices, such as collecting and documenting as many species as possible before they disappear. All of this depends on reviving the venerable study of natural history and taxonomy. Doing nothing, by denying the crisis or just accepting it, is not an option, since they make it possible for the Earth to continue its unfortunate trajectory towards the sixth mass extinction (Cowie *et al.*, 2022).

In accordance with the above, this research aimed at characterizing the diversity of plant mites in the three continental regions of northern Ecuador: Amazon, Coast and Highland.

Through this research, it is intended to establish the base for a thorough knowledge of the plant mites found in Ecuador, which will require many years of work considering the great biodiversity of the country. Within the constraint of time available for the conduction of this work, the intention was to determine most mite groups at least to genus level, going further to morphospecies for the most important families, and to describing a new species of predatory mites collected in the study when possible.

1.1. Plant mite systematics

According with Larsen *et al.* (2017), it is assumed that mites only represent 0.25 (on average) per "other" arthropod species and, considering there would be 51 million arthropods then could be 10.2 million mite species. By other hand, about 66,000 mites have so far been described and clearly there is some room to expand that descriptions, as mentioned by Klompen (2021).

Descriptions have changed substantially with the addition of molecular data and new imaging techniques. Molecular work includes standard sequencing of small loci, but it was recently added Next Generation Sequencing with population genetic studies of ticks by Paula Lado getting enough DNA for a modest number of markers from a single mite, although the Next Generation Sequencing-NGS work could only be done on individuals of something the size of ticks (enormous mites), as stated by Klompen (2021).

Because mites have always had an issue because they are just too small, and specimens are on microscope slides, the standard way to study these organisms, where they are crushed, and do not look particularly attractive, so, imaging is one of the more amazing areas of progress for mite studies, as they look in natural form. These issues are being resolved by improved techniques in Scanning Electron Microscopy (SEM) and by confocal microscopy. The big advance in SEM was Low Temperature SEM, which allows to image very soft bodied mites in their natural state. In addition, confocal microscopy is another dimension, by allowing to study internal structures, in example, to make major advances in understanding mouthpart mite function or evolution of reproductive structures. This technique also allows construction of 3D models, so it is possible to visualize specific structures in their natural state and from multiple angles, helping to solve the “too small to see” impediment, as stated by Klompen (2021).

On the other hand, although it is possible to agree with Hebert and Gregory (2005), who stated that by reversing the logic of standard taxonomic approaches that “operate in an a priori fashion—seeking morphological discontinuities”, DNA barcoding may be “a posteriori approach”. Still, it is necessary to relate a morphological description to a bar code. This has been very useful in studies of taxonomic definitions as demonstrated by Bolton *et al.* (2017), in their research on “Morphological support for a clade comprising two vermiform mite lineages: Eriophyoidea (Acariformes) and Nematalycidae (Acariformes)”.

About the molecular systematics of Eriophyoidea and Nematalycidae, the last findings carry them consistently outside of Trombidiformes order, falling into Sarcoptiformes order, which are confirming the results of recent molecular studies of Pepato & Klimov (2015); Xue *et al.* (2016); Xue *et al.* (2017); and Bolton *et al.* (2017). Despite the evidence presented, until the investigation of the group of this superfamily Eriophyoidea is finished, this superfamily is in this thesis kept as part of the Trombidiformes.

In this sense, the studies in this document, which sought to determine the diversity of plant mites in northern Ecuador, are descriptions based on stable morphological characters, which have allowed the different specialists in each group to establish keys for the different taxonomic levels.

Mites as members of the phylum Arthropoda, share the characteristics as jointed legs and a chitinous exoskeleton and are a vast assemblage of terrestrial and marine invertebrates considered a monophyletic taxon (Weygoldt, 1998). Mites also possess the

arthropodan features of an open circulatory system, ventral nerve cord, alimentary canal, striated muscles, and (in many cases) Malpighian tubules. Unlike other arthropods, lack antennae and mandibles (Krantz & Walter, 2009).

Small size and lack of a substantial exoskeleton have limited the availability of fossil evidence relating to the origins of most terrestrial Arthropoda. However, the information presently available suggests that arachnids first appeared on land in the late Silurian or early Devonian periods (ca. 425 mya), perhaps in the form of a now-extinct relative of a pulmonated uigonotarbid (Arachnida, Trigonotarbida). This momentous event took place more or less on the heels of the remarkable period of arthropod evolution and diversification that occurred during the Cambrian period, approximately 200 million years ago (Gould, 1989; Walter & Proctor, 1999; Krantz & Walter, 2009).

Lindquist (1984) established transformation series for 40 morphological, physiological, and developmental characteristics of 12 extant arachnid orders, including those composing the Acari (the Opilioacariformes, Parasitiformes, with the Holothyrida considered a separate order, and Acariformes), and concluded that all mites are derived from a common, albeit remote, ancestral stock. Based primarily on the joint possession of a movable gnathosoma and of a hexapod larva and three octopod nymphal instars, concluding that the monophyletic Acari and the order Ricinulei (Kaestner, 1980), are sister groups.

Despite the existence of a strong case for monophyly in the Acari, spermatological evidence compiled by Alberti (2000) on the Chelicerata does not necessarily support a common origin for acariform and nonacariform mite lineages. The limited arachnid fossil record, coupled with continued conjecture regarding the utility of morphological and behavioral characters invoked in evolutionary studies of arachnid taxa, leaves room for continued speculation regarding the ancestral origins of the Acari. Dunlop & Alberti (2007) have provided an in-depth review of the morphological, developmental, and molecular evidence that discuss monophyly in the Acari.

According to Evans & Till (1979), the taxon Acari, stated as subclass by Krantz & Walter (2009), is considered to represent two distinct assemblages which indicate, at least, a diphyletic origin of the group. The assemblages first defined by Grandjean (1935) were characterized by optical and chemical properties of the setae and sensilla of the body and legs, defining to the groups as the Anactinochitinosi and the Actinochitinosi. Zakhvatkin (1952) in his new classification of the Chelicerata, placed the Actinochitinosi together with

the Palpigradi, Solifugae, Schizopeltida and Pseudoscorpiones in the division Actinochaeta and the Anactinochitinosi, with the Amblypygi, Araneae, Ricinulei and Opiliones, in the division Actinoderma. Finally, Zakhvatkin also proposed the taxa Parasitiformes and Acariformes for the Anactinochitinosi and Actinochitinosi, respectively.

Currently Grandjean's classification of the Acari referred to the two divisions as Anactinochaeta and Actinochaeta, and Anactinotrichida and Actinotrichida, respectively (Evans *et al.*, 1961; Evans & Till, 1979; Hammen, 1961).

While phylogenetic relationships within the Arachnida and between arachnid assemblages is not always clear, morphological differentiation of the two presently recognized mite superorders from other terrestrial arachnids is relatively straightforward (Krantz & Walter, 2009). In this sense the major divisions of the Acari are established in the present as: Phylum: Arthropoda, Subphylum: Chelicerata, Class: Arachnida and Subclass: Acari, Superorders: Parasitiformes and Acariformes.

The large groups and, in the case of the most diverse families, the genera of the mites belonging to the families can be separated using dichotomous keys as elaborate mechanisms for separation of taxonomic groups. They are designed by experts to be used by experts or by people at least familiar with the groups covered in them. Moraes & Flechtmann (2008) warn that the key only leads to the determination of a presumed taxon; for its correct identification, it is necessary to consider complete descriptions of the species.

In case of lack of dichotomous key for species, it is necessary to compare species reported around the world with the specimen under study, firstly comparing with scientific reports from the own country, then from neighbor countries and then, from reports for far away countries.

1.1.1. Mites reported from Ecuador

Before this research, the only reports of mites from Ecuador were: 58 Phytoseiidae species (25 in the continental region and 33 in the insular), one species in both, the continental and insular regions (Demite *et al.*, 2021); 16 Ascidae (8 in the continental region and 8 in insular) (Santos *et al.*, 2021a); 54 species of Blattisociidae (43 in the continental region and 11 in the insular) (Santos *et al.*, 2021b); 24 Melicharidae (20 in the continental region and 4 in the insular) (Santos *et al.*, 2021c); 11 Laelapidae in insular region (Karg, 1993); 4 Tetranychidae and 1 Stigmaeidae in the continental region (Vásquez & Dávila,

2018); 1 Tenuipalpidae in the continental region (Alcívar *et al.*, 2020), 6 Macrochelidae, 9 Laelapidae, 9 Podocinidae, 2 Ameroseiidae, 2 Ascidae (already included before in Santos *et al.*, 2021a), 3 Rhodacaridae, 1 Veigaiidae and 2 Parasitidae in the insular region (Karg, 1994); 3 Rodacaridae; 4 Ologamasidae; 9 Gamasiphidae; and, 7 Veigaiidae in the continental region (Karg, 1998); and, 1 Parholaspidae, 11 Laelapidae (1 insular), 2 Ameroseiidae, 4 Ologamasidae, 1 Parasitidae and 5 Veigaiidae in the continental region (Karg, 2006). The last reports comes from (Melo-Molina, 2022), who mention between soil mites 1 Ameroseiidae, 6 Blattisociidae, 3 Digamasellidae, 1 Eviphidae, 12 Laelapidae, 3 Macrochelidae, 3 Ologamasidae, 1 Pachylaelapidae, 6 Parasitidae, 4 Phytoseiidae, 2 Rhodacaridae. This author also reports into Uropodina group as follows 1 Clausiadinychidae, 1 Discourellidae, 1 Macrodynychidae, 1 Nenteriidae, 1 Oplitidae, 2 Rotundabaloghiidae, 2 Trachytidae, 1 Trachyuropodidae, 2 Trematuridae, 2 Trichouropodellidae, 3 Urodynychidae, 2 Uropodidae and 1 Uroactiniidae.

1.2. Plant mite and host relationships

Phytophagy, polynophagy, and nectavoria occurs in different mite groups (Krantz and Walter, 2009). But phytophagy is sufficiently broad among the Trombidiformes, which suggests that there was a co-evolution with the primitive lineages of trombidiform predators and saprophagous and the plants.

Most phytophages, such as Trombidiformes feed exclusively on the subepidermal liquid components of their host's tissues, which, according to studies, occurs due to the modification of the mobile digit, transforming the chelicera into a pungent and sucking structure.

Species in Tydeidae and Stigmaeidae have a short stylet inserted in a free or partially fused cheliceral base, like many predatory or fungivorous species. The Tarsonemidae extruding stylet-like mobile digit, which includes fungivores, algivores, predators, parasitoids, and parasites (Lindquist, 1986), are contained in a gnathosomatic capsule composed of the bases of the modified chelicerae and the elements of the rostrum (Nuzzaci *et al.*, 2002). Phytophages tend to be specific to vascular plant families or genera, so exclusively phytophagous species such, as Tetranychidae and Tenuipalpidae, have a pair of elongated extrudable chelicerae, inserted in a fused suprarostrum sheath or stylophore, comprising the fused cheliceral bases, then the contents of subepidermal cells and

substances are sucked into the channel created by the appression of these cheliceral elements (Krantz & Walter, 2009). On the other hand, the chelicera and auxiliary stylets of the highly specific Eriophyidae, Phytoptidae and Diptilomiopidae are inserted into a pommel that lies on the rostrum (Krantz & Walter, 2009).

According to Moraes & Flechtmann (2008), although there are many plant inhabiting mites, relatively few mites are considered serious agricultural pests. However, several of these species are of fundamental importance, as they attack several species of cultivated plants, have wide world distribution, and can be found in large populations.

As an example, the mites of the relatively large Tetranychidae family stand out as strictly phytophagous. These are also known as “web mites”, “red spotted mite”, “arañita roja” or “spider mites”. Bolland *et al.* (1998) reported 1,189 species of spider mites belonging to 71 genera, but now this family comprise more than 1,300 phytophagous species ranging from 200 to 900 μm . More than a hundred of them can be considered as pests and about ten as major pests. In electronic catalogue stands, until June 2019, 1,321 valid species recorded, in 1,762 references, with 16,221 host records on 3,917 different plants and, 8,063 geographic distribution records, according with Migeon & Dorkeld (2016).

Yaninek & Moraes (1991) reported 54 species as pests of different crops around the world, and the most polyphagous mentioned is *T. urticae*. Among other causes, Flechtmann (1990) mentioned that it is because tetranychids are favored by low relative humidity, their ability to ingest a larger amount of food and eliminate water through evaporation through the cuticle.

Furthermore, some phytophagous species are quite specific, such as *Mononychellus tanajoa* (Bondar), known only on *Manihot* species and on *Passiflora cincinnata* Mart; *Oligonychus ilicis* (McGregor), on coffee and occasionally on eucalyptus and azaleas; *Panonychus citri* (McGregor), almost exclusively on citrus and other rutaceous plants; and *Panonychus ulmi* (Koch), on rosaceous plants (Moraes & Flechtmann, 2008).

Trombidiform subepidermal feeding damages include leaf spotting, mottling, tanning, blistering and curling, as well as sprout, flower and stem distortion (Krantz & Walter, 2009). Defoliation is common in plants heavily infested with tetranychids, whereas damage to eriophyids results in a variety of galls and other teratological abnormalities, but nevertheless can cause general changes in plant growth patterns (Krantz & Walter, 2009). In addition,

eriphids that do not produce galls, produce reddish rust and isolated leaf discoloration that do not produce obvious symptomatology (Amrine & Stansny, 1994).

In relation to predatory mites, they are commonly found on the aerial plant parts, where they feed on small insects and phytophagous or mycophagous mites. Others can be found in wood attacked by Coleoptera or in sporocarps that invade dead trees (Krantz & Walter, 2009).

Ground-dwelling mesostigmatid predators have extensive idiosomatic sclerotization although it is often faintly tanned and ill-defined. Prostigmatic predators are numerous on most plants and are often brightly colored in shades of red, yellow, or green, often taking on the color of the prey species on which they feed. Most of these predators look for their prey on the surface of leaves and stalks, but some Cheyletidae are ambush predators that wait until the prey is close enough to capture it (Denmark & Muma, 1975; Krantz & Walter, 2009).

Species, mainly of the mesostigmatid family Phytoseiidae, are reported as important in the suppression of tetranychids and eriophyids in commercial orchards and grapevines by McMurtry (1983), McMurtry *et al.* (2013) and Krantz & Walter (2009).

Many of these can successfully feed and develop on other food types, including immature insects, and some can supplement their diet with plant juices, pollen and/or honeydew. Likewise, those of the genus *Proctolaelaps* (Melicharidae) can optionally be pollenophages or saprophagous on plants (Krantz & Walter, 2009).

The ascids *Asca citri* Hurlbutt and *A. tarsalis* De Leon, slow-moving species of orchard trees, are associated with scale insects, but it is not clear as to whether they use them as prey. Other *Asca* species collected in the tropics are common on or below dead plant foliage (Krantz & Walter, 2009) and can feed primarily as saprophagous rather than as predators.

Many trombidiform families have representative members that feed on arthropods associated with the plant; among these, the species of the families Anystidae, Cheyletidae, Erythraeidae, Stigmaeidae and Tydeidae have species that have proven to be effective predators of orchard pests (Krantz & Walter, 2009).

Zetzellia mali (Ewing), a stigmaeid predator of tetranychid and eriophid eggs on apple trees also feeds on the eggs of predatory phytoseiids if the population levels of phytophagous mites are low (Krantz & Walter, 2009).

Species of *Acaronemus* (Tarsonemidae) prey on eggs of tenuipalpids and tetranychids according by Smiley & Landwehr (1976), and species of the arboreal tarsonemid *Dendroptus*

are suspected to prey on eriophyids (Lindquist, 1986). Eggs and postembryonic stages of insects can serve as food sources for some trombidiform predators, according to Krantz & Walter (2009).

Given the importance of agricultural production in many countries, in addition to the problems generated from the abuse on the use of synthetic biocides, there is a considerable volume of research on predatory mites, mainly Phytoseiidae, used for biological suppression, as part of the integrated pest management programs, as cited, in example, by researchers as Moraes & Flechtmann (2008) and McMurtry *et al.* (2015).

1.3. Characteristics of Ecuadorian continental regions

To understand the relationships of mite fauna in continental Ecuadorian regions, it is necessary to know the characteristics of the ecosystems of these regions.

In general aspects, the flora of the Andean regions has climatic characteristics that respond to migratory processes facilitated by continental drift and specifically by the union of the two continental masses of America and the rise of the Andes from the Cretaceous. On the other hand, the lowlands of the Amazon and the Coast are characterized by having floristic elements characteristic of tropical regions, many of them with African ancestors. The distribution of these groups has been determined by a series of biogeographic events on a timescale of millions of years since the separation of the continental massif from Gondawana. The following characterization of the different regions to which this study refers was provided by the Ministry of Environment of Ecuador (Ministerio del Ambiente, 2012), which is the entity that meets all the official information of Ecuador in this thematic.

1.3.1. Coastal region

In the Coast biogeographic region, 27 ecosystems are identified. The evergreen lowland forests of the Esmeraldas River basin are dominated by tree species from the Fabaceae, Meliaceae, Moraceae and Myristicaceae families with a continuous canopy approximately 40 m high, with few gaps. The absence of clearings and the relative abundance of large trees (DBH \geq 70) are characteristics that differentiate them from Amazonian forests. Occasionally there are emergent trees of more than 60 m such as *Ficus dugandii*, in the sub-canopy the dominant species is *Wettinia quinara*, other palms such as *Iriartea deltoidea*, *Oenocarpus bataua* and *Socratea exorrhiza* are less abundant, several species of *Matisia* spp.

(Bombacaceae) are also common. The understory is dense and composed of several species of Rubiaceae and small palms, especially *Geonoma*. Epiphytes are common and are found covering the lower part of the trunks of most trees; instead, lianas are rare, but there is a rich variety of shrubby and arborescent hemiepiphytes, mainly of the genera *Clusia* and *Philodendron*.

Physically isolated from the Andes, the Coast has species that are also present in the highest Andean cloud forests 100 km to the southwest, as well as endemic species from Chocó. The cold Humboldt current causes a clouding effect from May to September, called “garúa” in Chongón-Colonche and “brisa” in Manabí. This contribution of humidity determines different plant formations in the upper parts of the mountain range (≥ 400 meters above sea level). In the lower parts the vegetation is arid, and the level of alteration is high.

The foothill of the western cordillera is a narrow strip of forest located on the lower Andean slopes with a floristic composition corresponding to the Chocó, where the shafts of the trees are covered by orchids, bromeliads, ferns, and Araceae. Closer to the south, the vegetation changes, with presence of forests lowland deciduous up to 400 meters above sea level, ecosystem where most tree species lose their foliage in the dry season and shrubs and herbs are scarce. Located on both sides of equatorial line, there are areas where potential evapotranspiration exceeds precipitation. During the dry season, the canopy is very open, but when the leaves sprout, they can have a coverage of up to 50 %. They are in relatively populated areas, often on soils suitable for crops which explains why they have been heavily altered and destroyed much more than the humid forests. Ascending in the mountain range there is low montane semi-deciduous forests. The dry period lasts 5–6 months, resulting in forests of smaller stature and basal area than the humid forests, although with a particular floristic composition. Between 25 and 75 % of the floristic elements that make up this type of forest lose their leaves in the dry season. It presents an arboreal layer with abundant shrubs and herbaceous plants in the rainy season. The vegetation is scattered, with few as umbrellas trees over 20 m high.

Finally, the western part of the Guayas province is clearly stratified with a tendency to aridity as it approaches the sea, particularly in the Santa Elena peninsula, which has an arid desert climate. The vegetation that characterizes the area is made up of scrub, thorny forest and deciduous to semi-deciduous intermountain forest. The main problem with this type of

ecosystem is its gradual degradation due to logging and grazing, which often do not leave natural patches.

1.3.2. Highland region

In the biogeographic region of the highland a total of 30 ecosystems is presently identified. Mountain forests have a combination of humidity, temperature, geomorphology, and evolutionary history that determine a very high floristic diversity, typical of the species recorded in montane forests. Epiphytes of the Orchidaceae and Bromeliaceae families are diverse and abundant, as are liverworts and bryophytes. Due to the geomorphological conditions of steep slopes and anthropic intervention processes, mountain ecosystems are fragile. The erosive phenomena of heavy rain regimes and the aforementioned factors cause landslides with the subsequent secondaryization of the forest and loss of habitat, thus reducing the diversity of this ecosystem. Floristically, the forests of the external slopes of the eastern mountain range of the Andes are more diverse than those of the inter-Andean valleys and the internal slopes of the mountain range, however the western forests are characterized by a higher index of endemism. In the eastern foothills the forests are continuous and very humid, while in the western foothills the forests are extensive and continuous in the north of Ecuador; on the contrary, in the south of the country the strip of forest is less humid and narrower.

In the Andes there is also the páramo biogeographic sector, distributed in an almost uninterrupted Valley on the forest line of the western and eastern mountain ranges of the Andes, about 3,300 and 3,500 m of altitude, respectively, and 2,800 m in the south of the country, occupying an area of 1,337,119 ha (5 % of the territory), present in 18 of the 24 provinces, in which humid areas (swamps and peat bogs) large bodies of stable water and many streams and rivers are formed, surrounded by species such as *Distichia muscoides*, *Oreobolus* spp., *Plantago rigida*, *Sphagnum* spp., *Werneria* spp., among others. In the highest peaks there are desert or sandy páramo areas at elevations above 4,200 m, with sparse vegetation, in small patches in isolation. The number of species and their cover decreases rapidly with altitude and few species reach the snow line (4,800–4,900 m) such as *Calcutium* sp., *Draba* spp., *Nototriche* spp.

The inter-Andean valley is a succession of basins separated by transversal branches called nodes with elevations between 3,000 and 3,400 m. The valleys include the dry and

humid montane scrub, and the low montane wet scrub, whose original vegetation has been almost destroyed during the last centuries and replaced by fields dedicated to agriculture and pastures. Remnants are restricted to streams and isolated mountains, mainly composed of small trees and shrubs, frequently with thorns. The inter-Andean valleys are currently dominated by *Eucalyptus globulus*, a species introduced from Australia around 1860; species found along roads and fields, as well as in silvicultural patches for timber production. In some areas there are *Pinus radiata* and *Pinus patula* that were introduced from California and Mexico, respectively, in the early 20th century, while the grass *Pennisetum clandestinum* introduced from Africa predominates in most grasslands. Towards the south of the country, between 2 000 and 3 000 m of altitude, the valleys present shrubs and small trees, sometimes with bare soil between the woody plants. Among the most common species are: *Bejaria aestuans*, *Cantua quercifolia*, *Hypericum laricifolium*, *Lomatia hirsute* and *Oreocallis grandiflora*.

In desert and semi-desert areas of the lower parts of the valleys, rainfall present less than 300 mm, which is why there are small shrubs such as *Acacia macracantha*, *Caesalpinia spinosa*, *Croton wagneri*, *Dodonaea viscosa*, and on the slopes *Agave americana* and *Aloe vera* (introduced). Cacti such as *Opuntia soederstromiana*, *O. pubescens* and *O. tunicata*, epiphytic bromeliad species that adapt to long periods of drought such as *Tillandsia recurvata* and *T. secunda*, which frequently grow on the branches of *Acacia macracantha* shrubs. In humid places, small trees of *Salix humboldtiana* and *Schinus molle*. The Tumbes – sub-Andean sector includes low montane semi-deciduous forests. The dry period lasts 5–6 months, determining the presence of forests of smaller stature and basal area than the humid forests. On slopes with moderate slopes between 40 and 50 % with very stony soils, between 75 and 25 % of floristic elements of this type of forest develop, which lose their leaves in the dry season. In the rainy season, there is an arboreal layer with abundant shrubs and herbaceous plants, with scattered vegetation, with few parasolized trees over 20 m high.

1.3.3. Amazon region

In the biogeographic sector of the Amazon there are 25 ecosystems. With approximately 9,260,000 hectares, have a variable altitudinal range between north and south, which on average goes from 180-190 m above sea level in the lower part of the Amazonic plain and

2,900 at the summits of the cordilleras. It includes flood plains of Andean and Amazonian rivers and their interfluviums, as well as the foothills of the Eastern Mountain range and the sub-Andean or amazonian mountain ranges to the south. To the north there are forests on a series of dissected to highly dissected hills, areas of swamps, bruises or palm forests, and black-water lake systems.

Geomorphologically, the lower Amazon (below 300 m of altitude) there are plains and peneplains made up of hills, valleys, and plateaus, mainly composed of tree communities, where four main types of vegetation are distinguished: the mainland forests, the forests flooded by rivers of Amazonian and Andean origin, the locally flooded forests called moretales or swamps and the forests in lake-riparian systems of black waters called "igapós". Although the Ecuadorian Amazon is considered floristically homogeneous, recent studies show that floristic variation is abrupt and composition and abundance within tree communities can change dramatically over very short distances as one moves away from the base of the Andes towards the east and most presumably north and south of the Ecuadorian Amazon. Additionally, the Ecuadorian Amazon is classified as the most diverse in terms of flora and fauna in the world. The entire region is characterized by the immense diversity of plants, animals as well as similar climates, resulting in more than 5,000 species of vascular plants, equivalent to 35 % of the total richness of species described for Ecuador.

Evolutionarily, the Ecuadorian Amazon region has been constantly invaded and recolonized by populations of species that coincide with the patterns of oscillations in temperature and humidity; climatic fluctuations that probably resulted in favorable conditions for speciation processes. Thus, for example, the forests of the Province of Sucumbíos report one of the highest values of species per unit area worldwide.

1.4. Sampling, collecting, preservation, extraction and mounting of plant mites

Observations on the aerial plant parts are more difficult than sampling in soil and air as they are much more heterogeneous and in continuous change. It is convenient to take a part of the plant as a sampling unit. The resulting population estimate is not absolute, but a measure of population intensity. In the case of mite populations related to some tree health index, an estimation of "population intensity" may be relevant, but as the study refers to possible changes in the number of mites in each season, the intensity estimation series of the population could be easily misleading, because if the number of mites per leaf decreased

in the dry season, it could be due to an actual reduction in the mite population or by an increase in the number of leaves (Southwood & Henderson, 2000).

For the search and collection of the mite fauna, it is necessary to consider their ethology, such as the feeding habit, among what is considered the place and type of preferred and supplementary food. Adaptation to diverse dietary habits is correlated with morphological and physiological adaptations.

Mites have a much wider range of feeding habits than any other group of Arachnida. Exceptional is its ability to ingest liquid and particulate food of plant origin, such as higher plant tissue and cellular content, pollen, fungi, and algae, as well as the way in which many have adopted parasitic life. While some retain the predatory style so characteristic of the Arachnida as a whole, others feed on living plant material and still others are omnivores, feeding on decaying plant and animal organic matter, bacteria and even nematodes. The chelicerae with chelate form are typical of many predatory, pollenivorous, fungivorous and saprophagous mites that cut the epidermis of their hosts or other types of substrates, and even of certain phytophagous mites. In the latter case, there are mites that have the digits of robust chelicerae, with few and large teeth, which feed on very turgid plant tissues, in the ground or in warehouses, or on processed foods subjected to conditions of high humidity. On the other hand, the stylet-shaped mobile digit allows many mites to pierce different structures of their host, prey, hyphae or individual plant cells (Moraes & Flechtmann, 2008).

As an example, some families of mites and their preferred hosts or prey are mentioned to be found, according to the information of the specialists of the various groups of mites, as this source: phytophagous mites should be sought on plant structures such as leaves (Tetranychidae, Tenuipalpidae, Tarsonemidae, Eriophyidae and others), flowers (Ameroseiidae), fruits (Tuckerellidae, Eriophyidae), corms, bulbs (Acaridae, Eriophyidae), tree bark (Cheyletidae, Tenuipalpidae) mainly; while predators at the same sites as phytophagous, including immature forms of insects (Phytoseiidae, Stigmaeidae) and microorganisms as nematodes (Cunaxidae) or springtails (Bdellidae), mainly.

It is to be expected that due to the biological need to multiply and the need to assure the progeny to have enough food to complete the life cycle, the phytophagous mites will be found on the young plant tissue, in development or, developed and in complete foliar expansion, which allows them to carry out maximum photosynthesis. In this sense, these mites should be sought in the middle and upper thirds of the plant, rather than in the lower

third, where the mature leaves that completed their cycle and in their best time provided food for the phytophagous mites could not sustain the biological cycle of new generations of mites hungry for succulent food.

The collection can be made from any part of the plant, but Moraes & Flechtmann (2008) mention that it is recommended that, in the case of phytophagous mites, leaves at the beginning of infestation and leaves that are already quite infested be collected. The latter often have a greater number of male mites.

Prior to collecting the plant tissue with phytophagous and their predators, due to the high mobility of the latter, it is advisable to hit hard enough, for example the target branch, in the direction of a plastic tray, previously sprayed with 70 % alcohol or less, so that the mites trapped in the fluid can be collected with the help of an lens and a brush and, stored in an vials with 70 % ethanol (for morphological study) or 95 % (for molecular study). The plastic tray should be of a contrasting color to the main colors of the mites, so that it is easy to distinguish them once they are trapped in the alcohol. This extraction must be relatively fast, because the more concentrated the alcohol, the faster it will evaporate and part of the mites may regain mobility, fleeing the visual field.

Once the most mobile forms have been collected, we proceed to take the plant tissue where there could be mites, whether that tissue has or not signs of mite activity.

For this, leaves with complete foliar expansion are taken from the middle third of the plant, from between three to five plants of the same botanical species, as well as young tissue, from the apices, including flowers and fruits in initial formation, according to what various specialists from each group refer in their documentation, on biology and ethology of the different taxonomic groups of mites, as Flechtmann (1990); Moraes & Flechtmann (2008); Krantz & Walter (2009); Skoracka *et al.* (2010), and many others.

It is preferable to place the plant tissue in plastic bags with a zip-look closure, with a paper towel to collect the condensation produced by the metabolism of the plant tissue and prevent it from affecting the sample and the biota contained in that host.

The plastic bags, with the respective identification (place or locality, owner, community or province, coordinates, host, date, altitude and assigned code, collector), should be placed as soon as possible in thermal boxes, with synthetic ice, preferable to ice in cubes into a plastic bag, which when thawing could wet the samples in poorly closed covers. This artificial ice is placed to reduce the metabolism of the host (plant tissue sample) and the biota

present, until it is transferred to the laboratory for processing, maintaining into the thermal box between 15 to 20 °C (Zacarias & Moraes, 2002; Castro & Moraes, 2007). Samples will be preserved into the laboratory until their processing (mite extraction) (Thompson, 2003).

In addition, many plant mites may be directly hand-picked from the plant with the aid of a fine hairbrush and with the aid of a hand lens if they are too small to be seen with the naked eye. A little water on the tip of the brush may help to hold the mites during transfer. Mites may be transferred to a rearing unit for further laboratory studies or into a vial with some kind of preservative (e.g. 70 % ethanol) for later study (Zhang, 2003).

It is convenient to process as soon as possible the samples from the plastic bags, as the artificial ice loses its ability to reduce the metabolism and conservation of the samples, which will occur, depending on the environmental conditions where the thermal box is kept and moved, between 24 and 48 h.

In the laboratory, the mites are extracted one by one, with a moistened brush (number 000), with the help of a stereomicroscope at 40X, checking leaf by leaf, first on the abaxial and then on the axial leaf surface, transferring the mite to Eppendorf vials or mini tubes, with ethanol 75 % with 5 % glycerin. This is preferable in studies to search for the diversity of the mite-fauna, to the alternative of placing the leaves in a container and with soapy water (1 %) or alcohol shake them vigorously by 1-2 min or until 1-2 h (Faraji *et al.*, 2004), followed by double sieving, with a 24-mesh sieve over a 400-mesh sieve. In the upper sieve, larger residues will be retained for disposal and the material retained in the smaller mesh sieve will be collected and placed in a large petri dish, to extract with brush the mites (Bianchin *et al.*, 2010); this second alternative does not allow to find some mites that remain attached to the plant tissue damaged by the shaking.

For the mounting of the mites, Hoyer's medium is used, and except for the males of Tetranychidae (placed laterally for posterior aedeagus observation) and the Eriophyoidea mites (mounted at least dorso-ventral and laterally), they are placed in a dorso-ventral position, with the gnathosoma facing the operator.

Males of Tetranychidae should be positioned sidewise, making sure that the lateral ocelli stay one on top of the other (Moraes & Flechtmann, 2008); while in the case of Eriophyoidea mites they must be placed in number of four by slide, so that some remain in a lateral position and others in a dorso-ventral position.

Once the mites are positioned, their legs are arranged with the brush so that they stay preferably fully extended. Hoyer's medium drop is then placed on the coverslip, in sufficient quantity so that once it is placed on the mite on the microscope slide, the medium is completely distributed over the entire extension of the coverslip.

Most mounting media used by acarologists are water-based Hoyer's or Berlese media using acacia gum and chloral hydrate. The resulting slides are rarely permanent and many type specimens along time become unsatisfactory for study, for turning opaque, shriveled or too clear. Eriophyoid mites, mounted on microscope slides, must be adequately cleared of body contents to allow proper study. Simply placing them in Hoyer's, adding a cover glass and then heating on a hot plate rarely results in an adequately cleared specimen. Thus special clearing techniques must be employed to prepare satisfactory slides (Amrine & Manson, 1996).

Eriophyoid mites are very tiny and delicate, for which truly permanent specimen slides currently cannot be prepared, resulting in eventual loss of material, including type specimens. Often, published descriptions and drawings have not achieved the required level of quality, and thus many relevant taxonomic details have been permanently lost or neglected (De Lillo *et al.*, 2009).

Once the cover slip is placed, a circle should be drawn on the lower part of the microscope slide, with an indelible ink marker, so that in the future it will be easy to locate the place on the mounting slide where the mite has been.

The mounting slides should be placed in an oven at 45-50 °C to dry the medium for 7 days (Vacante, 2015); except in the case of eriophids, which must remain at 90 °C for 24 h, according with a personal communication of Philipp Chetverikov from his studies (Chetverikov *et al.*, 2016).

Subsequently, it must be sealed around the cover slip with oil-based paint, so that the medium does not rehydrate and can be manipulated without problems. Finish the assembly with the proper labeling (Krantz & Walter, 2009).

1.5. Biodiversity and diversity indexes

The biodiversity (quantity, variety, and variability of living organisms) of an ecosystem is approached from: genetic variability between populations of living beings, diversity of species, heterogeneity in habitats, etc. Plant diversity in a given region is observable at first

glance as patches in the territory of different color, texture, and coverage of plants; to evaluate this diversity and quantify for future uses or management, Whittaker (1960, 1972) proposed the terms *alpha*, *beta* and *gamma* diversities for the estimation of diversity at different scales of the landscape or region (Ferriol-Molina & Merle-Farinós, 2012).

The study of biotic variables defines ecological connotations resulting from the environmental conditions of the time or period of the investigation. Thus, the determined contingencies allow to understand not only the way in which the natural gradients have shaped them, but also the reverse, to infer about the conditions of the environment when they manifest themselves (Ramírez Gonzalez, 2006).

The meanings of the terms proposed by Whittaker (1960, 1972) are: a. *Alpha* diversity, characterized by diversity within the habitat or sampling unit; b. *Beta* diversity, characterized by variation in diversity between habitats or sampling units; and c. *Gamma* diversity, characterized by the combination of *alpha* and *beta* diversity, which he also defined as “regional diversity”, encompassing all habitats or sampling units (**Figure 1**).

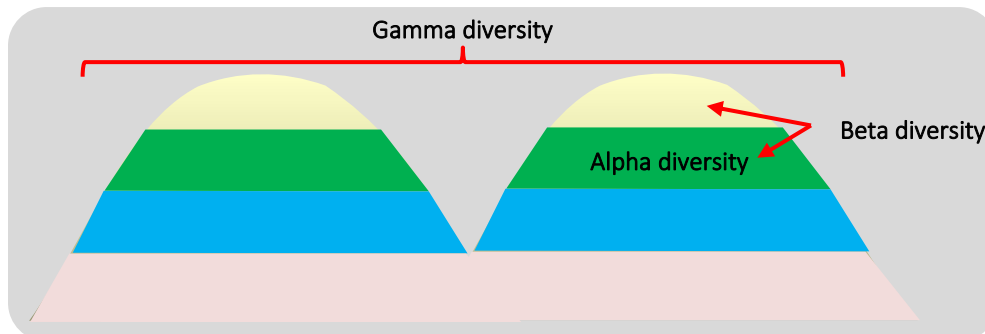


Figure 1. Representation of the *alpha*, *beta*, and range diversity (*gamma* diversity) of a landscape in which communities are distributed according to their functional gradient (Modified from Ferriol-Molina & Merle-Farinós, 2012).

The *alfa* and *beta* diversity are independent. According to Ferriol-Molina & Merle-Farinós (2012), a landscape may have an high *alpha* diversity (average of the *alpha* diversity values of each of the communities that comprise it) and low *beta* diversity or vice-versa.

As stated by Silva *et al.* (2022), there is no method that quantifies all parameters associated with biological diversity, whereby the choice of diversity metric will depend on the objective of the study, and on the information available to the researcher.

1.5.1. *Alpha* diversity

According to Moreno (2001) most methods to assess species diversity refer to diversity within communities (*alpha*). The different methods as a function of the biological variables that form, are divided into large groups (**Figure 2**), where **a.** methods based on the number of species present (specific richness) are registered; and, **b.** methods based on the structure of the community, understood as the proportional distribution of the importance value of each species (relative abundance of individuals, their biomass, coverage, productivity, etc.). Methods based on structure are classified according to whether they are based on dominance or community equity.

Basically, the *alpha* diversity is the intrinsic biodiversity of each concrete organism community in the landscape. Amongst the geographically distinct organism (*e.g.*, plants) communities contiguous in the territory, there will be different species and very probably common species. The *beta* diversity is the exchange rate in species of adjacent organism communities. It reflects both the difference in the composition of the communities and ultimately the heterogeneity of the landscape.

Species richness is an intuitive and easy-to-understand metric, referring to the number of species observed in a locality, which is influenced by sampling effort and thus pose an immense challenge in the proper determination (Magurran & McGill, 2011).

In turn, **Margalef index** (used in the present study, among other indices), calculates species richness by weighting the total abundance within each community (Magurran, 2004), where values below 2 indicate ecosystems with low biodiversity (anthropized) and above 5 constitute ecosystems with high biodiversity (Montero-Saiz, 2011).

$$D_{Mg} = \frac{S - 1}{\ln N}$$

S = Number of species recorded into the community.

ln = Natural logarithm.

N = Total number of individuals summed over all **S** species into de community.

D_{Mg} = Does not have a maximum value and its interpretation is comparative, with higher values indicating greater species richness.

Unlike species richness indices that do not consider their relative abundance (because it is considered that all species have the same abundance), **diversity indices** assess, in addition to richness, the dominance or rarity of species in communities. Thus, when comparing two communities with the same species richness, and one of the communities is dominated by a single species whereas the other has species with similar abundances, the second community must be considered as more diverse (Magurran & McGill, 2011).

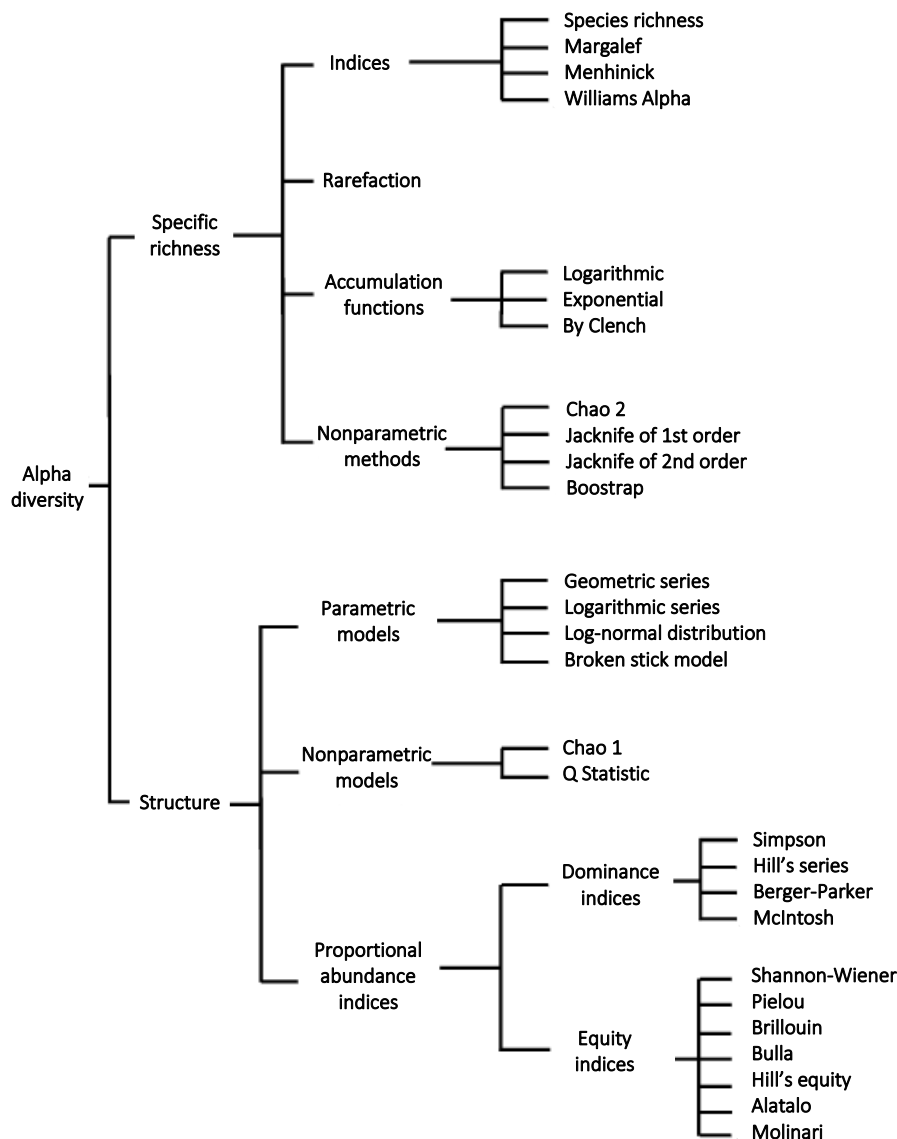


Figure 2. Classification of methods to measure *alpha* diversity (Moreno 2001).

The different diversity indices vary according to the different weights each index gives to species richness and equitability. According to Melo (2008), while a given diversity index may

indicate a community *X* to be more diverse than a community *Y*, another index may indicate the opposite. Therefore, it is necessary to choose which diversity index to use, according to the importance the researcher wants to give to richness in relation to the importance he wants to give to evenness of species in the study. The most used indices for biodiversity are Shannon-Wiener and Simpson indices.

The **Shannon-Wiener** index quantifies the uncertainty associated with predicting the identity of a species, given the number of species and the distribution of abundance for each species; being this index more sensitive to changes in the rare species in the community (Magurran & McGill, 2011).

$$H' = - \sum_{i=1}^S p_i * \ln p_i$$

p_i = Relative abundance of each species, calculated as the proportion of individuals of a species by the total number of individuals in the community.

ln = Natural logarithm (other logarithmic bases can be used).

H' = Does not have a maximum value and its interpretation is comparative, with higher values indicating greater diversity.

For the analysis of biodiversity in the present study, the PAST statistical software was used (Hammer *et al.* 2007), where the diversity ranges go from 0 to 4; where values close to 0 are considered low, values of 2 in the intermediate range and values above 2.5 high.

The **Simpson's index** quantifies the probability that two individuals taken at random from the community belong to the same species. This index is a measure of dominance. Just as the probability of individuals being of the same species decreases with increasing species richness, Simpson's index also decreases with richness (Magurran & McGill, 2011).

$$D = \sum_{i=1}^S p_i^2$$

p_i = Relative abundance of each species, calculated as the proportion of individuals of a species by the total number of individuals in the community.

D = Ranges varies from 0 to 1, with values close to 1 indicating less diversity, close to 0 indicating greater diversity. To avoid misinterpretation, Simpson's index is normally expressed as the inverse value (1 - D) so that higher values represent greater diversity. In this case, the inverse value is known in the literature as the Gini-Simpson index. For the Gini-Simpson index, the probability that two individuals randomly removed from the community are of different species is being evaluated.

1.5.2. *Beta* diversity

Is defined as the ratio between *gamma* diversity and *alpha* diversity (e.g., multiplicative *beta* diversity), quantifying not only the relationship between regional and local diversity, but also the degree of differentiation between communities. Most (dis)similarity indices used in ecology (e.g., Sørensen index) are indices that standardize *beta* diversity and generate values independent of the number of communities. They are calculated for incidence (presence and absence) or abundance data of species (Legendre & Legendre, 2012) and considering peer-to-peer comparisons, between communities, or comparisons between multiple communities (e.g., multiple-site).

Unlike *alpha* and *gamma* diversity, which can be easily measured in terms of the number of species, *beta* diversity is measured in another way, based on ratios or differences (Magurran, 1988). These proportions can be evaluated based on indices or coefficients of similarity, dissimilarity, or distance between the samples, based on qualitative data (presence or absence of species) or quantitative data (proportional abundance of each species as number of individuals, biomass, density, coverage, etc.), or with *beta* diversity indices themselves (Magurran, 1988; Wilson & Shmida, 1984). For these reasons, *beta* diversity measures are classified according to whether they are based on the dissimilarity between samples or on the replacement itself (**Figure 3**).

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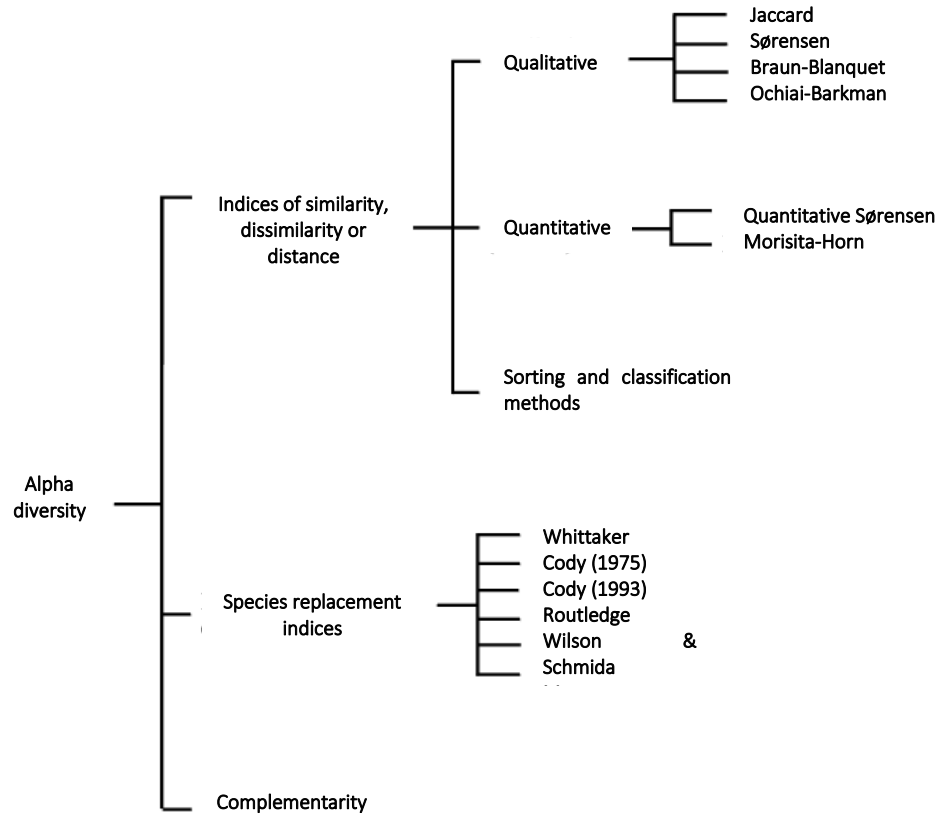


Figure 3. Classification of methods to measure *beta* diversity (Moreno, 2001).

Beta diversity or diversity between habitats is the degree of species replacement or biotic change through environmental gradients (Whittaker, 1972). Unlike the *alpha* and *gamma* diversities that can be easily measured as a function of the number of species, the *beta* diversity measurement has different dimension because it is based on proportions or differences. These proportions can be evaluated based on indices or coefficients of similarity, dissimilarity, or distance between the samples from qualitative data (presence or absence of species) or quantitative data (proportional abundance of each species measured as number of individuals, biomass, density, coverage, etc.), or with *beta* diversity indices themselves (Magurran, 1988).

Sørensen coefficient of similarity relates in percentage the number of species in common with the arithmetic mean of the species in two data sources, e.g., two regions (each time), two landscapes or 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 common to both regions

1.5.3. Species richness by *gamma* diversity

In third place, the *gamma* diversity is characterized by the combination of *alpha* and *beta* diversity or defined as regional diversity encompassing all habitats or sampling units (Silva *et al.* 2022). In this research compares the diversity of morphospecies between the three sampled regions in terms of their corresponding mite diversity.

The *gamma* diversity is the intrinsic diversity of a landscape and integrates the *alpha* and *beta* components of the diversity. It estimates the variety of species in each area, including all the communities found in it (**Figure 4**).

Gamma diversity is based also on the Shannon index (Moreno, 2001) using the following formulas for this purpose:

$$\mathbf{Gamma} = \mathbf{alfa\ diversity} + \mathbf{beta\ diversity}$$

In this case, *alfa* = Shannon average, but first, the *beta* diversity is calculated:

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

Where:

$$P_i = \sum_j q_j p_{ij}$$

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 the averages by species (*Pi*):

$$- \sum_i P_i \ln P_i$$

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

$$\sum_j q_j H_j$$

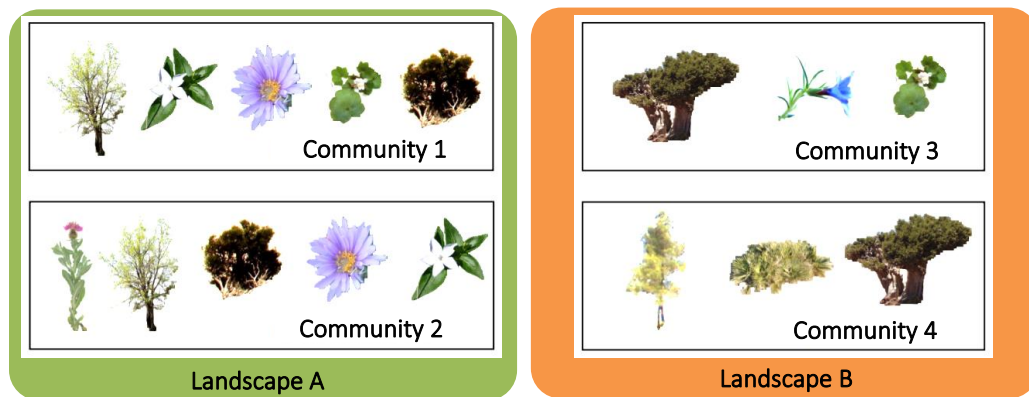


Figure 4. Fictional and simplified example of the diversity of different landscapes. The *alpha* diversity (number of distinct plant species) of the landscape A is 5, and of the landscape B is 3. Nevertheless, the *beta* diversity (number of distinct species with respect to the set of species of both communities) of landscape A is 0.3 (2/6), less than landscape B is 0.8 (4/5). Together, the *gamma* diversity (number of distinct plant species) of landscape A is 6, whereas there is landscape B and 5 (Ferriol-Molina & Merle-Farinós, 2012).

To reach the objective of this thesis, we initially set the stage to justify the relevance of the proposed work, as recommended for any type of scientific research, especially by discussing the importance of mites, the ecological diversity in Ecuador and the scarcity of information in the theme selected for study. The experimental procedure was then launched, consisting basically in sampling the plant mites present in the regions established for the study, identifying them at the lower possible taxonomic level and analyzing their diversity, bringing the results obtained within the context of similar studies conducted in other parts of the world. An additional endeavor consisted of the description of a new species found in the study, placing it within the context of the world species of the small group to which it belongs.

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2. PLANT MITE PROSPECTION IN CONTINENTAL ECUADOR

Abstract

The mite diversity in Ecuador is poorly known. Additionally, there are lack of studies about the relationships between each environment, each botanical species and their corresponding richness and mite abundance. Thus, monitoring and control of the genetic erosion or loss of diversity due to human activity or climatic changes over time are hampered. Knowing the biodiversity of an ecosystem is expected to help its conservation and rational use. Hence, in the present study, a survey was conducted in northern Ecuador, from the Coast, through the Highland to the Amazon, looking for mites on wild and cultivated plant hosts, to evaluate which and how many mite species are present, to promote their conservation and eventually their use as biological control agents of agricultural pests. The Coastal region was observed to have greater diversity of mite families, followed by Highland and the Amazon region. The number of represented families was higher in the order Trombidiformes than in the order Mesostigmata, with predominance of Tetranychidae in the first and Phytoseiidae the second. The results confirmed previous findings and demonstrated new records and new species. In total, 2,257 mites of 19 families of the orders Mesostigmata and Trombidiformes were identified, including possible new records for the country and new species, one of which was published as *Amblyseius yumbus* Ortega-Ojeda, Santos, Melo-Molina and Moraes 2021, mite with potential for predation of phytophagous mites.

Keywords: Acari taxonomy. Mesostigmata. Trombidiformes. Invertebrates. Ecuadorian regions.

2.1. Introduction

The mite diversity from Ecuador is poorly known. Reports of Ecuadorian mites were often reported in German and specimens have been since long ago deposited in German museums (Alcívar *et al.*, 2020; Karg 1993a, b, 1994, 1998b, 2003, 2006; Schuster, 1966; Vásquez & Dávila 2018). Some Ecuadorian mites have been included in the data base of the mites of the family Phytoseiidae (Mesostigmata) by Demite *et al.* (2014).

According to Santos (2003), knowing the biodiversity of an ecosystem is the first step for its conservation and rational use, because the lack of knowledge about the names of the species present in a given region makes conservation practices very difficult to be carried out. In addition, knowledge about the mites found on each plant species (or group of plant species) within each ecological setup further hampers the conduction of studies on genetic erosion or loss of diversity due to human activity or climatic changes over time.

This study was conducted to obtain information about mite diversity on plant hosts of different environments of continental Ecuador, selecting sampling points representative

of the different ecosystems, with different physical (temperature, humidity and rainfall) and biological (flora and fauna) characteristics. Thus, it was conducted in regions of the Coast, Highland and the Amazon environments.

Hence in the present study, a survey was conducted in northern Ecuador, from the Coast through the Highland to the Amazon, looking for the mites on both wild and cultivated plant hosts. The intention was to evaluate which and how many mites were present, to promote their knowledge and conservation and their eventual future use as biological control agents.

2.2. Materials and methods

The survey was carried out in February 2018, in the rainy season of Continental Ecuador, collecting mites on leaves of cultivated and wild plant species. Samples were taken from the median and top strata of the plants, considered separately in the analyses.

2.2.1. Sampling sites

The sampling points were as follows: Coast (Esmeraldas and Manabí provinces), Highland (Pichincha and Cotopaxi provinces) and Amazon (Napo, Sucumbíos, and Orellana provinces) (**Figure 5**).

Five sampling macro points were established in each region (**Figure 6**), approximately 60 km from each other, each composed by five sampling micro points with five wild and five neighboring cultivated host plants. Micro points were selected giving preference to small or medium farms with high botanical diversity (at least five crop types) and without intensive use of biocides, seeking for highest chances to find high mite biodiversity.

Samples were collected between January and February 2018, at the time of highest rainfall (wet season), according to the National Institute of Meteorology and Hydrology (INAMHI, 2017)) and Portilla Farfán (2018). Average annual rainfall for the provinces sampled was 234.71 mm (Esmeraldas, 173.6; Manabí, 142.8; Pichincha, 109.5; Cotopaxi, 414.3; Sucumbíos, 235.1; Orellana, 230.9; Napo, 336.8 mm) (INAMHI, 2018). The precipitations recorded in February 2018, for the continental Ecuador, was rather erratic, approximately 55 % below their normal averages (INAMHI, 2018).

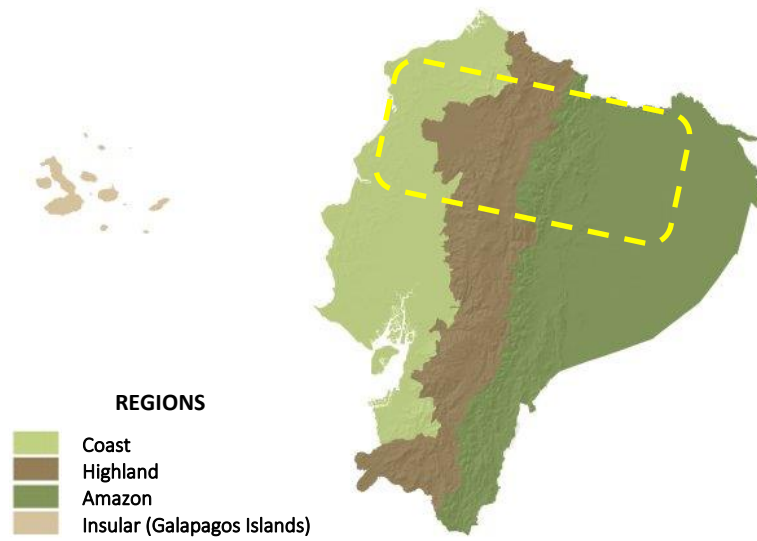


Figure 5. Geographic regions of Ecuador (Varela & Ron 2021). Broken yellow lines shows the general location of the sampling sites.

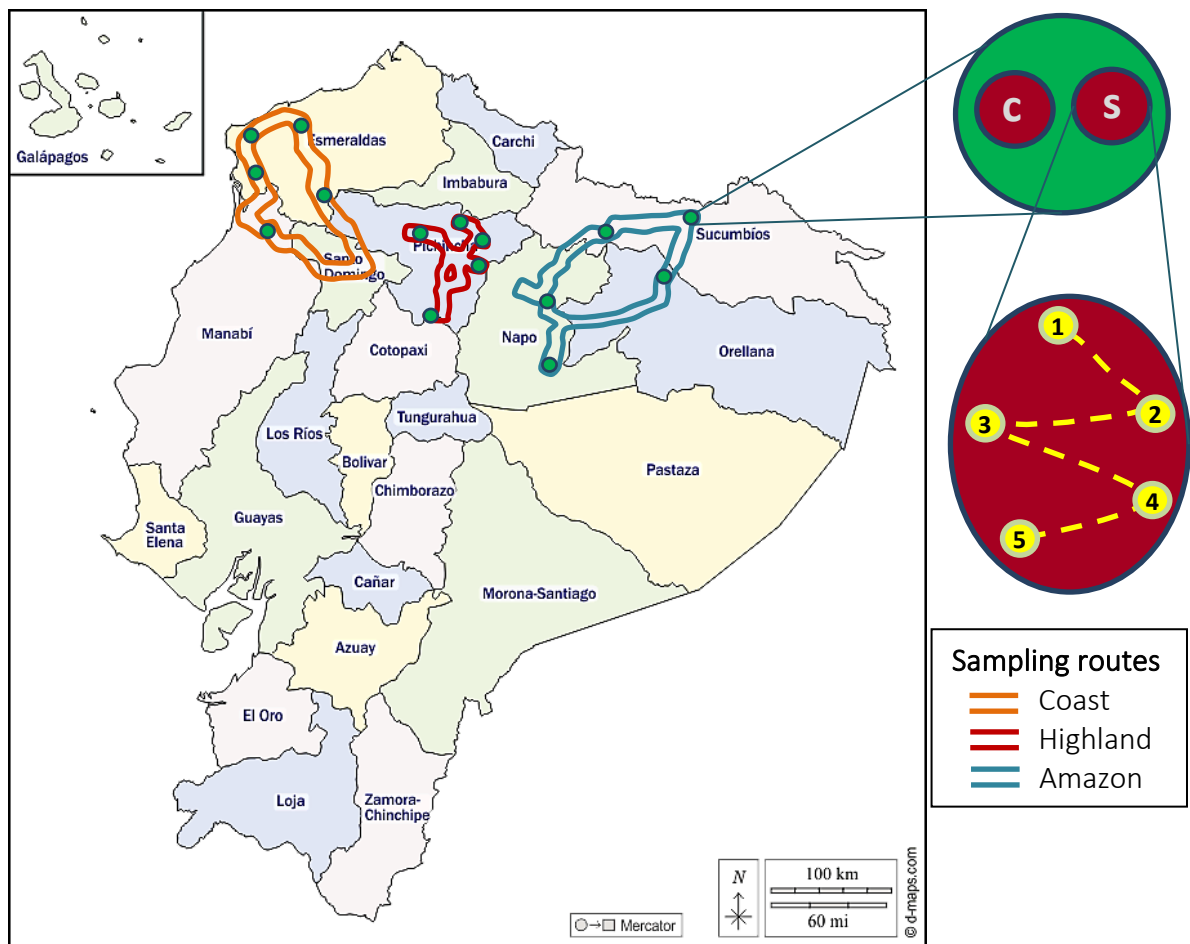


Figure 6. Political map of Ecuador (d-maps.com, 2007) showing the routes adopted for mite sampling, the five macro points per region, with cultivated (c) and wild (s) plant hosts (1 to 5 micro points); and, the transect of the micro points within each sampling macro point.

2.2.2. Sampling, mite extraction and identification

Five plants of each cultivated and equal number of wild botanical species were selected. From each, 25–50 leaves of each species were collected, including plants with and without symptoms of mite damage.

Sampled plants were photographed and the coordinates of sampling sites were taken with a cellphone (application GPS Essentials). Temperature and humidity of the sampling sites were recovered from database of INAMHI (Instituto Nacional de Meteorología), reported by Portilla Farfán (2018).

Once the collection site and the host plant had been selected, parts of branches and leaves were hit against and over a tray briefly sprayed with 70 % alcohol to trap the falling mites, to catch the most mobile specimens. These were picked up with the help of an optivisor and a fine brush and transferred to a vial with 75 % ethanol and 5 % glycerin, duly identified. Subsequently, a plastic bag (12 x 15 inches; 3 Liters in volume) was filled with leaves and pieces of branches of the upper and (separately, in another bag) of the middle third of the canopy of each plant. The bags were adequately sealed and placed in a styrofoam box containing frozen artificial ice, maintaining the box temperature at approximately 15 °C, according with recommendations of Zacarias & Moraes (2002) and Castro & Moraes (2007).

Samples were taken to the laboratory of Entomology and Acarology of the Faculty of Agricultural Sciences of the Central University of Ecuador, located in the Academic Teaching and Experimental Teaching Field Tola-CADET, in the Valley of Tumbaco, Quito, DM., in the province of Pichincha.

The samples were preserved in the laboratory at about 4 °C, until their examination under a dissecting microscope to extract the mites. Mites collected in the field and extracted in the laboratory were mounted with Hoyer's medium (Hempstead Halide®). The microscopy slides were labeled, dried in an oven at 50 °C for a week and later sealed with polyurethane paint.

In the identification process, the taxonomic concepts of the super orders and orders (Mesostigmata and Trombidiformes) were those of Krantz *et al.* (2009).

2.2.2.1. Trombidiformes families, genera and species identification

Trombidiformes families were identified based on the key of Walter *et al.* (2009). Once identified the families, the sources of the keys used for identifying genera and species were the following: Cunaxidae, Skvarla *et al.* (2014); Diptilomiopidae and Eriophyidae, Iolinidae, Ueckermann & Grout (2007) and Darbemamieh *et al.* (2015); Lindquist & Amrine (1996); Linotetranidae, Beard & Walter (2004) and Tassi *et al.* (2020); Smarididae, Meyer & Ryke (1959) and Costa *et al.* (2021); Stigmaeidae, Fan *et al.* (2016); Tarsonemidae, Lindquist (1986) and Jianzhen & Zhang (2002); Tenuipalpidae, Baker & Tuttle (1987); Mesa *et al.* (2009) and, Beard *et al.* (2012); and Tetranychidae, Flechtmann (2019); Tydeidae, Silva *et al.* (2016).

2.2.2.2. Mesostigmata families, genera and species identification

Within this order, families were identified based on the key of Walter *et al.* (2009). Then, the keys used for identifying genera of Phytoseiidae were that of Chant & McMurtry (2007). Species of this family were identified by comparisons with all reports around the world, beginning by comparing the specimens collected with the descriptions or redescriptions of species reported from Ecuador, secondly from Brazil, Colombia, Perú, and eventually other neighboring countries, thirdly from Central America and finally, other countries of the world.

Ameroseiidae, according to Narita *et al.* (2015) and Maśán (2017); Ascidae, Blattisociidae and Melicharidae were identified mostly according to Britto (2012); Laelapidae, according to Radovsky & Gettinger (1999); Ologamasidae, according to Castilho *et al.* (2016); and, Pachylaelapidae, according to Maśán & Halliday (2014).

2.2.3. Diversity indices

In this research, the diversity indices evaluated were *alpha*, *beta* and *gamma* diversity applied on mite fauna collected in each of the three regions, accord with definitions stablished previously (in the first chapter), by Whitaker (1960, 1972), Magurran & McGill (2011) and Montero-Saiz (2011); these indexes were Margalef, Shannon-Wiener and Simpson indices.

2.3. Results

2.3.1. Host plants with mites

Considering all regions together, mites were found on cultivated plants of 18 families: Annonaceae, Araceae, Arecaceae, Asteraceae, Caricaceae, Cucurbitaceae, Fabaceae, Lauraceae, Malvaceae, Musaceae, Myrtaceae, Passifloraceae, Poaceae, Rosaceae, Rubiaceae, Rutaceae, Solanaceae and Verbenaceae (Table 1). Mites were also found on wild plants of 35 families: Acanthaceae, Adoxaceae, Amaranthaceae, Araceae, Asteraceae, Betulaceae, Bignoniaceae, Borraginaceae, Bromeliaceae, Caesalpinaceae, Campanulaceae, Cecropiaceae, Convolvulaceae, Cyclanthaceae, Euphorbiaceae, Fabaceae, Geraniaceae, Heliconiaceae, Lamiaceae, Malvaceae, Melastomataceae, Meliaceae, Moraceae, Muntingiaceae, Onagraceae, Piperaceae, Poaceae, Rosaceae, Rubiaceae, Sapindaceae, Solanaceae, Urticaceae, Verbenaceae and Zingiberaceae.

Eight plant families were common between those two types of plants (cultivated and wild): Asteraceae, Fabaceae, Malvaceae, Poaceae, Rosaceae, Rubiaceae, Solanaceae and Verbenaceae.

2.3.2. Mites identified

Based on adults, 2,257 mites were identified to species and morphospecies in the three regions, the Amazon accounting for the highest number, followed by the Andean Highland and the Coast, accounting respectively for 1,087, 910 and 260 mites (Table 2).

In the Highland, higher mite abundance was found on wild than on cultivated plants (542 vs. 368, respectively); conversely, mite abundance was higher on cultivated than on wild plants in the Amazon (475 vs. 612) and the Coast (73 vs. 187), respectively (Table 2).

Within the identified orders, the Trombidiformes were the most numerous, followed by the Mesostigmata and the Sarcoptiformes, accounting for respectively 1,109, 741 and 401 mites (Table 2).

Table 2. Number of mites collected from wild and cultivated plants from three continental regions of Ecuador, in the rainy season of 2018.

Order	Coast			Highland			Amazon			Grand Total
	Cultivated	Wild	Total	Cultivated	Wild	Total	Cultivated	Wild	Total	
Mesostigmata	23	21	44	54	146	200	346	151	497	741
Trombidiformes	111	19	130	273	301	574	168	237	405	1,109
Sarcoptiformes	53	33	86	41	95	136	98	87	185	407
Total	187	73	260	368	542	910	612	475	1,087	2,257

About 19 families were found in total, seven of which belonged to Mesostigmata (within the cohort Gamasina: Ameroseiidae, Ascidae, Blattisociidae, Laelapidae, Melicharidae, Ologamasidae and Phytoseiidae), contained 675 specimens. The remaining belonged to the Sarcoptiformes order and cohort Uropodina, were not identified to lower levels because they were not of interest for this research (Table 3).

Table 1. Sample points with plants bearing mites in three regions of continental Ecuador, in rainy season of 2018.

Province	Locality/Sample site	Altitude (m)	Coordinates		Plant hosts				
			Crop	Wild	Cultivated	Wild			
Coast									
Esmeraldas	La Independencia	1	161.0	N 0°6.165 - W 79°21.289	N 0°6.465 - W 79°21.286	Malvaceae	<i>Theobroma cacao</i>	Urticaceae	<i>Laportea aestuans</i>
		2	150.0	N 0°6.503 - W 79°21.271	N 0°6.468 - W 79°21.282	Arecaceae	<i>Elaeis guinensis</i>	Araceae	<i>Phylodendron</i> sp.
		3	155.0	N 0°6.471 - W 79°21.356	N 0°6.496 - W 79°21.281	Rubiaceae	<i>Coffea arabica</i>	Piperaceae	<i>Piper peltatum</i>
		4	172.0	N 0°6.179 - W 79°21.482	N 0°6.486 - W 79°21.270	Passifloraceae	<i>Passiflora edulis</i>	Melatomataceae	<i>Clidemia hirta</i>
		5	24.0	N 0°6.480 - W 79°21.482	N 0°6.500 - W 79°21.273	Caricaceae	<i>Carica papaya</i>	Cecropiaceae	<i>Cecropia peltata</i>
Esmeraldas	Majua	1	29.8	N 0°42.656 - W 79°32.390	N 0°42.075 - W 79°31.726	Malvaceae	<i>Theobroma cacao</i>	Verbenaceae	<i>Lantana camara</i>
		2	29.8	N 0°42.866 - W 79°32.577	N 0°42.073 - W 79°31.724	Malvaceae	<i>Gossypium hirsutum</i>	Cyclanthaceae	<i>Carludovica palmata</i>
		3	26.9	N 0°42.866 - W 79°32.577	N 0°42.072 - W 79°31.721	Rutaceae	<i>Citrus cinensis</i>	Rubiaceae	<i>Borreria leavis</i>
		4	24.4	N 0°42.686 - W 79°32.461	N 0°42.073 - W 79°31.716	Caricaceae	<i>Carica papaya</i>	Poaceae	<i>Panicum maximum</i>
		5	27.9	N 0°42.678 - W 79°32.460	N 0°42.073 - W 79°31.713	Malvaceae	<i>Theobroma cacao</i>	Piperaceae	<i>Piper aduncum</i>
Esmeraldas	Súa	1	1.7	N 0°50.926 - W 79°51.777	N 0°50.503 - W 79°49.870	Anacardiaceae	<i>Mangifera indica</i>	Moraceae	<i>Morus</i> sp.
		2	0.0	N 0°50.503 - W 79°51.860	N 0°50.508 - W 79°49.863	Malvaceae	<i>Theobroma cacao</i>	Fabaceae	<i>Phaseolus</i> sp.
		3	18.5	N 0°50.503 - W 79°51.860	N 0°50.508 - W 79°49.865	Passifloraceae	<i>Passiflora edulis</i>	Solanaceae	<i>Solanum</i> sp.
		4	11.5	N 0°50.503 - W 79°51.860	N 0°50.509 - W 79°49.866	Rutaceae	<i>Citrus limon</i>	Piperaceae	<i>Piper umbellatum</i>
		5	22.1	N 0°50.503 - W 79°51.860	N 0°50.492 - W 79°41.881	Caricaceae	<i>Carica papaya</i>	Muntingiaceae	<i>Muntingia calabura</i>
Esmeraldas	Bolívar	1	0.7	N 0°27.255 - W 80°1.446	N 0°27.235 - W 80°1.438	Arecaceae	<i>Elaeis guinensis</i>	Borraginaceae	<i>Heliotropium</i> sp.
		2	0.0	N 0°27.248 - W 80°1.423	N 0°27.230 - W 80°1.448	Rutaceae	<i>Citrus limon</i>	Borraginaceae	<i>Heliotropium</i> sp.
		3	0.0	N 0°27.254 - W 80°1.430	N 0°27.231 - W 80°1.447	Passifloraceae	<i>Passiflora edulis</i>	Meliaceae	<i>Cedrela</i> sp.
		4	12.7	S 0°27.254 - W 86°1.420	N 0°27.243 - W 80°1.944	Cucurbitacea	<i>Cucurbita ficifolia</i>	Convolvulaceae	<i>Merremia aegyotia</i>
		5	36.5	N 0°27.259 - W 80°1.414	S 0°27.243 - W 80°1.446	Araceae	<i>Colocasia esculenta</i>	Araceae	<i>Philodendron</i> sp.
Manabí	Estero ancho, km 48	1	305.0	S 0°4.280 - W 79°47.316	S 0°4.259 - W 79°47.314	Lauraceae	<i>Persea americana</i>	Fabaceae	<i>Erithrina poeppigiana</i>
		2	319.0	S 0°4.269 - W 79°47.309	S 0°4.260 - W 79°47.315	Rutaceae	<i>Citrus limon</i>	Borraginaceae	<i>Heliotropium</i> sp.
		3	309.0	S 0°4.266 - W 79°47.307	S 0°4.263 - W 79°47.313	Myrtaceae	<i>Psidium guajava</i>	Solanaceae	<i>Solanum</i> sp.
		4	324.0	S 0°4.268 - W 79°47.314	S 0°4.261 - W 79°47.312	Annonaceae	<i>Annona muricata</i>	Piperaceae	<i>Piper</i> sp.
		5	320.0	S 0°4.257 - W 79°47.310	S 0°4.261 - W 79°47.312	Lauraceae	<i>Persea americana</i>	Lamiaceae	<i>Hiptis capitata</i>

		Highland						
Pichincha	Alchipichí, Puéllaro							
	1	2,089.0	N 0° 2.373 - W 78° 24.079	N 0° 2.371 - W 78° 24.059	Rutaceae	<i>Citrus limon</i>	Bignoniaceae	<i>Tecoma stans</i>
	2	2,090.0	N 0° 2.381 - W 78° 24.069	N 0° 2.374 - W 78° 24.062	Verbenaceae	<i>Aloysia citriodora</i>	Euphorbiaceae	<i>Euphorbia laurifolia</i>
	3	2,096.0	N 0° 2.379 - W 78° 24.067	N 0° 2.371 - W 78° 24.067	Lauraceae	<i>Persea americana</i>	Verbenaceae	<i>Lantana camara</i>
	4	2,090.0	N 0° 2.378 - W 78° 24.068	N 0° 2.369 - W 78° 24.071	Rosaceae	<i>Prunus salicifolia</i>	Solanaceae	<i>Datura stramonium</i>
	5	2,094.0	N 0° 2.373 - W 78° 24.063	N 0° 2.363 - W 78° 24.067	Rosaceae	<i>Eriobotrya japonica</i>	Asteraceae	<i>Taraxacum officinale</i>
Pichincha	Central University of Ecuador UCE-CADET (CADET)							
	1	2,504.0	N 0° 13.886 - W 78° 22.152	S 0° 13.889 - W 78° 22.164	Fabaceae	<i>Inga feuilleei</i>	Euphorbiaceae	<i>Euphorbia laurifolia</i>
	2	2,504.0	S 0° 13.886 - W 78° 22.155	S 0° 13.895 - W 78° 22.152	Asteraceae	<i>Smallanthus sonchifolius</i>	Solanaceae	<i>Solanum nigrum</i>
	3	2,504.0	S 0° 13.892 - W 78° 22.152	S 0° 13.900 - W 78° 22.145	Myrtaceae	<i>Eucalyptus globulus</i>	Bignoniaceae	<i>Tecoma stans</i>
	4	2,503.0	S 0° 13.877 - W 78° 22.157	S 0° 13.814 - W 78° 22.165	Cucurbitaceae	<i>Cucurbita pepo</i>	Verbenaceae	<i>Lantana camara</i>
	5	2,502.0	S 0° 13.869 - W 78° 22.195	S 0° 13.804 - W 78° 22.175	Ciruelo chino	<i>Prunus salicina</i>	Acanthaceae	<i>Megaskepasma erythrochlamys</i>
Pichincha	GIEM, Mindo							
	1	1,535.0	S 0° 4.787 - W 78° 44.961	S 0° 4.788 - W 78° 44.961	Myrtaceae	<i>Psidium guajava</i>	Melastomataceae	<i>Leandra lacunosa</i>
	2	1,526.0	S 0° 4.775 - W 78° 44.971	S 0° 4.787 - W 78° 44.964	Rutaceae	<i>Citrus limon</i>	Acanthaceae	<i>Megaskepasma erythrochlamys</i>
	3	1,532.0	S 0° 4.841 - W 78° 44.770	S 0° 4.847 - W 78° 44.763	Rubiaceae	<i>Coffea arabica</i>	Rosaceae	<i>Rubus rosifolius</i>
	4	1,546.0	S 0° 4.840 - W 78° 44.763	S 0° 4.862 - W 78° 44.757	Poaceae	<i>Saccharum officinarum</i>	Solanaceae	<i>Acnistus arborescens</i>
	5	1,592.0	S 0° 4.849 - W 78° 44.770	S 0° 4.859 - W 78° 44.745	Musaceae	<i>Musa paradisiaca</i>	Melastomataceae	<i>Brachyotum coronatum</i>
Cotopaxi	La Vaquería, Pastocalle							
	1	3,429.0	S 0° 42.443 - W 78° 39.132	S 0° 42.028 - W 78° 39.427	Poaceae	<i>Vicia avena</i>	Asteraceae	<i>Baccharis latifolia</i>
	2	3,392.0	S 0° 42.436 - W 78° 38.944	S 0° 42.027 - W 78° 39.426	Fabaceae	<i>Medicago sativa</i>	Solanaceae	<i>Solanum nigrum</i>
	3	3,417.0	S 0° 42.554 - W 78 38.782	S 0° 42.014 - W 78° 39.420	Solanaceae	<i>Solanum tuberosum</i>	Asteraceae	<i>Taraxacum officinale</i>
	4	3,423.0	S 0° 42.552 - W 78 38.796	S 0° 41.983 - W 78° 39.389	Poaceae	<i>Zea mays</i>	Betulaceae	<i>Alnus jorullensis</i>
	5	3,438.0	S 0° 42.556 - W 78 39.496	S 0° 42.088 - W 78° 39.436	Fabaceae	<i>Lupinus mutabilis</i>	Solanaceae	<i>Lochroma fuchsioides</i>
Pichincha	University of the Armed Forces (ESPE-IASA I) (IASA)							
	1	2,702.0	S 0° 23.029 - W 78° 24.889	S 0° 23.071 - W 78° 24.937	Rutaceae	<i>Citrus limon</i>	Malvaceae	<i>Hibiscusrosa-sinensis</i>
	2	2,709.0	S 0° 23.025 - W 78° 24.897	S 0° 23.071 - W 78° 24.940	Rosaceae	<i>Prunus persica</i>	Adoxaceae	<i>Sambucus nigra</i>
	3	2,709.0	S 0° 23.024 - W 78° 24.899	S 0° 23.078 - W 78° 24.938	Solanaceae	<i>Solanum betaceum</i>	Lamiaceae	<i>Mentha piperita</i>
	4	2,708.0	S 0° 23.021 - W 78° 24.900	S 0° 23.077 - W 78° 24.941	Passifloraceae	<i>Passiflora tacsonia</i>	Onagraceae	<i>Oenothera tetragona</i>
	5	2,714.0	S 0° 23.027 - W 78° 24.537	S 0° 23.090 - W 78° 24.939	Fabaceae	<i>Phaseolus vulgaris</i>	Geraniaceae	<i>Pelargonium hortorum</i>

Amazon

Napo	Between Santa Rosa de Quijos and El Chaco							
	1	1,529.0	S 0° 19.537 - W 77° 47.610	S 0° 19.539 - W 77° 47.604	Rutaceae	<i>Citrus limon</i>	Malvaceae	<i>Hibiscus rosa-sinensis</i>
	2	1,530.0	S 0° 19.537 - W 77° 47.610	S 0° 19.533 - W 77° 47.606	Verbenaceae	<i>Aloysia triphylla</i>	Euphorbiaceae	<i>Ricinus communis</i>
	3	1,537.0	S 0° 19.534 - W 77° 47.611	S 0° 19.539 - W 77° 47.606	Convolvulaceae	<i>Ipomoea batatas</i>	Cyclanthaceae	<i>Carludovica palmata</i>
	4	1,531.0	S 0° 19.531 - W 77° 47.611	S 0° 19.537 - W 77° 47.601	Solanaceae	<i>Solanum quitoense</i>	Rosaceae	<i>Rubus rosifolius</i>
	5	1,535.0	S 0° 19.536 - W 77° 47.602	S 0° 0.538 - W 77° 47.600	Fabaceae	<i>Inga feuilleei</i>	Solanaceae	<i>Cestrum reticulatum</i>
Sucumbíos	Alma Ecuatoriana							
	1	1,189.0	S 0° 0.544 - W 77° 8.342	S 0° 0.538 - W 77° 28.338	Rutaceae	<i>Citrus limon</i>	Rubiaceae	<i>Rubus rosifolius</i>
	2	1,183.0	S 0° 0.549 - W 79° 8.345	S 0° 0.539 - W 77° 28.338	Rubiaceae	<i>Borojoa patinoi</i>	Acanthaceae	<i>Pachystachys lutea</i>
	3	1,173.0	S 0° 0.546 - W 77° 28.342	S 0° 0.549 - W 77° 28.339	Myrtaceae	<i>Eugenia stipitata</i>	Solanaceae	<i>Brunfelsia grandiflora</i>
	4	1,168.0	S 0° 0.547 - W 77° 28.339	S 0° 0.550 - W 77° 28.337	Piperaceae	<i>Piper auritum</i>	Fabaceae	<i>Erythrina edulis</i>
	5	1,185.0	S 0° 0.543 - W 77° 28.338	S 0° 0.550 - W 77° 28.341	Cucurbitaceae	<i>Cyclanthera pedata</i>	Urticaceae	<i>Pourouma cecropiifolia</i>
Sucumbíos	Nueva Loja (East)							
	1	294.0	S 0° 6.052 - W 76° 52.235	S 0° 6.051 - W 76° 52.237	Rutaceae	<i>Citrus limon</i>	Sapindaceae	<i>Sapindus saponaria</i>
	2	298.0	S 0° 6.052 - W 76° 52.235	S 0° 6.048 - W 76° 52.244	Myrtaceae	<i>Psidium guajava</i>	Moraceae	<i>Ficus americana</i>
	3	300.0	S 0° 6.045 - W 76° 52.246	S 0° 6.044 - W 76° 52.239	Musaceae	<i>Musa paradisiaca</i>	Malvaceae	<i>Urena lobata</i>
	4	308.0	S 0° 6.043 - W 76° 52.253	S 0° 6.049 - W 76° 52.242	Arecaceae	<i>Cocos nucifera</i>	Campanulaceae	<i>Siphocampylis</i> sp.
	5	309.0	S 0° 6.048 - W 76° 52.241	S 0° 6.055 - W 76° 52.241	Fabaceae	<i>Inga feuilleei</i>	Cecropiaceae	<i>Cecropia obtusifolia</i>
Orellana	Joya de Los Sachas							
	1	283.0	S 0° 19.621 - W 76° 53.287	S 0° 19.626 - W 76° 53.292	Myrtaceae	<i>Psidium guajava</i>	Araceae	<i>Colocasia esculenta</i>
	2	275.0	S 0° 19.622 - W 76° 53.289	S 0° 19.615 - W 76° 53.293	Verbenaceae	<i>Aloysia triphylla</i>	Fabaceae	<i>Senna</i> sp.
	3	289.0	S 0° 19.617 - W 76° 53.293	S 0° 19.615 - W 76° 53.294	Malvaceae	<i>Theobroma cacao</i>	Heliconiaceae	<i>Heliconia rostrata</i>
	4	284.0	S 0° 19.614 - W 76° 53.296	S 0° 19.611 - W 76° 53.298	Anacardiaceae	<i>Mangifera indica</i>	Urticaceae	<i>Urera baccifera</i>
	5	290.0	S 0° 19.613 - W 76° 53.295	S 0° 19.612 - W 76° 53.292	Caricaceae	<i>Carica papaya</i>	Poaceae	<i>Coix lacryma-jobi</i>
Napo	Tena							
	1	610.0	S 0° 53.827 - W 77° 48.128	S 0° 53.830 - W 77° 48.130	Rutaceae	<i>Citrus limon</i>	Melastomataceae	<i>Tibouchina lepidota</i>
	2	608.0	S 0° 53.824 - W 77° 48.133	S 0° 53.830 - W 77° 48.125	Musaceae	<i>Musa paradisiaca</i>	Rubiaceae	<i>Borojoa patinoi</i>
	3	604.0	S 0° 53.813 - W 77° 48.120	S 0° 53.828 - W 77° 48.125	Malvaceae	<i>Gossypium herbaceum</i>	Cecropiaceae	<i>Cecropia sciadophylla</i>
	4	610.0	S 0° 53.823 - W 77° 48.109	S 0° 53.836 - W 77° 48.133	Poaceae	<i>Saccharum officinarum</i>	Zingiberacea	<i>Renalmia sessilifolia</i>
	5	633.0	S 0° 53.816 - W 77° 48.113	S 0° 53.811 - W 77° 48.120	Lauraceae	<i>Ocotea floribunda</i>	Caesalpiniaceae	<i>Bauhinia grandiflora</i>

Likewise, the 1,109 mites of the order Trombidiformes belonged to 12 families (Bdellidae, Cunaxidae, Diptilopiopidae, Eriophyidae, Iolinidae, Linotetranidae, Smaridiidae, Stigmaeidae, Tarsonemidae, Tenuipalpidae, Tetranychidae and Tydeidae). Finally, 407 mites of the suborder Oribatida were found, and these were also not identified at lower taxonomic levels, because they were not of interest in this research (Table 3).

Table 3. Families of plant mites identified from three continental regions of Ecuador in wild and cultivated plants, in the rainy season of 2018.

Orden/Family/Group	Coast			Highland			Amazon			Grand Total	(%)
	Cultivated	Wild	Total	Cultivated	Wild	Total	Cultivated	Wild	Total		
Mesostigmata											
Gamasina	23	21	44	54	124	178	302	151	453	675	91.1
Ameroseiidae	3	2	5		3	3	6		6	14	1.9
Ascidae					2	2	4	19	23	25	3.4
Blattisociidae				1	5	6	11		11	17	2.3
Laelapidae						0		2	2	2	0.3
Melicharidae					1	1	2		2	3	0.4
Ologamasidae				1		1	1		1	2	0.3
Phytoseiidae	20	19	39	52	113	165	278	130	408	612	82.6
Uropodina¹					22	22	44		44	66	8.9
Total	23	21	44	54	146	200	346	151	497	741	100
Trombidiformes											
Bdellidae					1	1			0	1	0.1
Cunaxidae	8	1	9	1	7	8	10	17	27	44	4.0
Diptilomiopidae					1	1		10	10	11	1.0
Eriophyidae	63	3	66		26	26			0	92	8.3
Iolinidae	5		5	2	34	36	18	3	21	62	5.6
Linotetranidae		1	1			0			0	1	0.1
Smarididae					1	1			0	1	0.1
Stigmaeidae	12	1	13	19	25	44	1	4	5	62	5.6
Tarsonemidae	16	1	17	9	11	20	2	7	9	46	4.1
Tenuipalpidae	3	1	4	18	12	30	33	37	70	104	9.4
Tetranychidae	1	3	4	148	35	183	77	90	167	354	31.8
Tydeidae	3	8	11	76	148	224	27	69	96	331	29.8
Total	111	19	130	273	301	574	168	237	405	1,109	100
Sarcoptiformes											
Oribatida ¹	53	33	86	41	95	136	98	87	185	407	100
Total										2,257	

¹ Identification at lower levels not considered for this research

Identification to the species level, is not always possible for the lack of sufficient details. For example, in several genera of Tetranychidae, males are required for species

identification, and these were not always available. In many different mite groups, identification based on immatures only is not possible; and in other cases, identification was not possible when mites were for some reason not adequately mounted.

When it was not possible to reach the taxonomic level of species, it was identified only as morphospecies.

2.3.3. Mites by region and type of host plants

As shown in Table 3, among the Mesostigmata, the Phytoseiidae, potential biological agents for control of small pest species (mainly whiteflies, thrips and phytophagous mites, stood out as the most common mite group in the three regions (82,6 %). These represented 32.8 % of all mites identified up to species and morphospecies when species level was not possible.

Within the mesostigmatids, the Coast (23 cultivated vs. 21 wild host plants) and the Amazonian (346 cultivated vs. 151 wild host plants) regions had the highest number of specimens on cultivated host plants; the reverse was observed in the Highland (54 cultivated vs. 146 wild host plants).

Within the Trombidiformes, the tetranychids were stood out, accounting for 31,8 % of the Trombidiformes mites, followed by Tydeidae (29,8 %). Each of the other families (Cunaxidae, Eriophyidae, Iolinidae, Stigmaeidae, Tarsonemidae and Tenuipalpidae) accounted for 4.0 to 9.4 %.

Like the Mesostigmata, within the Trombidiformes, only in the Coastal region the number of specimens was higher on cultivated than on wild plants (111 on cultivated vs. 19 on wild plants). Conversely, in the Highland and Amazon, the higher mite numbers were found on wild plants (273 on cultivated vs. 301 on wild and 168 on cultivated vs. 237 on wild plants, respectively).

The Amazonian region clearly had more families (highest mite diversity) and corresponding specimens (574), followed by the Highland region (405) and finally the Coastal region (130); eight families found in the first two regions were not found in the Coast (Table 3).

2.3.3.1. Mesostigmata

As mentioned before, specifically on Mesostigmata, 387 mites (Uropodina not included), were identified, belonging to seven families, being Phytoseiidae the most numerous (334 mites) followed by Ascidae (32 mites) and Blattisociidae (8 mites) (Table 4).

Within the families identified, 29 known genera and one possible new genus were found, and within those genera 96 species/morphospecies were found. The most diverse of the Mesostigmata's genera were *Asca*, *Amblyseius* and *Proprioseiopsis*, with respectively 13, 14 and 17 species/morphospecies corresponding to 3.36, 3.62 and 4.39 % of the total specimens (387). The other genera had about 1 to 6 species/morphospecies each.

Concerning the distribution among regions, the highest number was found in the Amazon (202), followed by the Highland (144), and the Coast (41).

Considering the three regions together, the most abundant morphospecies were *Euseius* sp. 1 (11.1 %), *Amblydromalus yunquensis* De Leon (7.0 %), *Amblyseius vasiformis* Moraes & Mesa (6.5 %), *Amblyseius perditus* Chant & Baker (5.7 %), *Amblyseius anacardii* De Leon and *Honduriella maxima* Denmark & Evans (each 3.6 %), and *Typhlodromalus aripo* De Leon (3.1 %); the abundance of each of the other species was at most 3.0 % (Table 4).

The following possibly new phytoseiid taxa were found: six *Amblyseius*, two each of *Galendromus* and *Iphiseiodes*, and one new genus and species. Two possibly new species of the blattisociid *Cheiroseius* were also found (Table 4).

Nineteen of the Mesostigmata collected had already been reported for continental Ecuador, namely *Gamasiphis salvadori* Castilho, Narita & Moraes (Ologamasidae), *Amblyseius tubocalicis* Karg, *A. anacardii* De Leon, *A. vasiformis*, *Iphiseiodes nobilis* (Chant & Baker), *Neoseiulus californicus* (McGregor), *Proprioseiopsis ovatus* (Garman), *Typhlodromina conspicua* (Garman), and the genera *Asca* (Ascidae), *Lasioseius* (Blattisociidae), *Pseudoparasitus* and *Ololaelaps* (Laelapidae), *Proctolaelaps* (Melicharidae), *Amblydromalus*, *Arrenoseius*, *Graminaseius*, *Proprioseiopsis*, *Proprioseius* and *Typhlodromina* (Phytoseiidae) (Table 4).

Table 4. Morphospecies of plant mites of the order Mesostigmata identified from three continental regions of Ecuador on wild and cultivated host plants, in the rainy season of 2018.

Family/Morphospecies	Specimens by region						Total
	Coast	%	Highland	%	Amazon	%	
Ameroseiidae							
<i>Epicriopsis atuberculatus</i> Narita & Moraes*	5	63	3	38			8
Total	5	63	3	38	0	0	8
Ascidae							
<i>Asca</i> ** sp. 1					8	100	8
<i>Asca</i> sp. 2					4	100	4
<i>Asca</i> sp. 3					1	100	1
<i>Asca</i> sp. 4					1	100	1
<i>Asca</i> sp. 5					7	100	7
<i>Asca</i> sp. 6			1	100			1
<i>Asca</i> sp. 7					3	100	3
<i>Asca</i> sp. 8					1	100	1
<i>Asca</i> sp. 9					2	100	2
<i>Asca</i> sp. 10					1	100	1
<i>Asca</i> sp. 11					1	100	1
<i>Asca</i> sp. 12					1	100	1
<i>Asca</i> sp. 13					1	100	1
Total			1		31		32
Blattisociidae							
<i>Lasioseius helvetius</i> Chant*					1	100	1
<i>Lasioseius</i> sp. 1**					1	100	1
<i>Lasioseius</i> sp. 2			1	100			1
<i>Lasioseius</i> sp. 3			1	100			1
<i>Cheiroseius</i> pos. n. sp.			4	100			4
Total			6		2		8
Laelapidae							
<i>Pseudoparasitus</i> ** sp. 1					2	100	2
<i>Ololaelaps</i> ** aff. <i>Rectagoni</i>					1	100	1
Total					3		3
Melicharidae							
<i>Proctolaelaps</i> ** sp. 1			1	100			1
Total			1				1
Ologamasidae							
<i>Gamasiphis salvadori</i> Castilho, Narita & Moraes**			1	100			1
Total			1				1
Phytoseiidae							
<i>Amblydromalus yunquensis</i> De Leon*					27	100	27
<i>Amblydromalus</i> ** sp. 1			2	100			2
<i>Amblydromalus</i> sp. 2			1	100			1
<i>Amblydromalus</i> sp. 3					2	100	2
<i>Amblydromalus</i> sp. 4					3	100	3
<i>Amblydromalus</i> sp. 5					3	100	3
<i>Amblyseiesella</i> aff. <i>Rusticana</i>			1	100			1
<i>Amblyseius deleoni</i> Muma & Denmark*					1	100	1
<i>Amblyseius faerroni</i> Denmark & Evans*					3	100	3
<i>Amblyseius fijiensis</i> McMurtry & Moraes*					2	100	2
<i>Amblyseius perditus</i> Chant & Baker*					22	100	22
<i>Amblyseius tubocalicis</i> Karg**			1	100			1
<i>Amblyseius anacardii</i> De Leon**	2	14	9	64	3	21	14
<i>Amblyseius vasiformis</i> Moraes & Mesa**	10	40			15	60	25
<i>Amblyseius</i> aff. <i>Curticervicalis</i>			2	100			2
<i>Amblyseius</i> aff. <i>Paulofariensis</i>					4	100	4
<i>Amblyseius</i> aff. <i>Ainu</i>					1	100	1
<i>Amblyseius</i> pos. n. sp. 1			3	100			3
<i>Amblyseius yumbus</i> n. sp.			6	100			6
<i>Amblyseius</i> sp. 1					2	100	2
<i>Amblyseius</i> sp. 2			1	13	7	88	8
<i>Arrenoseius</i> ** sp. 1			4	100			4

Family/Morphospecies	Specimens by region						Total
	Coast	%	Highland	%	Amazon	%	
<i>Arrenoseius</i> sp. 2					1	100	1
<i>Euseius</i> sp. 1			43	100			43
<i>Euseius</i> sp. 2	1	100					1
<i>Euseius</i> sp. 3			1	100			1
<i>Euseius</i> sp. 4			1	100			1
<i>Galendromus</i> pos. n. sp.			4	100			4
<i>Graminaseius</i> ** sp. 1					2	100	2
<i>Graminaseius</i> sp. 2					2	100	2
<i>Graminaseius</i> sp. 3			2	100			2
<i>Graminaseius</i> sp. 4					1	100	1
<i>Honduriella maxima</i> Denmark & Evans*					14	100	14
<i>Iphiseiodes quadripilis</i> (Banks)*					3	100	3
<i>Iphiseiodes nobilis</i> (Chant & Baker)**	1	13	7	88			8
<i>Iphiseiodes</i> pos. n. sp.	1	100					1
<i>Kampimodromus</i> sp. 1*					6	100	6
<i>Kampimodromus</i> sp. 2					2	100	2
<i>Neoseiulus californicus</i> (McGregor)**			9	100			9
<i>Neoseiulus</i> sp. 1			2	100			2
<i>Paraamblyseius</i> * sp. 1					8	100	8
<i>Phytoscutus sexpilis</i> (Muma)*					10	100	10
<i>Phytoseius plumifer</i> (Canestrini & Fanzago)*	2	100					2
<i>Phytoseius pernambucanus</i> Moraes & McMurtry*					1	100	1
<i>Proprioseiopsis caliensis</i> (Moraes & Mesa)*			10	100			10
<i>Proprioseiopsis ovatus</i> (Garman)**			2	100			2
<i>Proprioseiopsis</i> ** sp. 1	1	100					1
<i>Proprioseiopsis</i> sp. 2	2	100					2
<i>Proprioseiopsis</i> sp. 3	1	100					1
<i>Proprioseiopsis</i> sp. 4	1	100					1
<i>Proprioseiopsis</i> sp. 5			3	100			3
<i>Proprioseiopsis</i> sp. 6					3	100	3
<i>Proprioseiopsis</i> sp. 7					2	100	2
<i>Proprioseiopsis</i> sp. 8					1	100	1
<i>Proprioseiopsis</i> sp. 9					1	100	1
<i>Proprioseiopsis</i> sp. 10					2	100	2
<i>Proprioseiopsis</i> sp. 11					1	100	1
<i>Proprioseiopsis</i> sp. 12					3	100	3
<i>Proprioseiopsis</i> sp. 13			4	100			4
<i>Proprioseiopsis</i> sp. 14					1	100	1
<i>Proprioseiopsis</i> sp. 15					1	100	1
<i>Proprioseius</i> sp. 1**					2	100	2
<i>Transeius herbarius</i> (Wainstein)*			2	100			2
<i>Transeius</i> aff. <i>Herbarius</i>			4	100			4
<i>Transeius</i> aff. <i>Cristobalensis</i>			2	100			2
<i>Transeius</i> aff. <i>Oocarpus</i>			1	100			1
<i>Transeius</i> sp.	1	33	2	67			3
<i>Typhlodromalus aripo</i> De Leon*	12	100					12
<i>Typhlodromina conspicua</i> (Garman)**			2	100			2
<i>Typhlodromina</i> aff. <i>Tropicus</i>			1	100			1
<i>Typhlodromips biflorus</i> Denmark & Evans*					3	100	3
<i>Typhlodromips</i> ** sp. 1	1	100					1
pos. n. g. & sp.					1	100	1
Total	36		132		166	334	334
Uropodina			21			21	21
Grand Total	41		165		202		408

*
New report,

**previous report, aff. = afinis with, pos. n. sp. = new species

Also 19 of the Mesostigmata collected had not been previously reported from the country, namely *Epicriopsis atuberculatus* Narita & Moraes (Ameroseiidae), *Lasioseius*

helvetius Chant (Blattisociidae), *Amblydromalus yunquensis* De Leon, *Amblyseius deleoni* Muma & Denmark, *A. faerroni* Denmark & Evans, *A. fijiensis* McMurtry & Moraes, *A. perditus*, *Honduriella maxima* Denmark & Evans, *Iphiseiodes quadripilis* (Banks), *Phytoscutus sexpilis* (Muma), *Phytoseius plumifer* (Canestrini & Fanzago), *Phytoseius pernambucanus* Moraes & McMurtry, *Proprioseiopsis caliensis* (Moraes & Mesa), *Transeius herbarius* (Wainstein), *T. aripo*, *Typhlodromips biflorus* Denmark & Evans and the genera *Kampimodromus* and *Paraamblyseius* all belonging to Phytoseiidae (Table 4).

Most species were found in the Amazon region (53 species, 55.2 %), followed by the Highland (36 species, 37.5 %) and, finally, with very few species in the Coast (14 species, 14.6 %). *Amblyseius anacardii* was found in the three regions; *Amblyseius* morphospecies 2 was found in both Highland and the Amazon; *A. vasiformis* was found in the Coast and the Amazon; *E. atuberculatus*, *I. nobilis* and *Transeius* sp. were found in the Coast and Highland regions.

Within the three regions, the most abundant mesostigmatid mites were found on botanical species of 28 plant families, including 20 families of wild plants (onto which 71.4 % of the mesostigmatid mites were found) and eight families of cultivated plants (onto which 28.6 % of the mesostigmatids were found) (Table 5).

The most abundant mesostigmatid species in each region were: in the Coast, *A. vasiformis*, *E. atuberculatus* and *T. aripo* (65.9 % of all mesostigmatids), and these mite species were found on both cultivated and wild plants; in the Highland, *Euseius* sp. 1, *P. caliensis*, *A. anacardii* and *N. californicus* (49.3 % of all mesostigmatids), the first three found on both plant types, while the last was found only on cultivated plant; in the Amazon, *A. yunquensis*, *A. perditus*, *A. vasiformis* and *H. maxima* (38.6 % of all mesostigmatids), the first and the last only on wild plants and the others on both plant types (Table 5).

2.3.3.2. Trombidiformes

In total, 1,120 mites of 11 families of the order Trombidiformes were identified, Tydeidae being the most numerous (33.5 %) followed by Tetranychidae (31.6 %) and Tenuipalpidae (10.6 %). Other families accounted for less than 6.1 % of the mites of this order (Table 6).

These mites were classified in 120 species/ morphospecies, distributed in 62 genera. Eight of the morphospecies were considered as possibly new to science, belonging to

loliniidae (*Metapronematus* n. sp. 1, and n. sp. 2), Tarsonemidae (*Hemitarsonemus* n. sp. 1, *Heterotarsonemus* n. sp. 1), and Tydeidae (*Krantzlorryia* n. sp., *Melissotydeus* n. sp., *Orfareptydeus* n. sp. and *Prelorryia* n. sp.). *Lorryia* was the genus with the largest diversity (14 morphospecies); followed by *Tydeus* (nine morphospecies) and *Brevipalpus* (seven morphospecies). Other genera had 1–5 morphospecies (Table 6).

The most abundant morphospecies for the three regions were *Tetranychus urticae* Koch (9.5 %), *Aculus* sp. 1 (5.8 %), *Oligonychus letchworthi* Reeves (4.3 %), *Tydeus africanus* Baker and *Tydeus riopardensis* Silva, Cunha & Ferla (4.1 %). As in Mesostigmata, most of the species were found in the Amazon region (66 species, 55.0 %), followed by the Highland (49 species, 40.8 %) and, finally, the Coast (27 morphospecies, 22.5 %) (Table 6).

Agistemus sp. 2, *Brevipalpus yothersi* Baker, *Quasitydeus feresi* Silva & Ferla and *Tarsonemus viridis* Ewing, were found in the three regions; while *Iponemus boreus* Lindquist, *T. urticae*, and *T. riopardensis* were found in the Coast and the Highland; whereas *Agistemus* sp. 4, *Eotetranychus* sp. 1, *Paracunaxoides newzealandicus* Smiley, *Pseudolorryia nikitensis* Livshitz, *Ultratenuipalpus coprosmae* Collyer and *Xenotarsonemus pirassunungaensis* Lofego, Moraes & Ochoa, were found in the Highland and in the Amazon regions.

The region with the highest number of Trombidiformes mites was the Highland (569 mites), followed by Amazon (395 mites) and finally Coast (155 mites).

Only five of the identified species had been previously reported from Ecuador, namely *Aceria* sp. 1, and the species of *B. yothersi*, *Polyphagotarsonemus latus* Banks, *Tetranychus tumidus* Banks and *T. urticae* (Table 6). Nothing can be said about the other 91 morphospecies, as they could not be identified to species.

The Trombidiformes were found on plants of 19 families, ten of which contained wild plants, and hosted 52.6 % of the mite species, whereas nine contained only cultivated plants and hosted 47.4 % of the mite species (Table 7).

The most abundant Trombidiformes mites in each region were: Coast, *Aculus* sp. 1, *Agistemus* sp. 2, *Perafrottydeus meyeræ* Baker and *Pseudolorryia nicaraguensis* Baker (67.3 % of all Trombidiformes), found on cultivated plants, except the second species, on both plant types; Highland, *T. urticae*, *T. africanus*, *T. riopardensis* and *T. nieuwkerkeni* (42.2 % of all Trombidiformes), the first just on cultivated plants, the second on wild plants, and others on both plant types; and the Amazon, *Brevipalpus azores* Beard & Ochoa, *Lorryia evansi*

Baker, *O. letchworthi*, and *Oligonychus propetes* Pritchard & Baker (33.7 % of all Trombidiformes), the first and the third just on wild and others on cultivated plants.

Table 5. Species and morphospecies of mesostigmatid mites more abundant by wild and cultivated plant host in three regions of Ecuador, in the rainy season of 2018.

Family, species/morphospecies	Number of specimens by host				Plant host			
	Cult.	Wild	Total	%	Cultivated		Wild	
Coast								
Phytoseiidae								
<i>Typhlodromalus aripo</i> De Leon	3	9	12	29.3	Malvaceae <i>Gossypium hirsutum</i>	Lamiaceae	<i>Ocimum</i> sp.	
						Piperaceae	<i>Piper aduncum</i>	
						Solanaceae	<i>Acnistus arborescens</i>	
						Convolvulaceae	<i>Merremia aegyptia</i>	
<i>Amblyseius vasiformis</i> Moraes & Mesa	9	1	10	24.4	Malvaceae <i>Theobroma cacao</i>	Urticaceae	<i>Pourouma cecropiifolia</i>	
					Lauraceae <i>Persea americana</i>	Heliconiaceae	<i>Heliconia rostrata</i>	
					Rutaceae <i>Citrus limon</i>			
					Myrtaceae <i>Psidium guajava</i>			
					Poaceae <i>Saccharum officinarum</i>			
Ameroseiidae								
<i>Epicriopsis atuberculatus</i> Narita & Moraes	3	2	5	12.2	Lauraceae <i>Persea americana</i>	Lamiaceae	<i>Hyptis capitata</i>	
						Bignoniaceae	<i>Tecoma stans</i>	
						Acanthaceae	<i>Megaskepasma erythrochlamys</i>	
					Myrtaceae <i>Psidium guajava</i>	Melastomataceae	<i>Brachyotum coronatum</i>	
Total	41	15	12	27				
Highland								
Phytoseiidae								
<i>Euseius</i> sp. 1	10	33	43	29.9	Rosaceae <i>Prunus salicifolia</i>	Amaranthaceae	<i>Amaranthus retroflexus</i>	
					Fabaceae <i>Inga feuillei</i>	Convolvulaceae	<i>Ipomoea nil</i>	
					Myrtaceae <i>Eucalyptus globulus</i>	Euphorbiaceae	<i>Euphorbia laurifolia</i>	
						Bignoniaceae	<i>Tecoma stans</i>	
						Malvaceae	<i>Hibiscus rosa-sinensis</i>	
						Solanaceae	<i>Solanum nigrum</i>	
						Lamiaceae	<i>Mentha piperita</i>	
						Geraniaceae	<i>Pelargonium hortorum</i>	
<i>Proprioseiopsis caliensis</i> Moraes & Mesa	1	9	10	6.9	Rutaceae <i>Citrus limon</i>	Melastomataceae	<i>Leandra lacunosa</i>	
						Acanthaceae	<i>Megaskepasma erythrochlamys</i>	
<i>Amblyseius anacardii</i> De Leon		9	9	6.3		Melastomataceae	<i>Leandra lacunosa</i>	
						Rosaceae	<i>Rubus rosifolius</i>	
						Melastomataceae	<i>Brachyotum coronatum</i>	
<i>Neoseiulus californicus</i> (McGregor)	9		9	6.3	Rosaceae <i>Prunus persica</i>			
Total	144	20	51	71				
Amazon								
Phytoseiidae								
<i>Amblydromalus yunquensis</i> De Leon		27	27	13.4		Malvaceae	<i>Urena lobata</i>	
<i>Amblyseius perditus</i> Chant & Baker	9	13	22	10.9	Rutaceae <i>Citrus limon</i>	Rubiaceae	<i>Borojoa patinoi</i>	
					Rubiaceae <i>Borojoa patinoi</i>	Zingiberaceae	<i>Renalmia sessilifolia</i>	
						Urticaceae	<i>Urera baccifera</i>	
						Poaceae	<i>Coix lacryma-jobi</i>	
						Moraceae	<i>Ficus americano</i>	
						Campanulaceae	<i>Siphocampylus</i> sp.	
						Cecropiaceae	<i>Cecropia obtusifolia</i>	
<i>Amblyseius vasiformis</i> Moraes & Mesa	6	9	15	7.4	Myrtaceae <i>Psidium guajava</i>	Heliconiaceae	<i>Heliconia rostrata</i>	
					Poaceae <i>Saccharum officinarum</i>	Rubiaceae	<i>Borojoa patinoi</i>	
					Lauraceae <i>Ocotea floribunda</i>			
<i>Honduriella maxima</i> Denmark & Evans		14	14	6.9		Melastomataceae	<i>Tibouchina lepidota</i>	
Total	202	15	63	78				

Table 6. Families, species and morphospecies of trombidiid mites identified from three continental regions of Ecuador in wild and cultivated plant hosts, in rainy season 2018.

Family/Morphospecies *,**	Specimens by region						Total
	Coast	%	Highland	%	Amazon	%	
Bdellidae							
aff. <i>Odontoscirus</i> * sp. 1			1	100			1
Total			1				1
Cunaxidae							
<i>Armscirus bifidus</i> Corpus-Raros*					1	100	1
<i>Armscirus cyaneus</i> Kalúz*	1	33			2	67	3
<i>Armscirus pennsylvanicus</i> Skvarla & Dowling*					4	100	4
<i>Cunaxa eupatoriae</i> Chinniah & Mohanasundaram*					2	100	2
<i>Cunaxa guanotoleranta</i> Sergeenko*			6	100			6
<i>Cunaxa mageei</i> Smiley*			1	100			1
<i>Cunaxoides decastrae</i> Den Heyer*	4	100					4
<i>Dactyloscirus bengalensis</i> Gupta*					1	100	1
<i>Dactyloscirus orsi</i> Inayatullah & Shahid*	1	100					1
<i>Neobonzia longispina</i> Corpus-Raros & García*					2	100	2
<i>Neocunaxoides andrei</i> Baker & Hoffmann *					2	100	2
<i>Neocunaxoides lajumensis</i> Den Heyer*	1	33			2	67	3
<i>Orangescirula filipina</i> Corpuz-Raros					1	100	1
<i>Paracunaxoides newzealandicus</i> Smiley*			1	17	5	83	6
<i>Pseudobonzia gruesoi</i> Corpuz-Raros & García*					1	100	1
<i>Scirula papillata</i> Lin*					1	100	1
<i>Scutopalus trepidus</i> Kuznetsov Livshitz*					1	100	1
Total	7		8		25		40
Diptilomiopidae							
<i>Rhynacus</i> * sp. 1			3	100			3
Total			3				3
Eriophyidae							
<i>Aceria</i> ** sp. 1			26	100			26
<i>Acerimina</i> * sp. 1	3	25			9	75	12
<i>Aculus</i> * sp. 1	65	100					65
<i>Paracolomerus</i> * sp. 1					2	100	2
Total	68		26		11		105
Iolinidae							
<i>Homeopronematus anconai</i> (Baker)*			1	100			1
<i>Homeopronematus</i> * sp. 1	2	100					2
<i>Metapronematus</i> n. sp. 1			35	100			35
<i>Metapronematus</i> n. sp. 2					1	100	1
<i>Parapronematus geminus</i> Meyer & Rodrigues*	1	7			13	93	14
<i>Parapronematus ubiquitus</i> (McGregor)*					2	100	2
<i>Pseudopronematus</i> * sp. 1					1	100	1
<i>Pseudopronematus</i> sp. 2					4	100	4
Total	3		36		21		60
Linotetranae							
<i>Linotetranus</i> * sp. 1	1	100					1
Total	0						1
Smarididae							
<i>Smaris</i> * sp. 1			1	100			1
Total			1				1
Stigmaeidae							
<i>Agistemus</i> * sp. 1			35	100			35
<i>Agistemus</i> sp. 2	13	62	7	33	1	5	21
<i>Agistemus</i> sp. 3					3	100	3
Total	13		42		4		59
Tarsonemidae							
<i>Asiocortarsonemus</i> * sp. 1					1	100	1
<i>Dendroptus</i> * sp. 1	3	75			1	25	4
<i>Dendroptus</i> sp. 2	1	100					1
<i>Dendroptus</i> sp. 3					2	100	2
<i>Dendroptus</i> sp. 4	7	100					7
<i>Dendroptus</i> sp. 5			2	100			2
<i>Hemitarsonemus</i> n. sp. 1					1	100	1
<i>Heterotarsonemus</i> n. sp. 1	4	100					4
<i>Iponemus boreus</i> Lindquist *	1	50	1	50			2
<i>Polyphagotarsonemus latus</i> Banks**			10	100			10
<i>Tarsonemus viridis</i> Ewing*	1	33	1	33	1	33	3
<i>Xenotarsonemus pirassunungaensis</i> Lofego, Moraes & Ochoa*			2	40	3	60	5

Family/Morphospecies *,**	Specimens by region						Total
	Coast	%	Highland	%	Amazon	%	
<i>Xenotarsonemus</i> * sp. 1			1	100			1
<i>Xenotarsonemus</i> sp. 2			2	100			2
Total	17		19		9		45
Tenuipalpidae							
<i>Brevipalpus azores</i> Beard & Ochoa*					27	100	27
<i>Brevipalpus californicus</i> species group*	1	100					1
<i>Brevipalpus ferraguti</i> Ochoa & Beard*					21	100	21
<i>Brevipalpus obovatus</i> Donnadieu*					15	100	15
<i>Brevipalpus phoenicis</i> group*					3	100	3
<i>Brevipalpus tucuman</i> Beard & Ochoa*			1	100			1
<i>Brevipalpus yothersi</i> Baker**	3	19	11	69	2	13	16
<i>Pentamerismus erythreus</i> Ewing*			1	100			1
<i>Tenuipalpus sensu lato</i> *					2	100	2
<i>Ultratenuipalpus coprosmae</i> Collyer*			18	90	2	10	20
Total	4		31		72		107
Tetranychidae							
<i>Allonychus</i> * sp. 1					21	100	21
<i>Allonychus</i> sp. 2					9	100	9
<i>Bryobia praetiosa</i> Koch *			1	100			1
<i>Eotetranychus carpini</i> Oudemans*			1	100			1
<i>Eotetranychus cercocarpi</i> McGregor*			6	100			6
<i>Eotetranychus frosti</i> McGregor*			20	100			20
<i>Eotetranychus</i> * sp. 1			2	33	4	67	6
<i>Mononychellus</i> * sp. 1			1	100			1
<i>Mononychellus</i> sp. 2					12	100	12
<i>Neotetranychus decorus</i> Meyer & Bolland*			23	100			23
<i>Oligonychus bicolor</i> Banks*			1	100			1
<i>Oligonychus letchworthi</i> Reeves*					48	100	48
<i>Oligonychus pritchardi</i> McGregor*			1	100			1
<i>Oligonychus propetes</i> Pritchard & Baker*					24	100	24
<i>Oligonychus</i> * sp. 1					9	100	9
<i>Panonychus</i> * sp. 1					12	100	12
<i>Sonotetranychus</i> * sp. 1					13	100	13
<i>Tetranychus cocosi</i> McGregor*					1	100	1
<i>Tetranychus tumidus</i> Banks**					9	100	9
<i>Tetranychus urticae</i> Koch**			106	100			106
<i>Tetranychus</i> pos. <i>urticae</i>	4	19	17	81			21
Total	4		179		162		345
Tydeidae							
<i>Afrotydeus kenyensis</i> Baker*					1	100	1
<i>Krantzlorryia</i> n. sp.					5	100	5
<i>Lorryia argentinensis</i> Baker*					1	100	1
<i>Lorryia artichokei</i> El Bagoury & Momen*					1	100	1
<i>Lorryia evansi</i> Baker *					34	100	34
<i>Lorryia fabae</i> El-Bagoury & Momen*			2	100			2
<i>Lorryia formosa</i> Cooreman*			25	100			25
<i>Lorryia funki</i> Baker*			23	100			23
<i>Lorryia opima</i> Kuznetsov & Zapletina*			1	100			1
<i>Lorryia perlata</i> Kazmierski*			4	100			4
<i>Lorryia podocarpa</i> Baker*					6	100	6
<i>Lorryia sherekhani</i> Kazmierski *			1	100			1
<i>Lorryia turrialbensis</i> Baker *					5	100	5
<i>Lorryia trilobus</i> Karg*			1	100			1
<i>Lorryia wainsteini</i> Kuznetsov*					1	100	1
<i>Lorryia</i> * sp. 1			1	100			1
<i>Melissotydeus</i> n. sp.	2	100					2
<i>Metalorryia magdalenae</i> Gerson*	4	100					4
<i>Neolorryia pandana</i> Baker *					1	100	1
<i>Novzelorryia deserta</i> Kazmierski*					1	100	1
<i>Nudilorryia virginia</i> Kazmierski*	2	100					2
<i>Orfareptydeus</i> n. sp.					1	100	1
<i>Perafrotydeus meyeriae</i> Baker*	12	41			17	100	29
<i>Prelorryia</i> n. sp.					4	100	4
<i>Pretydeus panitae</i> Baker*					2	100	2
<i>Pseudolorryia nicaraguensis</i> Baker*	15	100					15
<i>Pseudolorryia nikitensis</i> Livshitz*			1	33	2	100	3
<i>Pseudolorryia</i> * sp. 1					1	100	1
<i>Quasitydeus feresi</i> Silva & Ferla*	1	5	19	90	1	100	21

Family/Morphospecies *,**	Specimens by region						Total
	Coast	%	Highland	%	Amazon	%	
<i>Quasitydeus ricensis</i> Baker *					3	100	3
<i>Tydeus africanus</i> Baker *			46	100			46
<i>Tydeus caryae</i> Khanjani & Ueckermann*					1	100	1
<i>Tydeus caudatus</i> Dugés*			3	100			3
<i>Tydeus dignus</i> Livshitz*					3	100	3
<i>Tydeus nieuwerkerkeni</i> André*			44	100			44
<i>Tydeus kochi</i> Oudemans*			6	100			6
<i>Tydeus plumosus</i> Karg*			2	100			2
<i>Tydeus riopardensis</i> Silva, Cunha & Ferla*	2	4	44	96			46
<i>Tydeus*</i> sp. 1	1	100					1
Total	39		223		91		353
Grand Total	155		569		395		1120

*New report, **previous report, n. sp. = new species

2.3.4. New mite species

Table 8 shows several mite species that did not match the names mentioned in the taxonomic keys used in this study, suggesting that they could be new species to science. In fact, in this research a new species of predatory *Amblyseius* (Acari: Phytoseiidae) was confirmed, and this was already described as new species for Ecuador, with a ventrianal divided shield different than the other three world species with similar type of shield (Ortega-Ojeda *et al.*, 2021).

The other unknown species, require consultations and additional studies to be conducted in a period longer than available for this research, so they are only expressed as possibly new species.

It is noticeable that eight possibly new species were found on wild plants, while five species were found on cultivated plants. Also, that about the same number of predaceous (six species) and phytophagous (eight species) species were considered in this work as possibly undescribed.

Table 7. Species and morphospecies of the most abundant Trombidiformes mites on wild and cultivated hosts in three regions of Ecuador, in the rainy season of 2018.

Family/Specie	Specimens				Plant				
	Cult.	Wild	Total	%	Cultivated		Wild		
					Family	Species	Family	Species	
Coast									
Eriophyidae	<i>Aculus</i> sp. 1	65		65	41.7	Caricaceae	<i>Carica papaya</i>		
Tydeidae	<i>Pseudolorryia nicaraguensis</i> Baker	14	1	15	9.6	Myrtaceae	<i>Psidium guajava</i>	Meliaceae	<i>Cedrela</i> sp.
Stigmaeidae	<i>Agistemus</i> sp. 2	13		13	8.3	Caricaceae	<i>Carica papaya</i>		
Tydeidae	<i>Perafrotydeus meyeriae</i> Baker	12		12	7.7	Lauraceae	<i>Persea americana</i>		
Total	N total: 156	104	1	105					
Highland									
Tetranychidae	<i>Tetranychus urticae</i> Koch	106		106	18.6	Fabaceae	<i>Phaseolus vulgaris</i>		
						Passifloraceae	<i>Passiflora tacsonia</i>		
Tydeidae	<i>Tydeus africanus</i> Baker			46	46	8.1		Adoxaceae	<i>Sambucus nigra</i>
								Malvaceae	<i>Hibiscus rosa-sinensis</i>
Tydeidae	<i>Tydeus nieuwkerkeni</i> André	24	20	44	7.7	Lauraceae	<i>Persea americana</i>	Onagraceae	<i>Oenothera tetragona</i>
						Rosaceae	<i>Prunus salicina</i>	Solanaceae	<i>Solanum nigrum</i>
						Verbenaceae	<i>Aloysia citriodora</i>		
Tydeidae	<i>Tydeus riopardensis</i> Silva, Cunha & Ferla	1	43	44	7.7	Fabaceae	<i>Phaseolus vulgaris</i>	Adoxaceae	<i>Sambucus nigra</i>
								Asteraceae	<i>Baccharis latifolia</i>
								Betulaceae	<i>Alnus jorullensis</i>
								Malvaceae	<i>Hibiscus rosa-sinensis</i>
								Solanaceae	<i>Solanum nigrum</i>
								Solanaceae	<i>Lochroma fuchsioides</i>
Total	N total: 569	133	177	310					
Amazon									
Tetranychidae	<i>Oligonychus letchworthi</i> Reeves		48	48	12.2			Sapindaceae	<i>Sapindus saponaria</i>
Tydeidae	<i>Lorryia evansi</i> Baker	1	33	34	8.6	Arecaceae	<i>Cocos nucifera</i>	Moraceae	<i>Ficus americana</i>
Tenuipalpidae	<i>Brevipalpus azores</i> Beard & Ochoa		27	27	6.8			Rubiaceae	<i>Rubus rosifolius</i>
								Solanaceae	<i>Brunfelsia grandiflora</i>
Tetranychidae	<i>Oligonychus propetes</i> Pritchard & Baker	24		24	6.1	Poaceae	<i>Saccharum officinarum</i>		
Total	N total: 395	34	141	175					

Table 8. Possibly new species by region and type of plant host in three regions of Ecuador, in the rainy season of 2018.

Order	Family	Specie	Region	Host Plant		
				Type	Family	Name
Mesostigmata						
	Blattisociidae					
		<i>Cheiroseius</i> pos. n.sp.	Highland	Wild	Bromeliaceae	<i>Guzmania</i> sp.
	Phytoseiidae					
		<i>Amblyseius</i> n.sp. 1	Highland	Wild	Acanthaceae	<i>Megaskepsma erythrochlamys</i>
		<i>Amblyseius</i> n.sp. 2	Highland	Cultivated	Rutaceae	<i>Citrus limon</i>
		<i>Galendromus</i> pos. n.sp.	Highland	Wild	Betulaceae	<i>Alnus jorullensis</i>
		<i>Iphiseiodes</i> pos. n.sp.	Coast	Wild	Solanaceae	<i>Acnistus arborescens</i>
		Pos. n. gen. n. sp.	Amazon	Wild	Caesalpinaceae	<i>Senna siamea</i>
Trombidiformes						
	Iolinidae					
		<i>Metapronematus</i> pos. n.sp. 1	Highland	Wild	Asteraceae	<i>Smallanthus sonchifolius</i>
			Highland	Wild	Solanaceae	<i>Solanum nigrum</i>
			highland	Wild	Verbenaceae	<i>Lantana camara</i>
		<i>Metapronematus</i> pos. n.sp.2	Highland	Wild	Onagraceae	<i>Oenothera tetragona</i>
	Tarsonemidae					
		<i>Hemitarsonemus</i> pos. n.sp. 1	Amazon	Wild	Cyclanthaceae	<i>Carludovica palmata</i>
		<i>Heterotarsonemus</i> pos. n.sp. 1	Coast	Cultivated	Passifloraceae	<i>Passiflora edulis</i>
	Tydeidae					
		<i>Krantzlorryia</i> pos. n.sp.	Amazon	Cultivated	Lauraceae	<i>Ocotea floribunda</i>
		<i>Melissotydeus</i> pos. n.sp.	Coast	Cultivated	Moraceae	<i>Morus</i> sp.
		<i>Orfareptydeus</i> pos. n.sp.	Amazon	Wild	Solanaceae	<i>Brunfelsia grandiflora</i>
		<i>Prelorryia</i> pos. n.sp.	Amazon	Cultivated	Rutaceae	<i>Citrus limon</i>

2.3.5. Ecological indices

2.3.5.1. Diversity indices of the Mesostigmata

Species richness (*alpha* diversity) of Mesostigmata was highest in the Amazon, followed by the Highland and last, the Coast (9.8, 7.0 and 3.5, respectively) (Table 9). The Margalef richness index was highest in the Amazon (9.8), also followed by the Highland (7.0) and the Coast (3.5).

Simpson's dominance index shows that there are no dominant species in any of the three regions (values near 0), indicating a high diversity for the three regions, with the lower index for the Coast (0.83) (Table 9).

The Shannon-Wiener diversity index shows the Amazonia and the Highland regions with highest and similar values (3.4 and 2.9, respectively) and the Coastal region with the lowest (2.1) (Table 9).

Table 9. Richness, dominance, and community equity uniformity of Mesostigmata mite diversity in three regions of Ecuador, in the rainy season of 2018.

Region	Morphospecies	N	Community structure		
			Richness	Dominance	Community equity uniformity
			Margalef Richness (D_{Mg})	Simpson Index (D)	Shannon-Wiener Index (H)
Coast	14	41	3.501	0.172	2.127
Highland	36	144	7.043	0.113	2.895
Amazon	53	202	9.796	0.053	3.403

The *beta* diversity, when comparing between the regions, shows that the percentage of common species to the regions is highest for the Coast and the Highland (16.0 %), lowest for the Amazon and the Highland (4.5 %) and the Amazon and the Coast (6.0 %), the last two like each other (Table 10).

Table 10. Proportion (%) of common morphospecies (Sørensen's coefficient) (*beta* diversity) of plant mesostigmatid mites in three regions of Ecuador, in the rainy season of 2018.

Region	Sørensen's similarity coefficient (%)
Amazon vs. Coast	6.0
Coast vs. Highland	16.0
Amazon vs. Highland	4.5

When calculating the *gamma* diversity for the three regions, with the Simpson index, it is determined that the *alpha* diversity, measured within each region, contributes with 99.99 % to the diversity of the morphospecies, while the *beta* diversity measured between the regions, contributes with 0.01 %. In this sense, the greatest diversity, as already mentioned, occurs in the Amazon, followed by the Highland and finally the Coast (53, 36, and 14 morphospecies, respectively).

In the Highland region, the highest number of morphospecies was found on wild hosts, confirmed by the Margalef index, showing the higher richness on the same plant type. There are no dominant species, as similar indices are presented in the two plant types and far from 1. On the other hand, the Shannon-Wiener equity index was similar for the two plant types, showing intermediate diversity, as suggested by values slightly lower than 2.0 (Table 11).

Table 11. Richness, dominance, and community equity uniformity of Mesostigmata mite diversity by host type in three regions of Ecuador, in the rainy season of 2018.

Host type	Morphospecies	N	Community structure		
			Richness		Community equity
			Margalef Richness (DMg)	Simpson Index (D)	Shannon-Wiener Index (H)
Coast					
Wild	10	20	3.004	0.240	1.868
Cultivated	8	21	2.299	0.243	1.723
Total		41			
Highland					
Wild	26	98	5.453	0.240	1.868
Cultivated	16	46	3.918	0.243	1.723
Total		144			
Amazon					
Wild	33	122	6.661	0.092	2.877
Cultivated	26	80	5.705	0.069	2.917
Total		202			

Finally, in the Amazon region, the largest number of morphospecies was found on wild plants, which coincides with what the Margalef richness index showed, i.e., a greater richness on this plant type. There are no dominant species, as the values are not close to 1 for any plant type. On the other hand, the equity indices were similar in both plant types, as the Shannon-Wiener diversity index was higher than 2.5 (Table 11).

The *beta* diversity, when comparing the two plant types, showed that the percentage of common species is higher for the Coast region, followed by the Highland and, finally, the Amazon (55.6 %, 28.6 % and 20.3 %, respectively) (Table 12).

Table 12. Proportion (%) of common morphospecies mites (Sorensen's coefficient) (*beta* diversity) of plant Mesostigmata mite diversity in two host types for three regions of Ecuador, in the rainy season of 2018.

Host type	Sørensen's Similarity coefficient (%)
Coast	
Cultivated vs. Wild	55.6
Highland	
Cultivated vs. Wild	28.6
Amazon	
Cultivated vs. Wild	20.3

2.3.5.2. Diversity indices in Trombidiformes

When calculating the *alpha* diversity index for foliar mites of the order Trombidiformes, greater diversity was found in the Amazon region, followed by the Highland and finally the Coast (10.9, 7.6 and 5.2, respectively).

Also, for this mite group, the Margalef index was highest in the Amazon (about 11.0). Dominant species were not observed (low Simpson indices). The Shannon-Wiener equity index showed high uniformity of species for the Amazon and Highland (values higher than 2.5) and intermediate for the Coast (2.3) (Table 13).

The *beta* diversity of the Trombidiformes were higher than observed for the Mesostigmata, when comparing the three regions. The percentage of common species is higher between the Coast and the Amazon (21.5 %), followed by the Coast vs. the Highland (18.7 %) and, finally, the Amazon vs. Highland (15.8 %) (Table 14).

Table 13. Richness, dominance, and community equity uniformity of Trombidiformes mite diversity in three regions of Ecuador, in the rainy season of 2018.

Region	Morphospecies	N	Richness		
			Margalef Richness (DMg)	Simpson Index (D)	Shannon-Wiener Index (H)
Coast	27	156	5.149	0.203	2.317
Highland	49	569	7.566	0.074	3.016
Amazon	66	395	10.870	0.047	3.486

Table 14. Proportion (%) of common morphospecies mites (Sørensen's coefficient) (*beta* diversity) of plant Trombidiformes mites in three regions of Ecuador, in the rainy season of 2018.

Region	Sørensen's similarity coefficient (%)
Coast vs. Highland	18.7
Amazon vs. Coast	21.5
Amazon vs. Highland	15.8

When calculating the *gamma* diversity for the three regions, by the Simpson index, it was determined that the *alpha* diversity of each region contributed with the 99.95 % to the diversity of the species and morphospecies, while the *beta* diversity between the regions contributed with 0.05 %. Likewise, the greatest diversity, as already mentioned, occurs in the

Amazon, followed by the Highland and, finally, the Coast (66, 49, and 27 between species and morphospecies per region, respectively).

When calculating the *alpha* diversity between the types of hosts (cultivated and wild), on the Coast the greatest number of morphospecies was found on cultivated plants. However, the Margalef index showed higher richness on the wild plants. There are no dominant species for the two plant types. On the other hand, the Shannon-Wiener diversity equity index presents intermediate values (close to 2.0) for the two plant types (Table 15).

As in the Coast, the largest number of morphospecies in the Highland region was found on cultivated plants. At the same time, the richness index of Margalef was similar on the two plant types, but there were no dominant species, as shown by the similar indices for both plant types. Finally, the Shannon-Wiener diversity equity index indicated high equity for both plant types, with a relatively high value (≥ 2.5) (Table 15).

Table 15. Richness, dominance, and community equity uniformity of Trombidiformes plant mite diversity by host type in three regions of Ecuador, in the rainy season of 2018.

Host type	Morphospecies	N	Community structure			
			Richness		Dominance	
			Margalef Richness (DMg)	Simpson Index (D)	Simpson Index (1-D)	Shannon-Wiener Index (H)
Coast						
Wild	13	19	4.075	0.097	0.903	2.452
Cultivated	19	137	3.659	0.256	0.744	1.987
Total		156				
Highland						
Wild	29	250	5.071	0.108	0.892	2.561
Cultivated	31	319	5.204	0.146	0.855	2.491
Total		569				
Amazon						
Wild	40	234	7.149	0.090	0.910	2.896
Cultivated	38	160	7.290	0.061	0.939	3.149
Total		394				

Finally, in the Amazon region there was a greater number of morphospecies on the wild plants, although the Margalef richness index showed similar richness for the two plant types. Again, no dominant species were found for any of the plant types and besides, as in the Highland region, the Shannon-Wiener diversity equity index indicated high equity for both plant types, with a relatively high value (≥ 2.5) (Table 15).

As to the *beta* diversity, when comparing between the plant types (cultivated and wild plants), higher percentage of common species was found in the Highland, followed by the Amazon and, finally, the Coast (36.7, 33.3 and 31.3 %, respectively) (Table 16).

Table 16. Proportion (%) of common morphospecies mites (Sørensen's coefficient) (*beta* diversity) of plant Trombidiformes mite diversity in two host type for three regions of Ecuador, in the rainy season of 2018.

Host type	Sørensen's similarity coefficient (%)
	Coast
Cultivated vs. Wild	31.3
	Higland
Cultivated vs. Wild	36.7
	Amazon
Cultivated vs. Wild	33.3

2.4. Discussion

2.4.1. Host plants with mites

Despite a careful search for farms and environments without or with minimum biocide selection pressure, almost twice as many plant species bearing mites were wild as compared to cultivated plants. This was expected, given that farmers always cause some type of environmental disturbance, as revolving the soil, pruning or harvesting are always done. This usually implies in that in the natural environments mite population grow and establish, turning them easier to be found, as determined in similar studies on plant mites by researchers as Demite (2010) and Sheeja *et al.* (2021), or Mirzaei-Pashami *et al.* (2020) in soil mite abundance studies. In these studies, the highest values of the Shannon-Wiener diversity indices were observed in the irrigated no-tillage system, in other words, in non-intervened environments. These results demonstrated that anthropogenic interventions produce significant changes in biodiversity, being mites the most prominent terrestrial arthropods which are very sensitive, overall, to tillage operations.

Conversely, perhaps because of the good environmental conditions, other studies have shown similar presence of mite diversity on plants, both, with and without anthropogenic intervention. For example, Araújo & Daud (2018) found no differences in species richness of mites and host plants between phytophagous and predatory mites in their networks. Besides, these results could be explained because of the natural vegetation remnants play an important role in the biological control of agroecosystems, when some beneficial mites

might migrate from native plants to cultivated plants; in same way, within environmental conditions with low or without anthropogenic intervention, it would be easy to migrate from wild to cultivated plant hosts, as mentioned by Araújo & Daud (2018), Demite *et al.* (2013), Rocha *et al.* (2015) and Tixier (2018).

As known from the beginning, because of the different botanical composition in each sampling point, it was not possible to compare mite diversity between plant families in each region. For this reason, it was decided to look for farms where at least five different types of crops were grown, with enough number of plants to be sampled, and where the use of biocides was minimum.

The results of this study demonstrated once again that plant inhabiting mites probably constitute one of the most diverse groups of Arachnida, as suggested by Pallini *et al.* (2007), Krantz *et al.* (2009) and Moraes & Flechtmann (2008) among other authors.

2.4.2. Mites identified

Among the mites identified in this study, both in number of families and in number of specimens, the Trombidiformes dominated; these were mainly phytophagous, except for a few polyphagous species, most of which inhabiting specific host plants (Fenton *et al.*, 2001; Hountondji *et al.*, 2002; Keifer *et al.*, 1982; Moraes *et al.*, 2005; Moraes & Flechtmann, 2008; Neto *et al.*, 2014; Silva *et al.*, 1992; Skoracka *et al.*, 2010; Zacarias & Moraes, 2002), it allows to infer that it was a success not to propose the present survey by a certain botanical families, but rather looking for sampling units with high botanical diversity, under no or minimal selection pressure with synthetic biocides, experimental approach that would have allowed such a high diversity to be found.

On the other hand, the lower number, both of families and of identified specimens, belonging to the mesostigmatids, is explained because they do not depend on specific hosts, but on prey, often regardless of where they are found; therefore, in their behavior they ascend and descend continuously, passing from one plant to another, helped by their long legs and rapid movement, in search of their food, composed mainly of phytophagous mites (all their stages) and even other arthropods (egg and immature stages), complementing this food with pollen and plant exudates, also from various crops (Castilho *et al.*, 2015; Castro & Moraes, 2007; Krantz *et al.*, 2009; McMurtry *et al.*, 2013, 2015; Moraes *et al.*, 2013, 2015; Moraes & Flechtmann, 2008; Neto *et al.*, 2014; Oliveira & Moraes, 1990; Yaninek & Moraes,

1991). That is why they would not need to be more numerous or diverse than the phytophagous.

2.4.2.1. Mesostigmata

Although the Mesostigmata are considered about the 20 % of all known mite species (Beaulieu *et al.*, 2011; Zhang, 2013), in this study the proportion of these mites was considerably higher (32.83 %).

In this study, the phytoseiids stood out because of their importance as natural enemies of foliar pests, especially phytophagous mites, and insects as coccids, whiteflies and thrips (Castilho *et al.*, 2015; Messelink *et al.*, 2008). But in addition to that, other mesostigmatids are important for the artificial biological control of the same pest groups, because of their predatory behavior (Moraes *et al.*, 2015). The importance of those mites is progressively expanding, given the interest of consumers for the consumption of healthy products, obtained with minimum or no use of synthetic biocides. In this study, although in lower proportions, mites of other families were also found, and some of these may also behave as predators of small arthropods that could behave as pests.

2.4.2.2. Trombidiformes

The higher abundance of these mites in the Coastal than the Highland and the Amazon, could be explained by their principal feeding behavior as phytophagous, therefore as the Coast is the Ecuadorian region with the largest cultivated area (Márquez, 2021) with large extensions of monoculture it makes sense that they were found also in larger abundance in the Coast.

In addition, the higher average temperature and lower average humidity levels in the Coast than the Highland (with a semi-humid to humid temperate climate in the inter-Andean zone, hot and dry in the inter-Andean valleys) and Amazon (with humid tropical climate) (Varela & Ron, 2021) would be expected to favor the presence of foliar trombidiform mites, as occurred in this study, according to reported for *T. urticae* abundance at several seasons by Esmaeel *et al.* (2018).

2.4.3. Mites by region and type of plant host

In this research, carried out next to the Pacific Ocean, the number of phytophagous mites was higher than the number of predators (741 Mesostigmata vs. 1,109 Trombidiformes). This pattern is the opposite of what was reported by Castro & Moraes (2007) in Brazil, a country closer to the Atlantic Ocean, where mite number was also high (1,562 specimens) but the Phytoseiidae represented 71 % of the specimens collected, while the phytophagous mites corresponded to 836 specimens, most of which (64 %) represented by the Tetranychidae.

Also the present study and the study conducted by Castro & Moraes (2007) differ from other studies, in which the number of predatory mites was about the same as the number of phytophagous mites (Araújo & Daud, 2018).

In this study, most Mesostigmata belonged to the Phytoseiidae (82,6 %) and in the Trombidiformes, most mites belonged to Tetranychidae (31,8 %), followed closely by the Tydeidae (29,8 %), families that were also the predominant in the study of Castro & Moraes (2007).

Because of the mesostigmatids are known as predators of the phytophagous mites and other microarthropods (Castilho *et al.*, 2015), their presence is expected where their prey are present, that is, in areas where agricultural activities are intense and where plants are mostly grown as monocultures, as it happens on the Coast, the region with the largest areas under cultivation, except for the natural pastures, most extensive in the Highland (Márquez, 2021).

In turn, in less disturbed areas, where the wild plants are most abundant, phytophagous mites are expected to be less abundant by the natural biological natural balance, which also reflects in lower populations of predatory mites. Thus, agricultural areas in more conserved environments (as the Amazon region in this study) could be less attacked by phytophagous mites, probably because of the controlling effect of the predators moving from wild to neighboring cultivated plants, what could explain lower occurrence of Trombidiformes on cultivated than on wild plants in this region.

2.4.4. New species and new reports of mites

As usually expected in the field of biodiversity (e.g. in Legesse *et al.*, 2002), there were higher mite diversity on wild (characteristically containing a rich variety of organisms)

than on cultivated host plants (host/environment disturbed), and the most diverse mite fauna were found within the trombidiforms, because the wild plants are often not disturbed by farmers, so that a natural numerical equilibrium is maintained on these plants, leading to higher levels of biodiversity.

The determination of lower numbers of predatory than of phytophagous mites seems compatible with the contention of Castilho *et al.* (2015), that several mesostigmatid groups have been little studied, especially for not being abundant.

In this research are reported two mite genera (*Gamasiphis* and *Graminaseius*) recently reported by Melo-Molina (2022) for Ecuador, but in soil substrate. And, as mentioned before, a new species of *Amblyseius* was found and described in the present work (see next chapter).

The conclusion about the occurrence of other possible new species will require a time not available in the present work. Thus, subsequent studies should be conducted to allow the collection of additional specimens, to confirm that some of the species collected in this study are new, and to prepare their descriptions for publication.

2.4.5. Ecological indices

The analyses of species richness (*alpha* diversity) for the Mesostigmata, indicated that the more anthropized region of the North Ecuador is the Coast, because the index value is close to 2.

On the other extreme, the less anthropized region is the Amazon, demonstrated by a very high diversity, reflecting the fact that the northern region of the Amazon has gone through little or no human intervention, which corroborates the findings of Montero-Saiz (2011), who indicates that this region constitutes an ecosystem with high mite richness.

Finally, in the Highland mite diversity is twice as high as in the Coast, demonstrating that despite the extensive urbanization, the impossibility of cultivating in extensive areas due to the "broken" terrain allows a greater diversity of crops than on the coast, so relatively high mite diversity is maintained in the Highland.

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3. A NEW *Amblyseius* BERLESE (MESOSTIGMATA: PHYTOSEIIDAE) SPECIES FROM ECUADOR, WITH A KEY TO THE *perditus* SUBGROUP OF THE *largoensis* SPECIES GROUP*

Abstract

Amblyseius n. sp. is described based on specimens collected in a subtropical highland environment in northern Ecuador, on *Musa paradisiaca* (Musaceae) and *Megaskepasma erythrochlamys* (Acanthaceae). A key for the identification of the species of the *perditus* subgroup of the *largoensis* group, to which this new species belongs, is presented.

Keywords: Taxonomy; *largoensis*; *perditus*; Mite diversity; Morphology.

3.1. Introduction

Phytoseiidae is the most important family of predatory mites used for applied biological control of pest arthropods (Knapp, 2018). In Ecuador, the phytoseiid species *Neoseiulus californicus* (McGregor 1954), *Phytoseiulus persimilis* (Athias-Henriot 1957), *Amblyseius swirskii* (Athias-Henriot 1962) and *Amblydromalus limonicus* (Garman & McGregor 1956) have been used for the control of *Tetranychus urticae* Koch (Colcha Rovalino 2013; Hidalgo Astudillo 2015; Koppert Biological Systems 2021). Until now, 57 phytoseiid species have been reported from Ecuador, 25 of which from continental Ecuador and 33 from Galapagos, one occurring in both places (Demite *et al.* 2016; Moraes *et al.* 2004).

Amblyseius Berlese is the second largest genus in the family (Demite *et al.* 2014, 2021; Moraes *et al.* 2004), with 414 valid species, of which nine are known from continental Ecuador and eight from Galapagos, as summarized by Schatz (1991) and Demite *et al.* (2020). Most of these have been reported by Schuster (1966), Moraes *et al.* (1991) and Karg (1993, 1994, 1998, 2003, 2006). *Amblyseius* was divided into five species groups by Chant & McMurtry (2004). The *largoensis* group is distinguished by having setae *J2* and *Z1* present, *z4* short/minute, and ventrianal shield vase-shaped or divided into separated ventral and anal plates, wider at level of anus than at level of *Zv2*. This group was divided into five subgroups, one of which was *perditus*, distinguished by having setae *s4*, *Z4* and *Z5* elongate, ventral and

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anal shields separated and calyx of spermatheca tubular and elongate (Chant & McMurtry 2004).

Three species of the *perditus* subgroup have been reported from Central and South America, so far none from Ecuador (Demite *et al.*, 2021). Since 2018, we have dedicated some effort to collect and identify the phytoseiid species from wild and cultivated plants from this country, envisioning their possible use in applied biological control. The objective of this paper is to describe a new *Amblyseius* species collected in surveys conducted in northern Ecuador, providing a key to separate the species of the *perditus* subgroup, to which it belongs.

3.2. Materials and Methods

Leaf samples were examined in the field and the phytoseiid mites were collected in 70 % ethanol. In the laboratory, they were mounted in Hoyer's medium (Palacios-Vargas & Mejía-Recamier 2007) and later examined under a phase contrast Zeiss (Axioskop) microscope for species identification, measuring structures of taxonomic interest with a graded eyepiece. Identification to genus was done based on Chant & McMurtry (2007), followed by identification to species group and subgroup based on Chant & McMurtry (2004), and to species based on comparisons with the original descriptions and redescriptions of each species of the subgroup. Upon the determination that one of the species collected was new to science, it was described based on the morphology of the adult female, given that adult males and immatures were not found. Setal nomenclature follows that of Lindquist & Evans (1965) as adapted by Rowell *et al.* (1978) for the dorsal setae, Chant & Yoshida-Shaul (1991) for the ventral setae, and Aponte & McMurtry (1987) for leg macrosetae. Measurements of structures are given in micrometers and presented as the respective mean followed by the range of all specimens measured, in parenthesis. Taxonomically important structures were illustrated with the help of a digital camera connected to an interference contrast microscope. Photos were processed with a digital tablet using Adobe Illustrator®.

3.3. Results

***Amblyseius* n. sp.**

Adult female (five females measured) (Figures 1-5).

Chelicera (Figure 1). Fixed digit 32 (31–34), with 12 teeth in addition to the apical tooth and the *pilus dentilis*; movable digit 33 (29–36) long, with three teeth in addition to the apical tooth.

Dorsum (Figure 2). Idiosomal setal pattern: 10A:9A/JV3-ZV (Chant & Yoshida-Shaul 1992). Single dorsal shield smooth, with nine pairs of lyrifissures and nine pairs of pores, 357 (351–369) long, 220 (187–234) wide (at level of s4). Measurement of setae: j1 32 (29–36), j3 47, j4 3 (3–5), j5 3 (3–4), j6 4 (4–5), J2 6 (5–8), J5 5, z2 5, z4 5, z5 3 (3–5), Z1 5, Z4 70 (65–73), Z5 133 (125–143), s4 76 (73–81), S2 9 (8–10), S4 7 (5–8), S5 6 (5–8), r3 16 (16–18), R1 5 (5–6). All setae aciculate and smooth, except Z5 long, thick, and serrate; setae r3 and R1 inserted on unsclerotized cuticle.

Peritreme (Figure 2). Extending to level of setae j1.

Venter (Figure 3). Sternal shield smooth with three pairs of setae (*st1* to *st3*) and two pairs of lyrifissures; distances between *st1–st3* 66 (65–68), *st2–st2* 69 (57–73); posterior margin truncate. Seta *st4* and lyrifissure *iv3* on metasternal platelet. Genital shield smooth, posteriorly truncate but with rounded posterolateral angles; distance between *st5–st5* 78 (73–81). Ventral and anal shields separate and smooth; ventral shield about hexagonal, 63 (60–68) long and 84 (81–86) wide (at level of *Zv2*), with three pairs of setae (*Jv1*, *Jv2* and *Zv2*); anal shield 59 (57–65) long and 75 (73–78) wide (at widest level), with circumanal setae. With a sclerotized line between genital and ventral shields. Two pairs of metapodal platelets. Four pairs of opisthogastric setae on unsclerotized cuticle. Measurement of setae: *Jv1* 33 (30–35), *Jv2* 24 (23–26), *Jv4* 14 (12–15), *Jv5* 33 (30–37), *Zv1* 28 (27–35), *Zv2* 20 (18–23), *Zv3* 12 (11–14). All ventral setae aciculate and smooth.

Spermatheca (Figure 4). Cervix tubular, about straight, 23 (21–39) long; slightly constricted near the conspicuous, globular atrium.

Legs (Figure 5). Macrosetae present on all legs: SgeI 49 (47–49), SgeII 44 (42–47), SgeIII 47 (47–49), StilI 38 (34–42), SgeIV 73 (67–81), StilIV 64 (62–65), and StIV 73 (70–75). All macrosetae aciculate and smooth. Chaetotaxy of genu II 2-2/0,2/0-1; genu III 1-1/1,2/1-1.

Male. Unknown.

Type material. Holotype female from Granja Integral Ecológica Morpho (GIEM) (0°04'50.9 S 78°44'46.2 W; 1547 m above sea level), Mindo, Pichincha Province, on *Musa paradisiaca* L. (Musaceae), February 10, 2018, deposited at Instituto Nacional de Biodiversidad del Ecuador (INABIO). One paratype female from GIEM (0°04'47.2 S 78°44'57.8

W; 1538 m), on *Megaskepassa erythrochlamys* L. (Acanthaceae), February 10, 2018, and one paratype female from GIEM (0°04'50.9 S 78°44'46.2 W; 1547 m), on *M. paradisiaca*, February 10, 2018. The two paratypes deposited at Laboratorio de Entomología y Acarología, de la Universidad Central del Ecuador (LEA-UCE). Two paratype females from GIEM (0°04'47.2 S 78°44'57.8 W; 1538 m), on *M. erythrochlamys*, February 10, 2018, deposited at Departamento de Entomologia e Acarologia da Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo (ESALQ-USP), Piracicaba, Brazil. All specimens collected by C.A. Ortega-Ojeda.

Etymology This species is named in honor of Yumbos aboriginal people that occupied the mountain territory of western Pichincha Province, where the type specimens were collected.

Remarks. This new species is morphologically most similar to *Amblyseius perditus* (Chant & Baker 1965). In addition to the common characteristics of this subgroup (spermathecal calyx tubular; ventral and anal shields separate), they have similar spermathecae (about straight). However, they differ by the shape of Z5 (smooth in *A. perditus*), the shape and extent of the ventral shield (ellipsoid and smaller, not reaching the preanal pores in *A. perditus*) and the characteristic of the atrium (inconspicuous in *A. perditus*). Comparisons between the new species here described and other species of the *perditus* subgroup are presented in the key subsequently provided.

In one paratype, *Jv2* is abnormally much closer to *Zv2* of one side than shown in the illustration (Figs. 3 and 3a), and the metasternal platelet and the respective *st4* are absent.

Key for species of the *perditus* subgroup of the *largoensis* species group (based on females only)

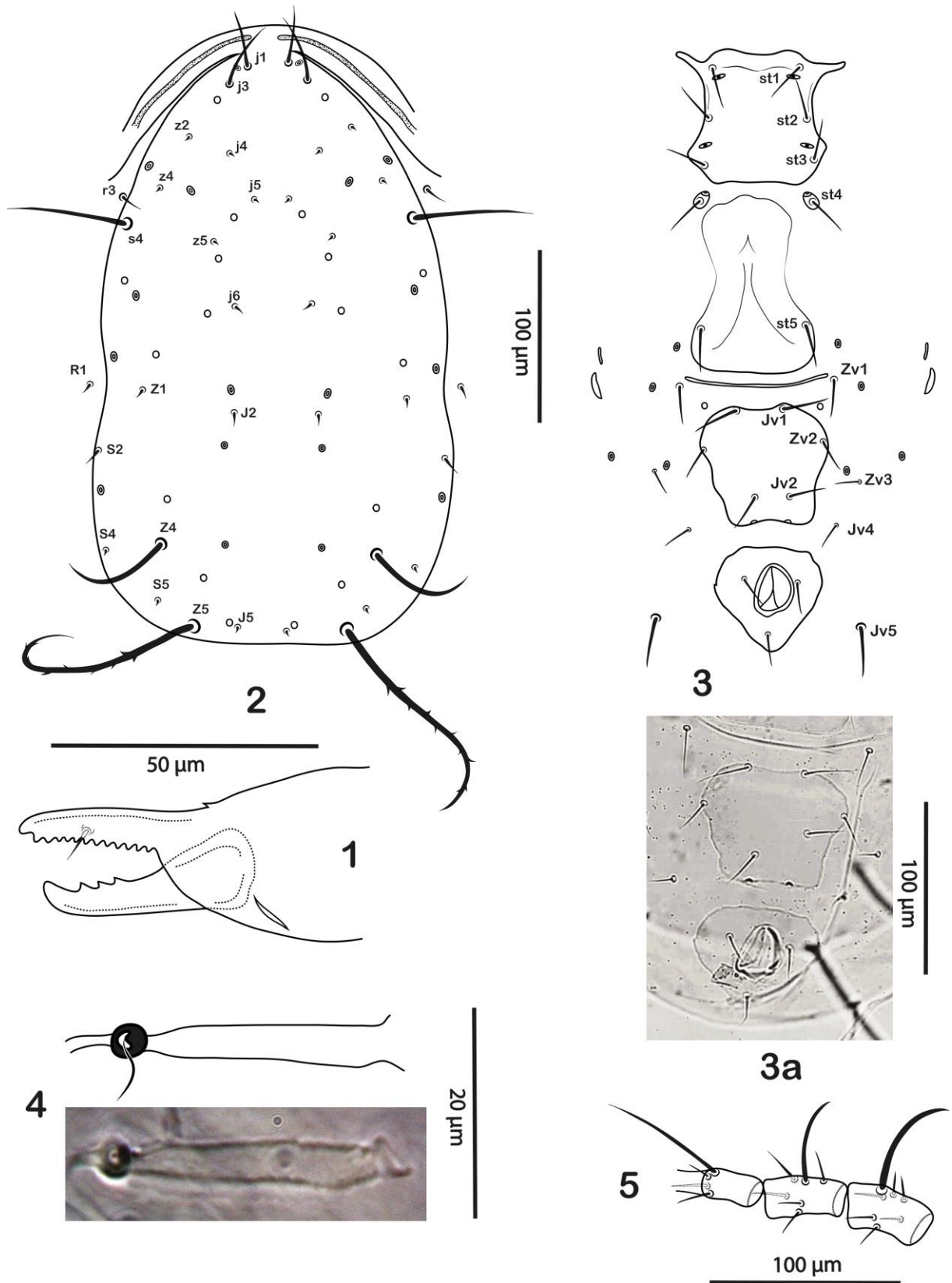
1. Calyx of spermatheca sinuous, flaring toward vesicle, at least 15 times longer than diameter at mid length..... **A.**
segregans
- 1'. Calyx of spermatheca straight and of about uniform diameter (or slightly constricted near atrium), less than 10 times longer than diameter at mid length..... **2**

2. Ventral shield relatively long, reaching well behind insertion of *Jv2*, incorporating preanal pores.....
A. n. sp.
- 2'. Ventral shield relatively short, ending immediately behind insertion of *Jv2*, well anterior of preanal pores..... **3**
3. Setae *Z4* and *Z5* smooth, the latter about three times as long as the former **A. perditus**
- 3'. Setae *Z4* and *Z5* serrate, the latter about 1.6 times as long as the former **A. neoperditus**

3.4. Discussion

Nine species of *Amblyseius* Berlese are known from continental Ecuador and eight from Galapagos, as summarized by Schatz (1991) and Demite *et al.* (2020), most of them reported by Schuster (1966), Moraes *et al.* (1991) and Karg (1993, 1994, 1998, 2003, 2006); but none of them had a divided ventral and anal shield.

Just three species of the *perditus* subgroup with separated ventral and anal shield have been reported from Central and South America, and as said before, so far none from Ecuador (Demitte *et al.*, 2021), being the proposed new species the fourth one. This work represents a great opportunity for increase the knowledge of Ecuadorian mite diversity with predation potential for phytophagous mite control for future studies, based on that these specimens were collected on the cultivated crop *Musa paradisiaca* and at the same time in the wild plant *Megaskepasma erythrochlamys* L. (Acanthaceae).



Figures 1-5. *Amblyseius* n. sp. Female: 1. Chelicera; 2. Dorsal shield; 3. Ventral idiosoma; 3a. One paratype seta *Jv2* variation; 4. Spermatheca; 5. Genu, tibia, basitarsus of leg IV. Lyrifissures and pores enlarged for improved visibility.

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4. FINAL REMARKS

As result of the work here reported, 2,257 adult mites were identified to species and morphospecies in the three regions where they were collected in northern Ecuador. The Amazon region accounted for the highest number, followed by the Andean Highland and the Coast. In the Highland, higher mite abundance was found on wild than on cultivated plants; conversely, mite abundance was higher on cultivated than on wild plants in the Amazon and the Coast.

Within the identified orders, the Trombidiformes were the most numerous, followed by the Mesostigmata and the Sarcoptiformes.

The mites identified belonged to 19 families (Oribatida and Uropodina not identified to families because they were not of interest in this research), seven of which belonged to Mesostigmata (within the cohort Gamasina: Ameroseiidae, Ascidae, Blattisociidae, Laelapidae, Melicharidae, Ologamasidae and Phytoseiidae) and contained 675 specimens.

Likewise, mites of the order Trombidiformes belonged to 12 families (Bdellidae, Cunaxidae, Diptilopiopidae, Eriophyidae, Iolinidae, Linotetranidae, Smaridiidae, Stigmaeidae, Tarsonemidae, Tenuipalpidae, Tetranychidae and Tydeidae).

Considering all regions together, mites were found on cultivated plants of 18 families, namely Annonaceae, Araceae, Arecaceae, Asteraceae, Caricaceae, Cucurbitaceae, Fabaceae, Lauraceae, Malvaceae, Musaceae, Myrtaceae, Passifloraceae, Poaceae, Rosaceae, Rubiaceae, Rutaceae, Solanaceae and Verbenaceae. Mites were also found on wild plants of the following 35 families: Acanthaceae, Adoxaceae, Amaranthaceae, Araceae, Asteraceae, Betulaceae, Bignoniaceae, Borriginaceae, Bromeliaceae, Caesalpinaceae, Campanulaceae, Cecropiaceae, Convolvulaceae, Cyclanthaceae, Euphorbiaceae, Fabaceae, Geraniaceae, Heliconiaceae, Lamiaceae, Malvaceae, Melastomataceae, Meliaceae, Moraceae, Muntingiaceae, Onagraceae, Piperaceae, Poaceae, Rosaceae, Rubiaceae, Sapindaceae, Solanaceae, Urticaceae, Verbenaceae and Zingiberaceae.

Although in previous studies the Mesostigmata were usually considered to account for about 20 % of mite species collected, in this study the proportion of these mites was considerably higher (32.83 %), while the Trombidiformes was, as usual, found in greater proportion of species/ morphospecies.

The Trombidiformes were found in higher abundance in the Coastal than the Highland and the Amazon regions, which seems to be expected, given that their principal feeding

behavior is phytophagy and that the largest cultivated areas in the Coastal Region in Ecuador.

Based on the analyses of species richness for the Mesostigmata, the results suggested that the Coast is the most anthropized and the Amazon to be the least anthropized regions in northern Ecuador, suggested by their very high diversity. Even the second highest mite diversity of the Highland is twice as high as in the Coast, despite the extensive urbanization. That allows us to infer that the greater anthropic activity would have influenced the biodiversity of each region.

Also, for the Mesostigmata, dominant species were not observed, and complementary equity index shows high uniformity of species for the Amazon and Highland and intermediate for the Coast.

In addition, when considering the Trombidiformes, in the Coast and in the Highland, the greatest number of morphospecies was found on cultivated plants; however, the higher richness was found on the wild plants in the Coast and was similar on both type of plants in the Highland. On contrary, in the Amazon region there was a greater number of morphospecies on wild plants, but with similar richness for the two plant types. No dominant species were found for any of the plant types in the three regions.

As an example of the new diversity found and the possible new species that need to be corroborated and reported, the new species *Amblyseius* n. sp. is described based on specimens collected in a subtropical highland environment in northern Ecuador, on *Musa paradisiaca* (Musaceae) and *Megaskepsma erythrochlamys* (Acanthaceae). Additionally, a key for the identification of the species of the *perditus* subgroup of the *largoensis* group, to which this new species belongs, is presented.