

**OCCURRENCE OF FEATHERWING BEETLES (COLEOPTERA:
PTILIIDAE) ON POLYPORE FUNGI (BASIDIOMYCOTA:
AGARICOMYCETES) FROM COSTA RICA AND A NEW SPECIES OF
*CYLINDROSELLA***

by

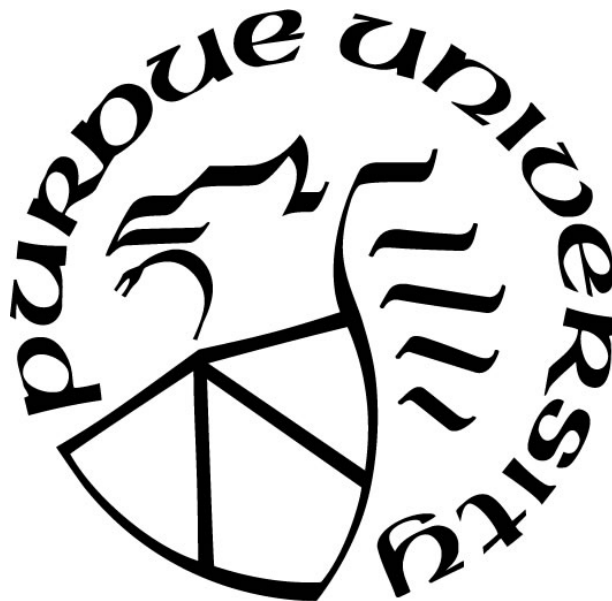
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I would like to dedicate this thesis to my husband and daughter, Michael and Rachael Topolski, for their unending support and encouragement to accomplish my dreams, to my mother, Virginia Higgins, who taught me to learn something new every day, and to my grandpa, Fred Matthews, who always encouraged me to explore things I loved and never said “girls can’t do that.” I also want to recognize so many of the amazing teachers and mentors I have had throughout my education, especially Mr. Charles Bowman, Dr. Bob Brodman, Dr. Jason Curtis, Dr. Chris Holford, and Dr. Christian Oseto.

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TABLE OF CONTENTS

LIST OF TABLES.....	7
LIST OF FIGURES	8
ABSTRACT.....	10
CHAPTER 1. LITERATURE REVIEW	11
1.1 Introduction.....	11
1.2 Ptiliidae morphology.....	13
1.3 Polypore fungi structure as a domicile for Ptiliidae.....	15
1.4 Host fungi preference.....	16
1.5 Polypore fungi taxonomy.....	16
1.6 Identifying characteristics of polypore fungi.....	17
CHAPTER 2. OCCURRENCE OF FEATHERWING BEETLES ON POLYPORE FUNGI FROM COSTA RICA AND DESCRIBING A NEW SPECIES OF PTILIIDAE IN THE GENUS CYLINDROSELLA	21
2.1 Abstract.....	21
2.2 Introduction.....	21
2.3 Materials and Methods.....	23
2.4 Results.....	24
2.5 Discussion	37
2.5.1 Co-occurrence.....	38
2.5.2 Fungal Host Specificity	39
2.5.3 Future Research Questions	41
2.6 Taxonomy: A New Species of <i>Cylindrosella</i> Barber (Coleoptera: Ptiliidae) From Polypore Fungus (Basidiomycetes: Polyporaceae) in Costa Rica.....	41
2.6.1 Introduction.....	41
2.6.2 Materials and Methods	42
2.6.3 Results.....	43
2.6.3.1 Type Locality	43
2.6.3.2 Type Material.....	43
2.6.3.3 Other Materials Examined	43

2.6.3.4	Etymology	44
2.6.3.5	Diagnosis.....	44
2.6.3.6	Description of Holotype, Female	44
2.6.3.7	Discussion	46
REFERENCES	56

LIST OF TABLES

Table 1.1. Family and genera of fungi containing Ptiliidae (Coleoptera) including spore types associated with polypore fungi collected in Costa Rica, 2007-2009. Spore types: s, single thin wall; t, thick single wall; d, double wall with inner wall ornamented.	18
Table 2.1. Occurrence of polypore fungi and genera of Ptiliidae. Costa Rica, 2007-2009. The occurrence table shows in which polypore a genus of Ptiliidae occurred in and the number of samples of each polypore fungus that was identified containing the beetle.	25
Table 2.2. Number of polypore fungi taxa containing each ptiliid or ptiliid group. Costa Rica. 2007-2009. Note: Taxon of polypore can represent genus or family, if family was most precise identification.	26
Table 2.3. Occurrence of single and co-occurring genera of Ptiliidae (Coleoptera) on polypore hosts collected in Costa Rica. 2007-2009. The number of samples of each fungus in which ptiliid beetle was found. Beetles are listed as either being found as the only occupant of the fungal sample or as co-occurring with other ptiliid genera.	27

LIST OF FIGURES

Figure 1.1. Higher system of fungal classification. Figure shows the classification system of higher levels of fungi taxa (Bauer <i>et al.</i> 2006, Hibbett <i>et al.</i> 2007, Mata 2003, Blackwell and Spatafora 2004).	17
Figure 2.1. Distribution of fungal samples collected in Costa Rica, 2007-2009.	24
Figure 2.2. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus <i>Acrotrichis</i> (Coleoptera: Ptiliidae). Costa Rica. 2007-2008.	29
Figure 2.3. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus <i>Cylindrosella</i> (Coleoptera: Ptiliidae). Costa Rica. 2007-2008.	30
Figure 2.4. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus <i>Nanosella</i> (Coleoptera: Ptiliidae). Costa Rica. 2007-2009.	31
Figure 2.5. Collection site of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus <i>Nephanes</i> (Coleoptera: Ptiliidae). Costa Rica. 2009.	32
Figure 2.6. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus <i>Nossidium</i> (Coleoptera: Ptiliidae). Costa Rica. 2008.	33
Figure 2.7. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus <i>Ptilium</i> (Coleoptera: Ptiliidae). Costa Rica. 2009.	34
Figure 2.8. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus <i>Throscoptilium</i> (Coleoptera: Ptiliidae). Costa Rica. 2007.	35
Figure 2.9. Collection site of polypore fungi (Basidiomycota: Agaricomycetes), which yielded an undescribed Ptiliidae (Coleoptera). Costa Rica. 2007.	36
Figure 2.10. Collection site of polypore fungi (Basidiomycota: Agaricomycetes), which yielded a second undescribed Ptiliidae (Coleoptera). Costa Rica. 2008.	37
Figure 2.11. <i>Cylindrosella costaricensis</i> , whole body without legs. Female. 40x, scale in mm. a) Dorsal view. b) Ventral view.	48
Figure 2.12. <i>Cylindrosella costaricensis</i> , prothoracic, mesothoracic, and metathoracic legs. Female. Oil, scale in mm, ventral view. a) Prothoracic leg, right. b) Mesothoracic leg, right, c) Metathoracic leg, right, d) Prothoracic tarsi, left, e) Mesothoracic tarsi, left, f) Metathoracic tarsi, left. emp, empodium with tarsal seta.	49
Figure 2.13. <i>Cylindrosella costaricensis</i> , head and antenna, ventral view. Oil, scale in mm. a) Head morphology. b) Antenna, left. dsen, digitiform sensilla; ta, tentorial arms.	50
Figure 2.14. <i>Cylindrosella costaricensis</i> , mouthparts and spores. Oil, scale in mm. a) Labrum, dorsal view. b) Labium and maxilla, ventral view. c) Maxilla, ventral view. d) Mandible, right, ventral view. e) spores, found in gut content of <i>Cylindrosella costaricensis</i> . bmax, base maxilla; card, cardo; dgsens, digitiform sensilla; gal, galea; guspr, gustatory pore; labi, labium; laci, lacinia; lbpalp, labial palp; mandsp, mandibular spine; max, maxilla; ment, mentum; mol, mola; mxpalp,	

maxillary palp; pment, prementum; sbment, submentum fused with head capsule; scp, antennal scape; segments I, II, III, and IV of maxillary palpus; stip, stipes..... 51

Figure 2.15. *Cylindrosella costaricensis*, mesothoracic and metathoracic wings. Scale in mm. a) Mesothoracic wing, left elytra, ventral view, oil. b) Elytral apex, right wing, ventral view, oil. Fine setae typical of Nanosellini. c) Metathoracic wing. 40x. Left featherwing, single wing strut, wing membrane long and narrow, setal formula 3 + (6-7) + (23-25). apict, apical subgroup of trichia; apt, anteroproximal subgroup of trichia; asf, apical setal field; ppt, posteroproximal subgroup of trichia; strf, stridulatory file..... 52

Figure 2.16. *Cylindrosella costaricensis*, oil, scale in mm. a) Mesoscutellum, dorsal view. b) Metendoventrite, ventral view. c) Metascutellum, with texture sampled in small area, dorsal view. d) Spermatheca, globular with anterior pump. ivcon, intermetacoxal condyle; mvr, ventral ridge of metanotum; pat, posteroapical tip; ssmg, scutoscuteellar median groove..... 53

Figure 2.17. *Cylindrosella costaricensis*, abdominal tergites, composite drawing. Oil, scale in mm. a) Abdominal segments, abdominal tergite VII has wingfolding fringe along posterior margin. b) magnification of abdominal segments II and III. pyg, pygidium; spir, spiracle; spset, spiracular seta, strig, strigula; wfm, wing folding mechanism..... 54

Figure 2.18. *Cylindrosella costaricensis*, ventral view, composite, oil, scale in mm. a) Proventrum. b) Mesoventrum. c) Metaventrum. d) Abdominal ventrites. coll, mesoventral collar; mesproc, mesoventral process; mslin, mesoventral line; msps, mesopleural suture; mtendo, metendoventrite; mtlin, metaventral line; mtsut, metaventral suture; myc, mycangium; pmarg, posterior margin. 55

ABSTRACT

Despite being distributed worldwide and easily collected, the biology, ecology, and taxonomy of Ptiliidae Heer, 1843, or featherwing beetles, have not been well studied. In a study from 2007 to 2009, Ptiliidae were extracted from various polypore fungi collected throughout Costa Rica in an effort to expand biogeographic knowledge of Ptiliidae. Fungi and Ptiliidae were identified to genera and collection sites mapped. Beetle genera are able to inhabit different polypore genera and were found at a higher rate of co-occurrence than reported in previous studies. We identified *Cylindrosella costaricensis* **sp. n.**, with the potential of two more new species to be described.

Keywords: Ptiliidae, polypore fungi, Costa Rica, *Cylindrosella*, Nanosellini, new species, taxonomy, featherwing beetles, neotropics, Staphylinoidea

CHAPTER 1. LITERATURE REVIEW

1.1 Introduction

This study was conducted to determine ptiliid associated with polypores in selected sites in Costa Rica. The tribe Nanosellini is described as unique in their association with Polyporaceae (Agaricomycetes: Polyporales). Beyond Hall's (1999) generic revision of the Nanosellini, few studies have reported the specific association of Nanosellini with Polyporaceae within a defined geographic region. Such fungus-insect interaction studies can contribute to expanding biogeographical knowledge of Ptiliidae Heer, 1848 (Polilov *et al.* 2019).

Despite being distributed worldwide and easily collected, the biology, ecology, and taxonomy of Ptiliidae Heer, 1843, or featherwing beetles, have not been well studied (Matthews 1872, Barber 1924, Hall 2007). Only a modest number of entomologists have debated about and published taxonomic studies of Ptiliidae, previously known as Trichopterygidae Erichson, 1845, in the past 180 years.

In writing his early history of Trichopterygia, Matthews (1872) expressed disappointment in the synonymy that was causing confusion among researchers, and he made great effort to trace back each re-named species to its original name. He cited Colonel Victor von Motschulsky as having contributed more at that time to the study of Trichopterygia than all other researchers combined. Matthews made note in his 1872 monograph that only 139 species were then known, and almost half of those were found in Great Britain and Ireland. Eighteen more were found throughout the rest of Europe, and the other 60 ptiliids were from the rest of the world.

Since then, the taxonomic levels of Ptiliidae have been debated by a small number of experts with a current consensus of Ptiliidae containing three subfamilies (Hall 2001). Nearly a century ago, Barber (1924) focused on the nanoselline genera and proposed the Nanosellinae as an additional subfamily. Nanosellinae was changed to a rank of tribe Nanosellini within the subfamily Ptiliinae after the change was agreed upon by Sörensson and Dybas roughly 70 years later (Hall 1999). The genera found in Ptiliinae display the most diversity in morphological features such as overall body shape and size. Two other subfamilies of Ptiliidae are found as well: the Acrotrichinae, which are the largest featherwing beetles in physical size and are generally oval in shape, and the Cephaloplectinae, which are limuloid in body shape (Hall 2007).

According to the Tree of Life webpage for Ptiliidae, as of 2007, there were 65 genera and 400 species described within the 3 subfamilies of featherwing beetles. Fifteen genera and 27 species at that time belonged to the tribe Nanosellini, which contains members that inhabit fungal hosts (Hall 2007). An increase in new species descriptions being written by Ptiliidae researchers resulted in the number of named ptiliid species increasing rapidly in the 2000's, and the number of ptiliids described have roughly doubled in less than 15 years.

Current world fauna of Ptiliidae consists of 817 valid species in 98 genera (Newton 2020) with the increase attributed largely (Polilov *et al.* 2019) to the work by Johnson (1966, 1968, 1975a, 1975b, 1982), Sörensson (1988, 1997, 2003), and Hall (1999) and recently by Polilov (2008), Polilov and Bibin (2004), Darby (2013, 2014a, 2014b, 2015a, 2015b, 2015c, 2016a, 2016b, 2017a, 2017b, 2017c, 2019, 2020, 2021), and Darby and Johnson (2011).

Within Ptiliidae, systematic relationships have not been established, and this is especially true within the subfamily Ptiliinae, which has been called the “wastebasket of subfamilies” by Hall. However, within Ptiliinae, it has been pointed out that the tribe Nanosellini appears to be a well-defined group that could benefit from more information so that hypotheses describing relationships within Ptiliidae can be made (Hall 1999).

While there has been an increase in the number of described species of ptiliid, a literature search through 2020 revealed that detailed studies of Ptiliidae in large areas remain sparse, which has contributed to the paucity of ptiliids serving as a biogeographic tool (Polilov *et al.* 2019). Research on ptiliids in Costa Rica is limited. Ptiliids were sampled in 2003 (Hall 2003) as part of a biodiversity project comparing surface-dwelling beetle diversity in different coffee production systems in Costa Rica. Hall (2003) reported 5510 individual beetles in 30 beetle families with 73 species represented in the litter layer of which Ptiliidae occupied 7.4% of the total beetle fauna, however, no ptiliid genera were listed individually.

Featherwing beetles inhabit many other moist environments as well, such as decaying vegetation, tree holes, and other habitats that support the growth and proliferation of fungi and spores (Dybas 1990). In addition to these habitats, ptiliids occur as antinquilines (Mann, 1926, Rettenmeyer *et al.* 2011), in termite nests (Dybas 1955), in phytotelmata (Darby and Chaboo 2015), and some assist in the release of pollen in palms (Listabarth 1993). According to Lawrence (2001) fourteen genera of Ptiliidae occur in Costa Rica. Mann (1926) described one new genus, *Eulimulodes*, and four new myrmecophilous ptiliid species, *Cephaloplectus flavus* Mann, *C.*

pusillus Mann, *C. mus* Mann (= *C. trilobitoides*), and *Eulimulodes mexicanus* Mann from various *Eciton* spp. of army ants. Another two species of myrmecophilous ptiliid, *Limulodes* (*Ecitolimulodes*) *stenotropis* Seevers and Dybas and *L. (Ecitolimulodes) manni*, were described by Seevers and Dybas (1943). Hall (1999) described *Limulosella waspucensis* Hall on *Fomes auberianus* (Polyporaceae) and *Scydoselloides alajuelaensis* Hall in mixed floor litter. Darby (2016a) described one new genus and species, *Seminis factiosum* Darby, from specimens collected in the Osa Peninsula by a net mounted on a truck. Additionally from that collection Darby described the new species *Nossidium schuelkei* Darby and *Ptenidium gruenbergae* Darby, and also *N. issyae* Darby that was collected under bark associated with ants.

Relationships have not been described as to the occurrence or possible specialization on the different polypores for the numerous known mycophagous ptiliid genera. The fluid nature of taxonomy and questions surrounding the classifications of both the ptiliids and the polypores complicates the confirmation of the identification and descriptions of each taxon and of their interactions. This project sought to identify which Ptiliidae at the generic level occurred in which polypore fungi in Costa Rica. To explore the occurrences of these tube dwelling genera of Ptiliidae on polypore fungi in Costa Rica, a collection of fungal samples was made and the beetles were extracted from the samples. Each fungus and beetle sample were identified to genus, and their geographic locations mapped. Although we cannot draw conclusions concerning the specificity of beetle genera to their host fungi, we do show which beetle genera are able to inhabit the different polypore species which we collected as a preliminary foundation for further studies. In our study, we found three endemic ptiliid species in Costa Rica associated with polypore fungi with one new *Cylindrosella* described in this publication and two more to be described later. The genus *Cylindrosella* was previously monotypic.

1.2 Ptiliidae morphology

The average size of most featherwing beetle species ranges from 0.5-1.5 mm in length, with a few species possessing the most extreme sizes at 0.3 mm and 2 mm in length (Hall 2007). The tribe Nanosellini includes many of the species found at the extreme minimum sizes and which often live on fungal hosts belonging to the family Polyporaceae and other polypores (Hall 1999). These nanosellines range in length from 0.3-0.8 mm, and are the smallest known beetles (Hall 2007).

The overall size of an organism influences the structure and function of its anatomical features. Body size affects reproduction, locomotion, morphology, oxygen delivery, and many other aspects of life, but often in biology we consider these topics of limitations as organisms get incredibly large or reach a maximum size supportable by metabolic and physiological functions (Schmidt-Nielsen 1975). Featherwing beetles are on the opposite end of the spectrum, as a miniature among beetles. Still, some of the same aspects of life must be contemplated. Featherwing beetles are unique in that their minute size has made them capable of or required them to adapt in several notable ways. As the size of a beetle is reduced to such a small value, flight muscles become too bulky, and oscillating wings are not favored (Rensch 1948). Also, if a ptiliid had an appropriately proportioned membranous wing, there would be too much drag on the typical membranous wing, and it would overcome the amount of lift necessary for flight. Because of this, the setaceous wings on which the beetles balloon became more favorable, hence the name featherwing (Dybas 1966). Also along with such small size comes the new problems of producing fewer eggs and finding an appropriate place to oviposit. Ptiliidae can only carry one egg at a time, and are so limited due to the adult female's size and the developing offspring's minimum requirement for yolk nutrients (Dybas 1966). Some species are suspected of being parthenogenic, as only females have been collected in samples, and low fecundity would impact the populations less if only females were produced (Dybas 1978).

Reduction in body size might lead to some rearrangement or packing together of indispensable organs, but it can also lead to the ability to occupy new niches, such as spore tubes of Polyporaceae fungi (Barber 1924, Polilov 2005, Rensch 1948). Dybas (1955, 1960, 1961b, 1966) found Ptiliidae in a number of habitats and locations, including treeholes, rotten wood, animal dung, forest floor litter, caves, and termite nests. All of these places are suitable for fungal growth, and so could support Ptiliidae's food source, the spores and hyphae of fungus. In addition to those studies, Dybas (1961a) examined Ptiliidae captured in amber on different continents collected by other investigators. Barber (1924) recognized that their ballooning behavior would take the tiny beetle to places they could not control but must take advantage of, and that because of this, the Ptiliidae could be found adapted to many different environments in many different body formations.

Previously, the featherwing beetles had three recognized forms which were named for the shape of the body overall: oval, elongate-oval, and elongate. As of Hall's 1999 paper on the generic

revision of the tribe Nanosellini, many more oval and elongate-oval forms had been collected and named over the preceding 150 years by Hall and his predecessors, and during that same time only 4 elongate genera had been listed (Hall 1999). A fourth shape, limuloid, was once proposed as its own family, Limulodidae, but has since been reclassified, joining the Ptiliidae as subfamily Cephaloplectinae (Dybas 1976, Lawrence and Newton 1982).

The extreme minimum size along with these body formations, especially the elongate form of some of the Nanosellini, allow the beetles to inhabit fungal hosts belonging to the family Polyporaceae and other polypores (Hall 1999). The unique feature of the polypore's poroid hymenophore provides a perfect habitat for Ptiliidae. Within the pores located on the underside of the bracket fungus, a ptiliid beetle can find food, shelter, and a place to breed, in some parts of the world year-round (Graves 1960, Dybas 1990).

1.3 Polypore fungi structure as a domicile for Ptiliidae

The general structure of a polypore fungus consists of a conk, which is the fruiting body, that is bracket or shelf shaped and often grows on dead trees or wood, with a stipe or mycelium extended into the rotting wood in order to break it down and draw nutrients for the fungus. Not all polypores are saprophytic, as some species grow on living sapwood or heartwood until they kill the tree. The upper layer of the shelf-shaped conk is waterproof and covers a corky or woody context layer underneath. The lower layer found on the underside of the conk is a formation of pores, which often resemble a miniature honeycomb. Within the pores are the basidia, club-shaped organs that produce the basidiospores on which Ptiliidae feed while sheltering within the pore (Graves 1960). If the polypore is a perennial species, new pores can be found developing on a layer below older pores, providing fresh habitat to new generations of mycetocole ptiliid beetles. A polypore is capable of producing a large number of spores quickly, as many as 250 billion spores in 10 days for some species, and therefore can theoretically support a large number of beetles (Graves 1960). Any benefit to the fungus such as dispersal of spores is not evident (Gilbertson 1984).

Those species of Ptiliidae that can live inside the pores have been proposed to position themselves differently according to their life stage. Barber (1924) noticed that adult beetles position themselves within the tube with their head downward, while larvae position themselves

with their head upward and their strongly armed tail nearly exposed to the outside. In this position larvae can eat softer spores as they develop on the basidia.

Ptiliidae possess some of the more primitive mouthpart traits to successfully eat spores. Adults and larva both have labial palps and maxillae that have a brush or comb-like structure on the galea and/or lacinia to help them pick up and manipulate a spore. Adults have mandibles that are set further back in the head capsule, developed, semi-membranous mola that crush the spore, and enlarged molar velar lobes proximally located that guide the spore into the pharynx (Betz *et al.* 2003, Newton 1984).

1.4 Host fungi preference

Some researchers believe some Ptiliidae beetles prefer specific polypores, while others have said they found no evidence of specificity. Observations previously made state that, when *Nanosellini* is split into groups of basal genera versus derived genera, derived genera appear to be more specific regarding their polypore host, but basal genera are not (Hall 1999). Derived genera were defined as having certain reduced morphological characters and were from the Nearctic and Neotropical regions, including the United States, Mexico, Central America, and South America, while basal genera retained primitive characters and are from only the southern hemisphere (Hall 1999). Other studies conducted within the United States have identified no preferences for specific polypore hosts and sometimes do not identify the polypore at all, but raised other questions about the stages of development and decomposition of the conk as playing a role in what species of organisms would be attracted at different times (Graves 1960).

1.5 Polypore fungi taxonomy

Past researchers have regarded the fungal family Polyporaceae as the main provider of domicile and nutrition for nanoselline adults and larvae (Hall 2007). However, fungal taxonomy has also been rapidly changing in the past 10 to 15 years, and it may be more correct to refer to the fungi in which Ptiliidae live in a more general manner, as a group within Phylum Basidiomycota: Class Agaricomycetes called polypores. This group consists of fungi belonging to many different families and is based on the morphological characteristic of having many pores that make up the hymenophore instead of gills, although some polypores are included in the group despite having

gills (Ryvarden 2004). Polypores can be identified as belonging to several different, sometimes distant, families in a minimum of 2 different orders.

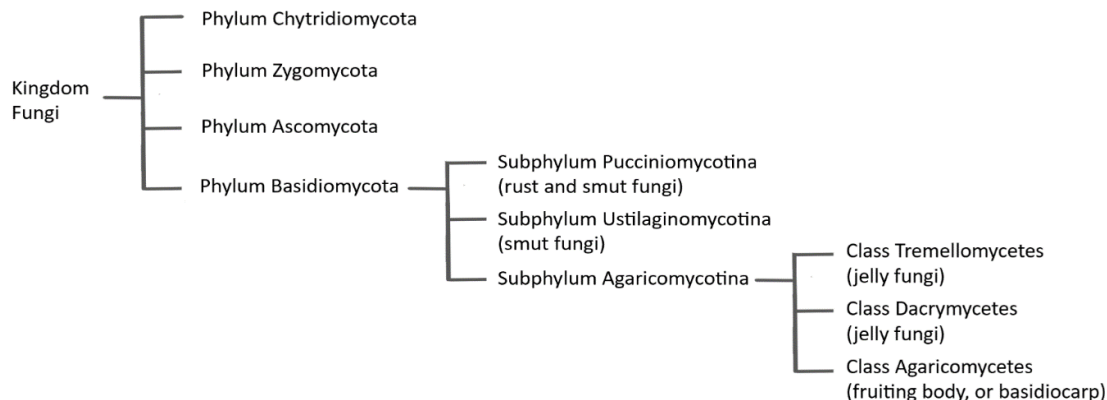


Figure 1.1. Higher system of fungal classification. Figure shows the classification system of higher levels of fungi taxa (Bauer *et al.* 2006, Hibbett *et al.* 2007, Mata 2003, Blackwell and Spatafora 2004).

Within the Kingdom Fungi, four phyla exist (Fig. 1.1). Chytridiomycota and Zygomycota are both microfungi living in aquatic biomes or insect guts, respectively. Ascomycota is the largest phylum, having approximately 111,000 species identified as of 2021 (Wijayawardene *et al.* 2021). Basidiomycota is the second largest phylum, with approximately 35,000 species as of 2017 (Nagy and Szöllösi 2017). Ascomycota and Basidiomycota are placed into separate phyla based on their different reproductive structures. Ascomycota produces spores, or ascospores, within an elongate pod-like structure called an asci, while Basidiomycota produces spores, or basidiospores, externally on a structure called a basidia. Polypores are found within the Phylum Basidiomycota: Class Agaricomycetes. Previously, this group was called Class Hymenomycetes and included all fleshy fungi that are found in forest ecosystems such as mushrooms, jelly fungi, and shelf fungi (Bauer *et al.* 2006, Hibbett *et al.* 2007, Mata 2003, Blackwell and Spatafora 2004).

1.6 Identifying characteristics of polypore fungi

Generally visible characteristics of polypores vary greatly even within their genera and are not reliable for identification in many cases. To identify a polypore with more certainty, it is

important to look at general characters such as conk color, attachment, shape and size, margin borders, pore shape, pore spacing, and dissepiment, and also some of the microscopic characters as well. Structure that are important to take note of in addition to the fruiting body characteristics are the basidiospores' shape, color, ornamentation, wall structure, and thickness; hyphae types, colorations, and density; as well as reproductive features found on the generative hyphae. Also, chemical testing for color change and swelling of hyphae is performed to identify polypore fungi to genus (Ryvarden 2004, 2015, 2016).

Table 1.1. Family and genera of fungi containing Ptiliidae (Coleoptera) including spore types associated with polypore fungi collected in Costa Rica, 2007-2009. Spore types: s, single thin wall; t, thick single wall; d, double wall with inner wall ornamented.

Order	Family	Genus	Spore type
Hymenochaetales	Hymenochaetaceae	<i>Phellinus</i>	t s or t
	<i>incertae sedis</i>	<i>Trichaptum</i>	s
Polyporales	Polyporaceae		s
		<i>Trametes</i>	s
		<i>Earliella</i>	s
		<i>Polyporus</i>	s
		<i>Perenniporia</i>	t
		<i>Pycnoporus</i>	s
	Ganodermataceae		d
	Irpicaceae	<i>Ganoderma</i>	d
		<i>Irpex</i>	s s

Fungi collected in our study include polypores from several families: Hymenochaetaceae, Polyporaceae, Ganodermataceae, and Irpicaceae (Steccherinaceae). Also in our collection are fungal samples of *Trichaptum*, of which the family is *incertae sedis*. These families are found in two different orders, Hymenochaetales and Polyporales (Table 1.1).

The order Hymenochaetales was formed after the observance of a unique morphological structure within the hyphae called an imperforate parenthosome in the family Hymenochaetaceae. Other families have been added to the order after results from molecular studies pointed to their relationship. There is no set of shared morphological characters that defines this order, including the imperforate parenthosome, which is not found in some families (Ryvarden 2004).

Fungi from Hymenochaetaceae can grow on both hardwood and softwood trees as well as grapevines. The genus *Phellinus* from this family is perennial with a thick, corky context that is tough and dark reddish brown, umber, or yellowish brown. Pores are uniform in diameter composing a brown underside surface. Layers of pores maybe be evident in the context according to the number of years of growth. They can live on both dead and living trees, both hardwoods and softwoods. The basidiospores of *Phellinus* range from globose to ellipsoid to cylindrical, are smooth, and can be translucent or rusty brown. Spore walls of *Phellinus* can be either thin or thick, but all are single. (Ryvarden 2004).

The classification of genus *Trichaptum* is under debate. Previously it was placed in the family Polyporaceae. However, due to results from genetic studies, it has been removed from the order Polyporales and placed into Hymenochaetales, with the family name yet undecided. The pore surface is violet when fresh, and fades to a brown with age. The cystidia, or sterile organs, found within the hymenium are encrusted. *Trichaptum* typically attacks softwood trees and occasionally hardwoods. Their basidiospores are cylindrical to ellipsoid, smooth, translucent, and thin-walled (Ryvarden 2004, 2016).

The order Polyporales includes many poroid families, but also includes families which lack pores, and so is not bound by a common hymenophore morphology as the name suggests. They can be found on living or dead trees as well as roots that are buried. Polyporales includes members that cause either white rot or brown rot (Ryvarden 2004, 2015, 2016).

Polyporaceae is a large family found in Polyporales with diverse characteristics. Most have a hymenium that is made up of pores with the basidia located within them, but some have gill structures. Also, most are broadly attached to wood as a bracket or shelf fungus, while others are attached by stipe. Some are very colorful, some are neutral in color, some are dense and thick, some are thin, some look like a heavy shelf, while others look like a large flower. Most cause white rot, but a few species cause brown rot. The genus *Polyporus* has no specific color to the basidiocarp as it varies. Fungi in this genus have a stipe that is located in the center of the basidiocarp. Spores

of *Polyporus* also vary widely and can be cylindrical to ellipsoid, but are all thin-walled, translucent, and smooth. *Pycnoporus*, another genus in the Polyporaceae, has a tough, corky basidiocarp that is a brick red or a very bright red-orange. They can be found on both hardwoods and softwoods. The basidiospores of *Pycnoporus* are thin walled, cylindrical, translucent, and smooth. Fungi from the genus *Trametes* are easily recognized as its fruiting bodies are often found in layers of thinner fanlike basidiocarp that have concentric zones of varying coloration. Under a microscope, the upper surface is pileate and the spores are smooth and single-walled. The fungi of genus *Earliella* also have an overall fanshape to its fruiting body, and as it ages, the central arc becomes deep red or brown red, while the margin creates a white border. The pore surface is white, and the dissepiment grows irregularly to make the underside appear “shaggy.” *Earliella* spores are smooth, single-walled, and cylindrical or oblong ellipsoid in shape. The genus *Perenniporia* has larger, denser, corky basidiocarps that are semicircular with no stipe. The pore surface has round pores, and the spores are subglobose to broadly ellipsoid, with single walls that are thick, and without ornamentation (Ryvarden 2004, 2015, 2016).

Family Ganodermataceae is represented here by only one genus found, *Ganoderma*. Fungi of this genus have double walled spore with structural support in between the two walls, and are easily identified by the horseshoe shape formed by the walls of the spores. They are a bracket fungus that is often used in traditional Asian medicine (Ryvarden 2004).

Also represented here by only one genus found is family Irpicaceae (Steccherinaceae). The genus *Irpex* has shaggy, hairlike dissepiments between the pores. It can attach itself to the wood in different arrangements, sometimes possessing a shelf, but other times being resupinate, or completely wrapped flat against the tree with its hymenophore exposed (Ryvarden 2004, 2015).

CHAPTER 2. OCCURRENCE OF FEATHERWING BEETLES ON POLYPORE FUNGI FROM COSTA RICA AND DESCRIBING A NEW SPECIES OF PTILIIDAE IN THE GENUS CYLINDROSELLA

2.1 Abstract

Beetles of the family Ptiliidae are distributed worldwide and easily collected, yet the biology, ecology, and taxonomy of Ptiliidae Heer, 1843, or featherwing beetles, have not been well studied. In a study from 2007 to 2009, ptiliids were collected from sites throughout Costa Rica by collecting their polypore hosts and extracted with a Berlese technique in an effort to expand biogeographic knowledge of Ptiliidae. Ptiliids and their host fungi were identified to genera and collection sites mapped. Featherwing genera are able to inhabit different polypore genera and were found at a higher rate of co-occurrence than reported in previous studies. We identified *Cylindrosella costaricensis* **sp. n.**, with the potential of two more new species to be described.

Keywords: Ptiliidae, polypore fungi, Costa Rica, *Cylindrosella*, Nanosellini, new species, taxonomy, featherwing beetles, neotropics, Staphylinoidea

2.2 Introduction

The family Ptiliidae (Order: Coleoptera), or featherwing beetles, contains the smallest known beetles ranging in size from 0.3-2.0 mm in length (Dybas 1990). Ptiliids are a cosmopolitan group that inhabits moist environments such as decaying vegetation, tree holes, seaweed on beaches (Dybas 1990), excrement of various animals such as cows, deer, and tigers (Polilov 2008), and other habitats that support the growth and proliferation of fungi and spores. In addition to these habitats, ptiliids occur as antinquilines (Mann, 1926, Rettenmeyer *et al.* 2011), in termite nests (Dybas 1955), in spore tubes of Polyporaceae (Barber 1924), in phytotelmata (Darby and Chaboo 2015), and some assist in the release of pollen in palms (Listabarth 1993).

In 1872, only 139 ptiliid species were known (Matthews 1872), with 61 species found in Great Britain and Ireland and 18 more species found throughout the rest of Europe, while the other 60 ptiliids were from the rest of the world. Current world fauna of Ptiliidae consists of 817 species in 98 genera (Newton 2020), with the increase attributed largely (Polilov *et al.* 2019) to the work

by Darby (2013, 2014a, 2014b, 2015a, 2015b, 2015c, 2016a, 2016b, 2017a, 2017b, 2017c, 2019, 2020, 2021), Darby and Chaboo (2015), Darby and Johnson (2011), Dybas (1955, 1960, 1961a, 1961b, 1961c, 1966, 1976, 1978), Hall (1999), Johnson (1966, 1968, 1975a, 1975b, 1982), Polilov (2008), and Sörensson (1988, 1997, 2003).

While there has been an increase in the number of described species of ptiliid, detailed studies in specific habitats over large geographic areas remain sparse, which has contributed to the paucity of ptiliids serving as a biogeographic tool (Majka and Sörensson 2010, Polilov *et al.* 2019). Studies of ptiliids in general habitats, especially beetles associated with polypore fungi (Basidiomycota: Agaricomycetes, Polyporales and Hymenochaetales), in Costa Rica are limited. According to Lawrence (2001) fourteen genera of Ptiliidae occur in Costa Rica on various hosts. Mann (1926) described one new genus, *Eulimulodes* Mann, and four new myrmecophilous ptiliid species, *Cephaloplectus flavus* Mann, *C. pusillus* Mann, *C. mus* Mann (= *C. trilobitoides*), and *Eulimulodes mexicanus* Mann from various *Eciton* spp. of army ants. Another two species of myrmecophilous ptiliid, *Limulodes* (*Ecitolimulodes*) *stenotropis* Seevers and Dybas and *L. (Ecitolimulodes) manni* Seevers and Dybas, were described by Seevers and Dybas (1943). Hall (1999) described *Scydoselloides alajuelaensis* Hall in mixed floor litter and *Limulosella waspucensis* Hall on *Fomes auberianus* (Polyporaceae) in Costa Rica. As part of a biodiversity project of beetles found in the litter layer of different coffee production systems in Costa Rica, Hall (2003) reported 5510 individual beetles in 30 beetle families of which Ptiliidae occupied 7.4% of the total beetle fauna; however, no ptiliid genera were listed.

Darby (2016a) described one new genus and species, *Seminis factiosum* Darby, and new species *Nossidium schuelkei* Darby and *Ptenidium gruenbergae* Darby from specimens collected on the Osa Peninsula in Costa Rica with a net mounted on a truck, and *N. issyae* Darby was collected under bark associated with ants. Darby (2016a) also reported the presence of *Petrotrichis nitidum* (Heer), *P. rotindata* Darby, and *Bambara invisibilis* Nieter in Costa Rica.

We undertook this study to provide information on genera of Ptiliidae associated with polypore hosts as a first step needed to studying the evolution of mycophagy of Staphylinoidea (Newton 1984).

2.3 Materials and Methods

Polypores were collected in various sites in Costa Rica from 2007 to 2009 under permits 01943 and 33797 issued by the Ministerio del Ambiente y Energia, Sistema Nacional de Areas Conservaci. Polypore fungi collected were located on decaying trees and other wooden structures. The entire fruiting body and attachment or stipe was placed in a modified Berlese funnel and invertebrates extracted for three days and stored in ethanol (70%) along with the fungus. All materials were transported to the laboratory for further processing and identification. Locations of the collected fungi are listed by park name, nearest city or village, and in some cases by GPS coordinates (Figs. 2.2-2.10).

To identify the polypores, we examined the fruiting bodies and spores. Slivers including spore tubes from each fungal sample were mounted on glass microscope slides in polyvinyl alcohol (PVA) (BioQuip, Rancho Dominguez, CA 90220), covered with a coverslip, and inspected. Fruiting bodies were cut using a razor blade to excise a small wedge, and thicker fruiting bodies were sliced into planar sections to remove a small piece of the most recent layer of hymenophore from the underside where pores are visible.

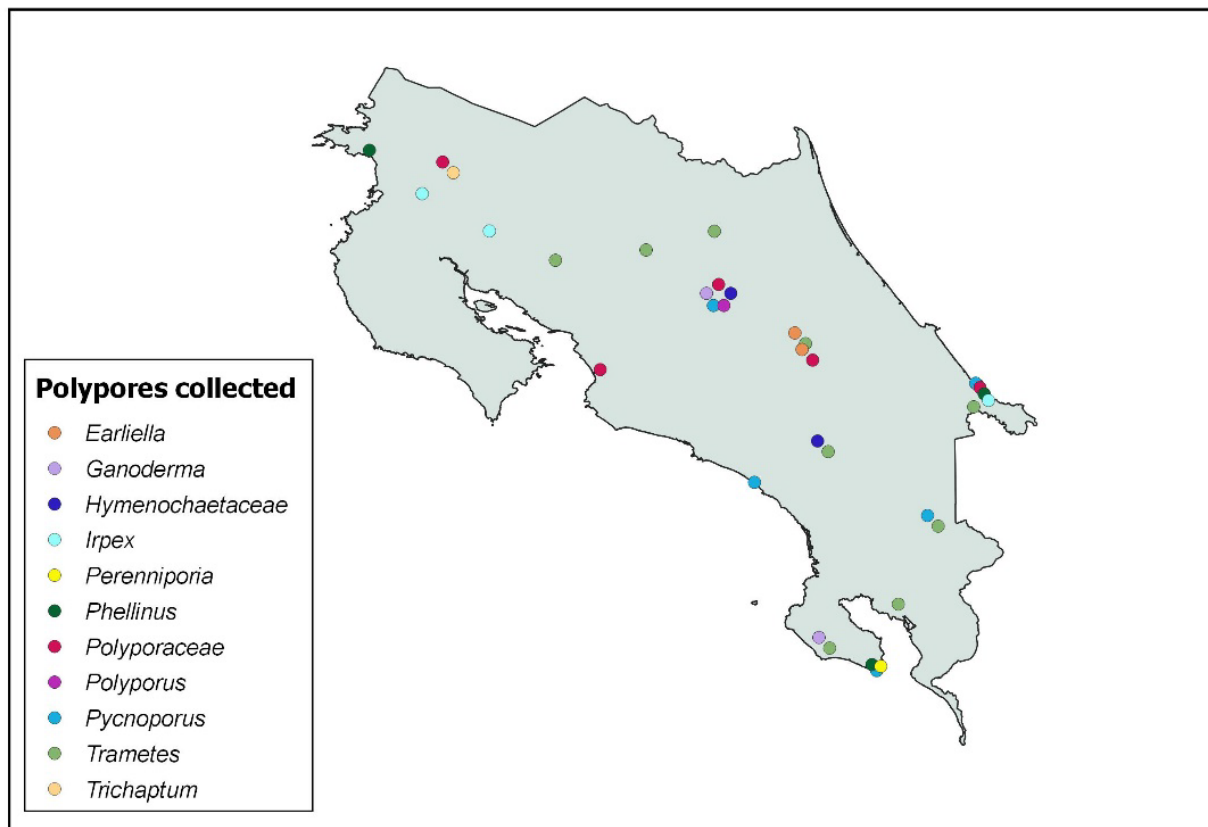
Pore tube samples and the spores they contain were then mounted on glass slides in PVA and covered with a coverslip to identify the fungus. Cotton blue in lactophenol stain (Sigma-Aldrich, St. Louis, MO 63103) was used to create a second slide of the same organic material. We used the keys by Ryvarden (2004, 2015, 2016) to identify the polypores to genera, and the identifications of the polypores were confirmed by Dr M. C. Aime, Department of Botany and Plant Pathology, Purdue University, West Lafayette, IN 47907.

Berlese samples were sorted for ptiliids under a stereomicroscope. Ptiliid beetles were cleared in lactophenol and subsequently mounted on glass microscope slides in PVA. Beetles were mounted with their ventral side up so that visualization and measurements of appropriate characters could be made. Elytra were removed on most specimens and placed alongside the body.

Measurements and drawings were made using a camera lucida attached to a Nikon Eclipse E600 phase contrast compound microscope fitted with Plan Fluor objectives. The equipment used to take measurements was a Model M202E Digital Readout (Gaertner Scientific Corporation, Skokie, IL 60076) and confirmed with a Nikon NIS Elements software package (Nikon Instruments, Melville, NY 11747). We used the ptiliid keys of Dybas (1990) and Hall (2001) to identify ptiliid genera.

2.4 Results

Collections were made from selected sites with 124 fungal samples taken throughout Costa Rica. Of the 124 fungal samples collected, we extracted beetles from 48 fungi (Fig. 2.1) representing nine fungal genera (Table 2.1) with 11 of the fungi identifiable only to family because of uncertainty of higher-level classification for the fungi (Hibbett *et al.* 2007, Justo *et al.* 2017). Our collection includes the fungus *Trichaptum* (Hymenochaetales), which belongs to an *incertae sedis* family. Other researchers have also experienced issues in identifying fungi to species. In his 2008 study, Polilov collected ptiliids associated with 11 genera of fungi of which 6 were not identified to species with *Trichaptum* as one of the fungi lacking a species name.



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Figure 2.1. Distribution of fungal samples collected in Costa Rica, 2007-2009.

Table 2.1. Occurrence of polypore fungi and genera of Ptiliidae. Costa Rica, 2007-2009. The occurrence table shows in which polypore a genus of Ptiliidae occurred in and the number of samples of each polypore fungus that was identified containing the beetle.

				Polyporales								Hymenochaetales													
				Ganodermataceae		Irpicaceae		Polyporaceae						incertae sedis		Hymenochaetaceae									
				Ganoderma		Irpex		Earliella		Perenniporia		Polyporus		Pycnoporus		Trametes		Polyporaceae		Trichaptum		Phellinus		Hymenochaetaceae	
				2		3		3		2		1		6		16		8		1		3		3	
				# fungus samples																					
				# beetles (identified)																					
Acrotrichinae	Acrotrichini	Acrotrichis	42	12			1										7		2						2
	Nephanini	Nephanes	2	1													1								
Ptiliinae	Ptiliini	Nossidium	3	2		1																		1	
		Ptilium	3	2																					
	Nanosellini	Nanosella	139	39	1	2		3	2					6				12		8		1	2	2	
		Throscopitium	9	2																1					1
	unknown	Cylindrosella sp.n.	5	4					1		1						1						1		
		undescribed 1	3	1							1														
		undescribed 2	1	1													1								

Table 2.1 shows the number of fungal samples from each fungal group identified containing beetles from family Ptiliidae. Included in the table is the total number of each type of fungus collected, the number of fungal samples containing each type of beetle, and the number of beetles mounted and identified of each genus of ptiliid. Taxonomic information includes order, family, and genus of fungi as well as subfamily, tribe and genus of beetle.

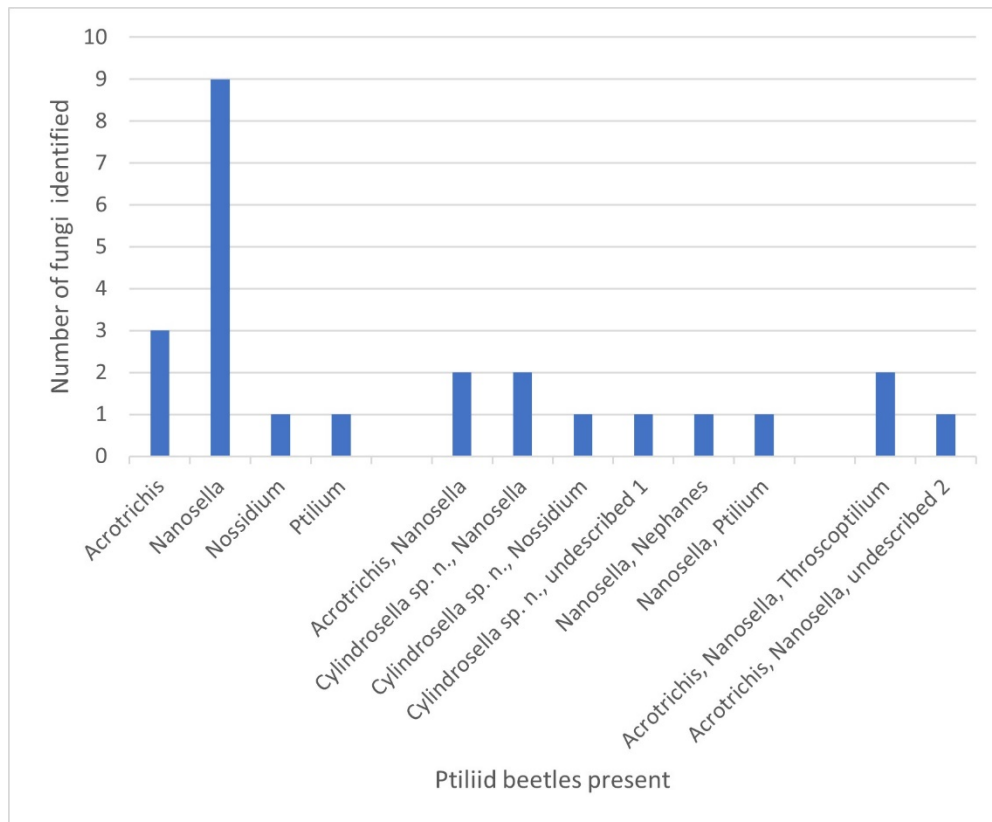
We found 48 polypore fungi belonging to two different orders and at least four different families containing ptiliid beetles. Fungi that could not be placed into a genus were identified to family.

In our collection of polypore fungi, we collected 9 genera of Ptiliidae representing two different subfamilies and at least four different tribes. Of the 198 ptiliids extracted, 189 were placed into six genera, while nine of the ptiliids failed to key to any described genus. One species of those nine specimens will be described here and the others in the near future. From the subfamily Acrotrichinae we found the genera *Acrotrichis* and *Nephanes*. All other beetles found are from different tribes of subfamily Ptiliinae. From the tribe Ptiliini two genera were identified, *Nossidium* and *Ptilium*. Beetles found from the tribe Nanosellini are *Nanosella*, *Throscopitium*, and our new *Cylindrosella* sp. n. described here. To the list of ptiliid genera recorded in Costa Rica by other researchers, we add three more genera: *Nephanes*, *Throscopitium*, and *Cylindrosella*.

From Table 2.1, we see that *Trametes* is the most abundant fungus in our collection, and that in *Trametes* six of our nine genera of beetle were occurring. Specimens of *Nanosella* were the most abundant beetle found in 10 different identified fungal types, which accounted for 39 of our 48 total fungal samples.

We believe in our collection there are three species of featherwing beetles that are new to science. One, *Cylindrosella* **sp. n.**, we describe here. Two others, undescribed 1 and undescribed 2, will be described in future publications. *Cylindrosella* **sp. n.** was found in four samples of fungus which each identified as a different type of polypore from two different families and orders. Undescribed 1 was found alongside *Cylindrosella* **sp. n.**, occupying the only sample of *Polyporus* we collected. Undescribed 2 was found in a sample of *Trametes*.

Table 2.2. Number of polypore fungi taxa containing each ptiliid or ptiliid group. Costa Rica. 2007-2009. Note: Taxon of polypore can represent genus or family, if family was most precise identification.



Four genera of ptiliid, *Acrotrichis*, *Nanosella*, *Nossidium*, and *Ptilium*, were each found occurring in at least one polypore genus or family alone, but each of these genera were also found co-occurring with at least one other genus of ptiliid in other fungal samples. As many as three genera of beetle were found to be co-occurring in polypores (Table 2.2).

Table 2.3. Occurrence of single and co-occurring genera of Ptiliidae (Coleoptera) on polypore hosts collected in Costa Rica. 2007-2009. The number of samples of each fungus in which ptiliid beetle was found. Beetles are listed as either being found as the only occupant of the fungal sample or as co-occurring with other ptiliid genera.

Ptiliidae (Coleoptera) Genera	Polypore (Basidiomycota:Agaricomycetes) Genus or Family	Number of Occurrences
<i>Acrotrichis</i>	<i>Irpex</i>	1
<i>Acrotrichis</i>	<i>Trametes</i>	3
<i>Acrotrichis</i>	Hymenochaetaceae	1
<i>Nanosella</i>	<i>Earliella</i>	3
<i>Nanosella</i>	<i>Ganoderma</i>	1
<i>Nanosella</i>	<i>Irpex</i>	2
<i>Nanosella</i>	<i>Perenniporia</i>	1
<i>Nanosella</i>	<i>Phellinus</i>	2
<i>Nanosella</i>	<i>Pycnoporus</i>	6
<i>Nanosella</i>	<i>Trametes</i>	6
<i>Nanosella</i>	<i>Trichaptum</i>	1
<i>Nanosella</i>	Polyporaceae	6
<i>Nossidium</i>	<i>Ganoderma</i>	1
<i>Ptilium</i>	<i>Trametes</i>	1
<i>Acrotrichis, Nanosella</i>	<i>Trametes</i>	3
<i>Acrotrichis, Nanosella</i>	Polyporaceae	1
<i>Cylindrosella</i> sp. n. , <i>Nanosella</i>	<i>Perenniporia</i>	1
<i>Cylindrosella</i> sp. n. , <i>Nanosella</i>	<i>Trametes</i>	1
<i>Cylindrosella</i> sp. n. , <i>Nossidium</i>	<i>Phellinus</i>	1
<i>Cylindrosella</i> sp. n. , undescribed 1	<i>Polyporus</i>	1
<i>Nanosella, Nephanes</i>	<i>Trametes</i>	1
<i>Nanosella, Ptilium</i>	Hymenochaetaceae	1
<i>Acrotrichis, Nanosella</i> , undescribed 2	<i>Trametes</i>	1
<i>Acrotrichis, Nanosella, Throscoptilium</i>	Hymenochaetaceae	1
<i>Acrotrichis, Nanosella, Throscoptilium</i>	Polyporaceae	1

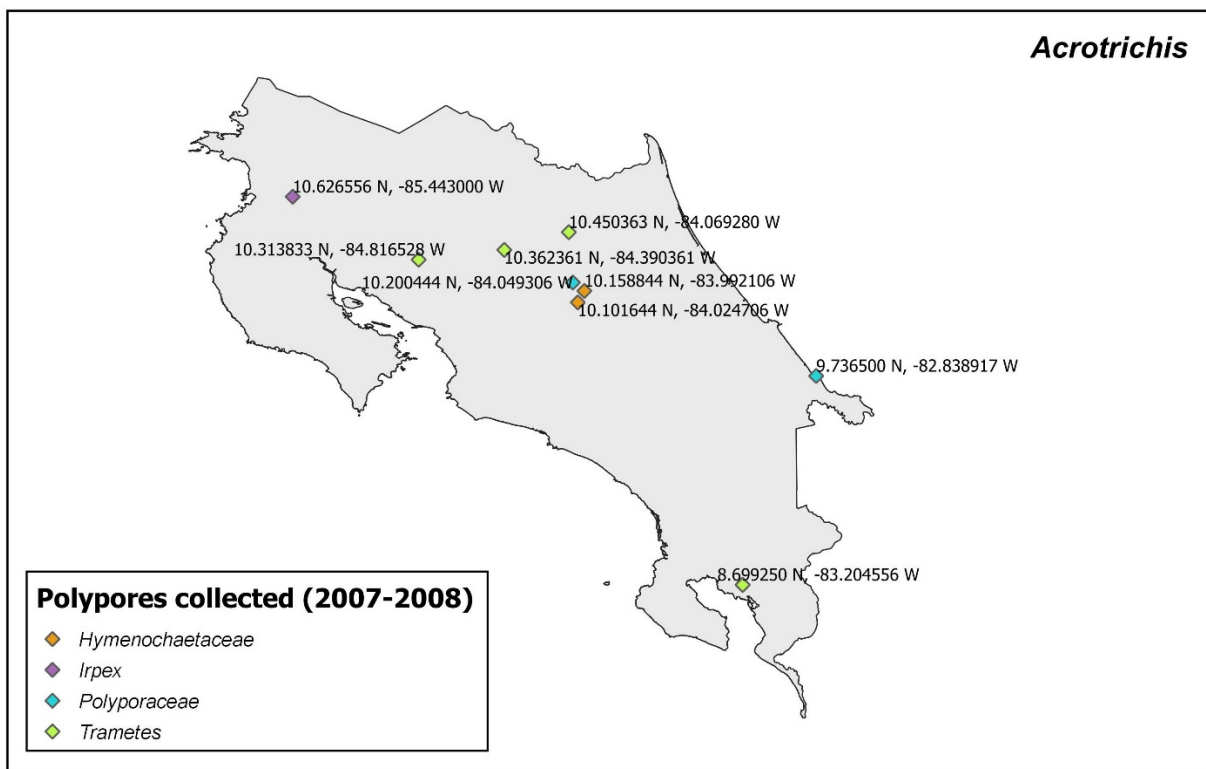
Table 2.3 shows in which polypore a genus of Ptiliidae occurred in and the number samples of each polypore fungus that was identified containing the beetle. Beetle genera listed alone signifies the only ptiliid genus in that fungal sample, while beetles list in groups were co-occurring.

Many fungal samples yielded ptiliid beetles from more than one genus, evidence that ptiliid beetles often co-occur in a single fungus with other ptiliid beetle genera, which was previously

thought to be rare. (Hall 2007). In our collection, 35 samples of fungus contained a single beetle genus alone and 13 samples were inhabited by at least 2 genera co-occurring. Every genus of Ptiliidae shared at least one fungal sample with at least one other genus (Table 2.3). *Nanosella* and *Acrotrichis* were found together in several different fungal samples, many of which were *Trametes*. *Acrotrichis* and *Nanosella* also shared *Trametes* with one of our yet undescribed ptiliids, and shared fungi from the families Polyporaceae and Hymenochaetaceae with *Throscoptilium*. The new *Cylindrosella* species described in this publication was found alongside *Nanosella* in *Perenniporia* and *Trametes*, and also alongside *Nossidium* in *Phellinus*. *Nanosella* also shared *Trametes* with *Nephanes* and shared a fungus from family Hymenochaetaceae with *Ptilium*. Of the only sample of *Polyporus* collected, we found two undescribed beetles, including *Cylindrosella* **sp. n.**.

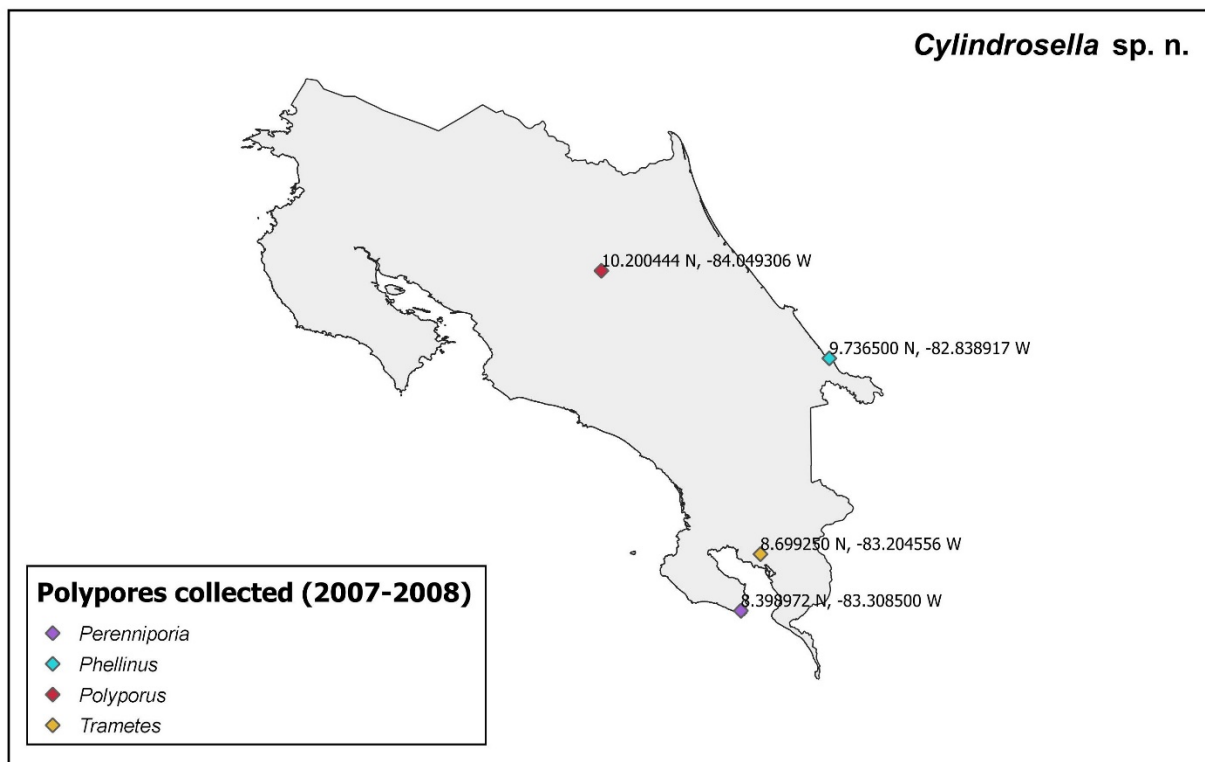
Nanosella spp. were the most numerous ptiliid collected (Table 2.1), occurring alone in nine different genera and family, while also co-occurring in three of those same fungal genera with other ptiliids, in addition to co-occurring with other ptiliids in a second family of fungi, for a total of ten fungal types inhabited by *Nanosella* (Table 2.3).

Cylindrosella **sp. n.** occurred in four different fungal genera, co-occurring with three different other ptiliid genera.



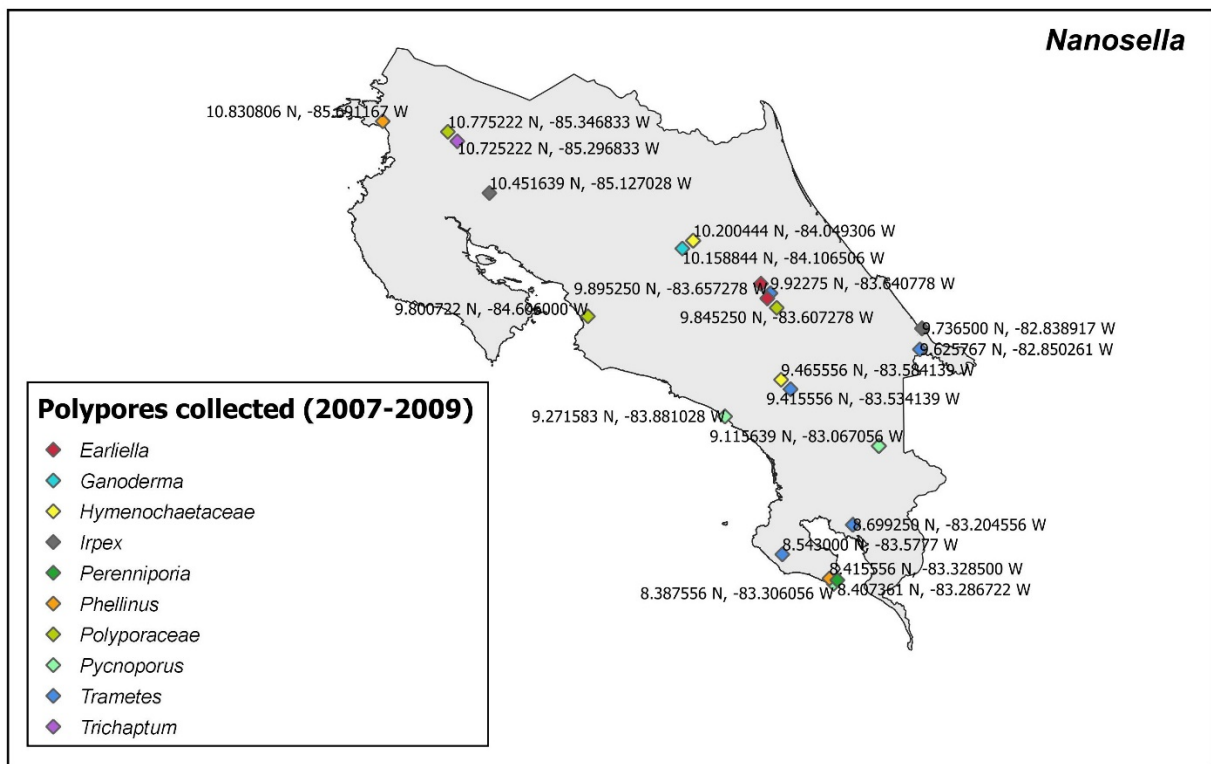
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Figure 2.2. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus *Acrotrichis* (Coleoptera: Ptiliidae). Costa Rica. 2007-2008.



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Figure 2.3. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus *Cylindrosella* (Coleoptera: Ptiliidae). Costa Rica. 2007-2008.



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Figure 2.4. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus *Nanosella* (Coleoptera: Ptiliidae). Costa Rica. 2007-2009.

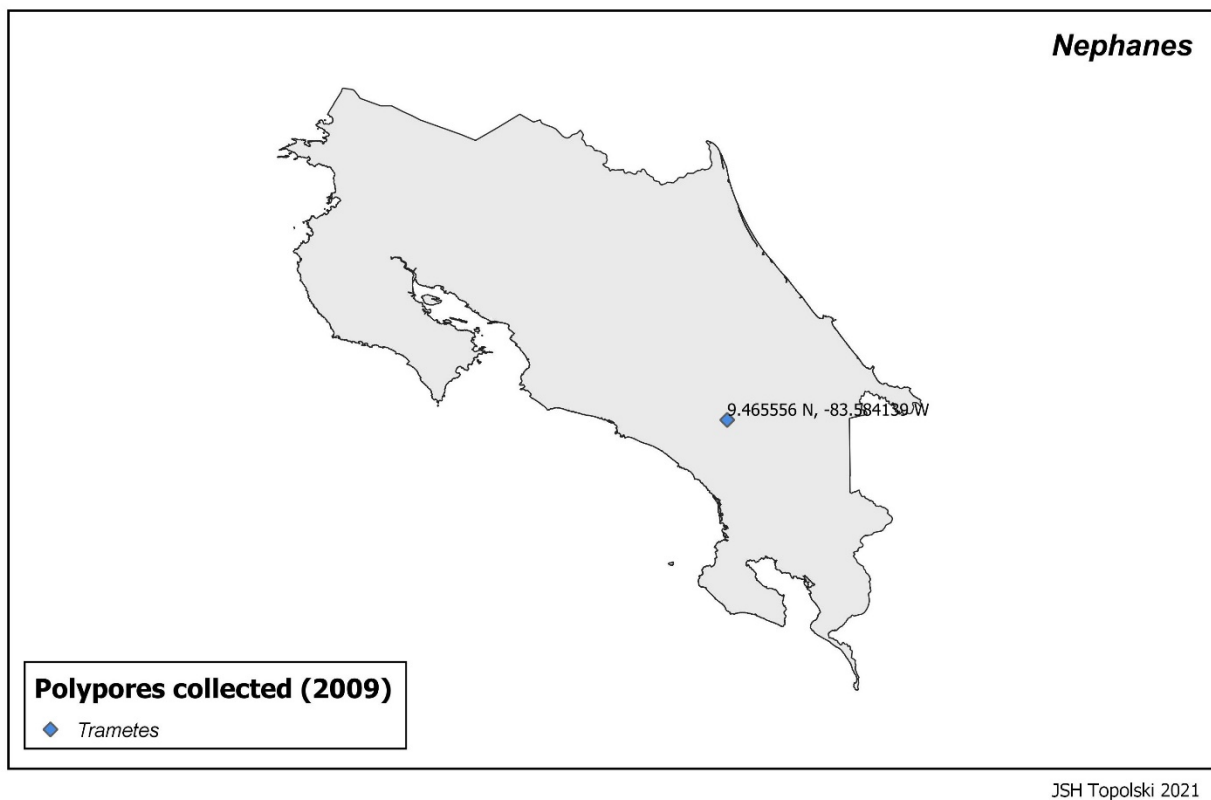


Figure 2.5. Collection site of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus *Nephanes* (Coleoptera: Ptiliidae). Costa Rica. 2009.

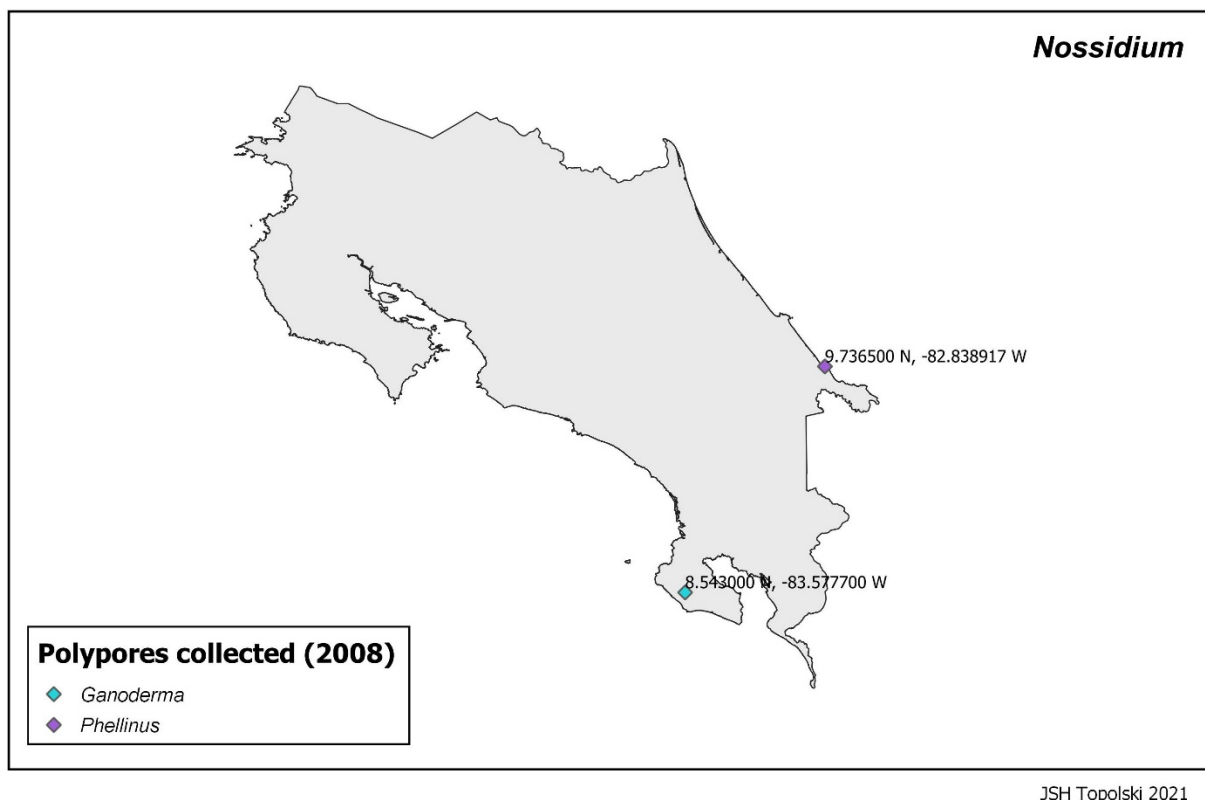
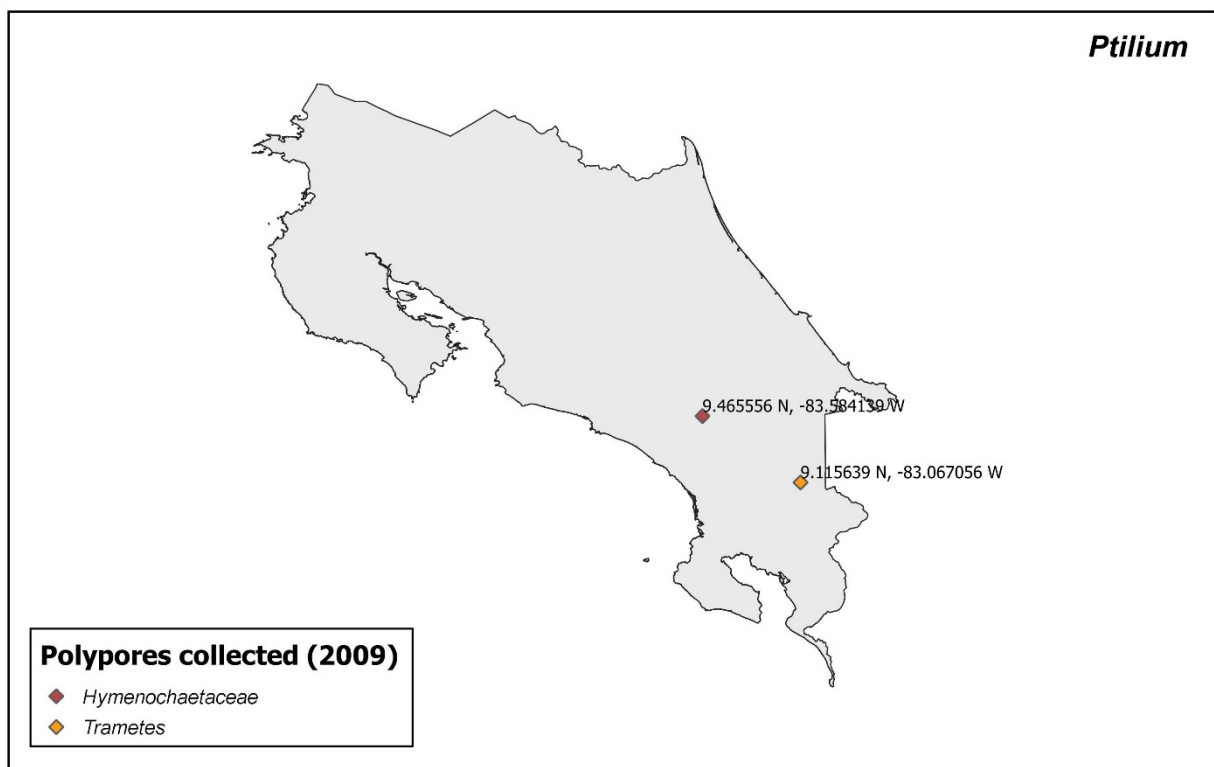
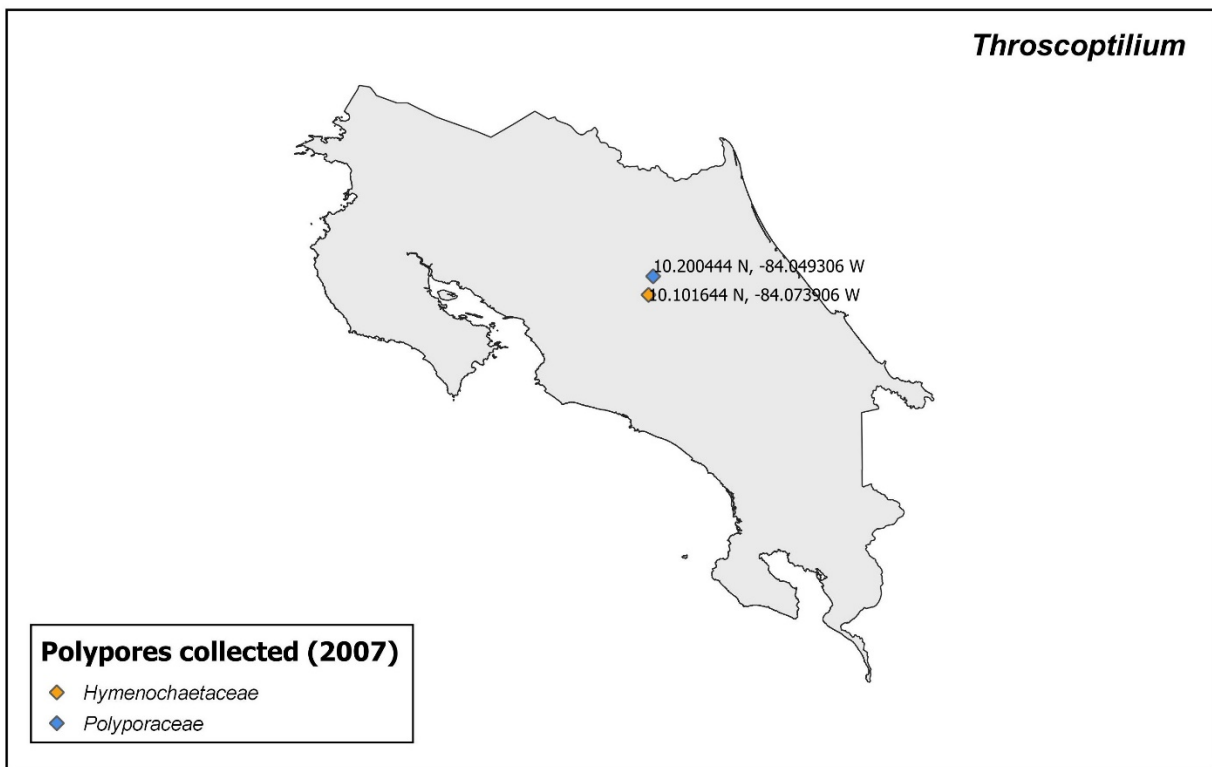


Figure 2.6. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus *Nossidium* (Coleoptera: Ptiliidae). Costa Rica. 2008.



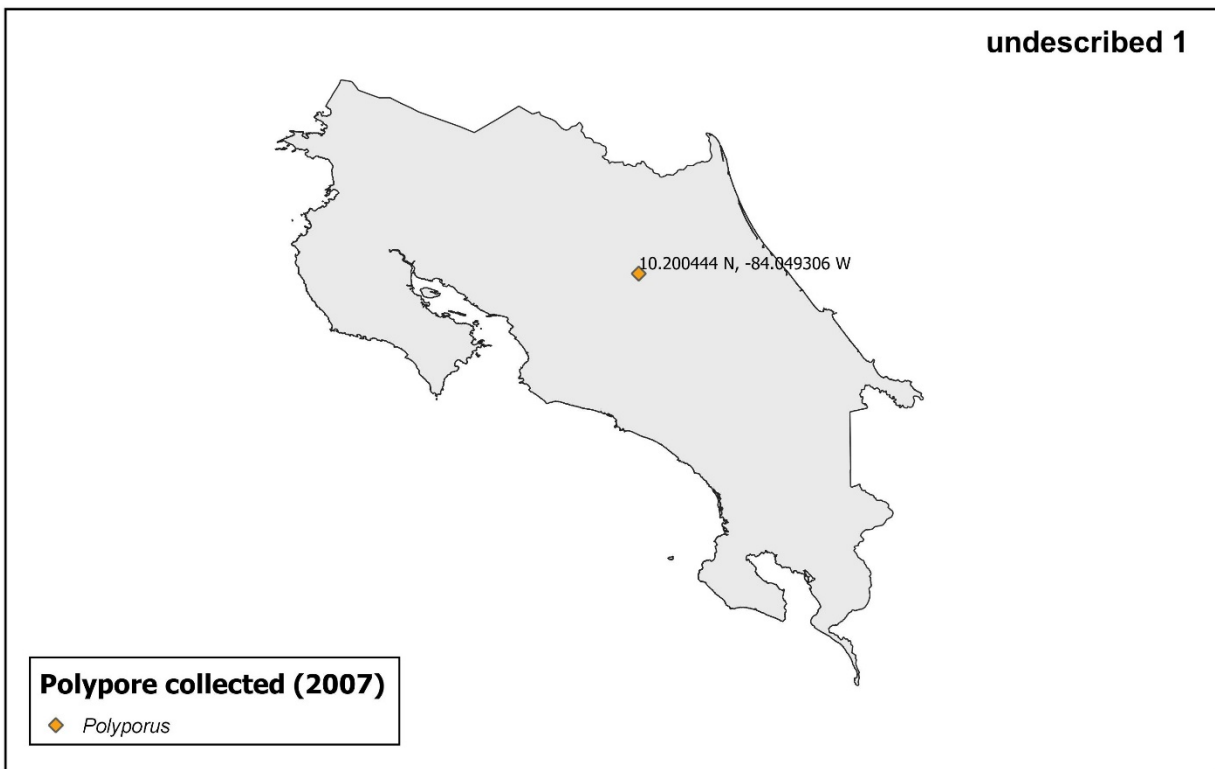
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Figure 2.7. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus *Ptilium* (Coleoptera: Ptiliidae). Costa Rica. 2009.



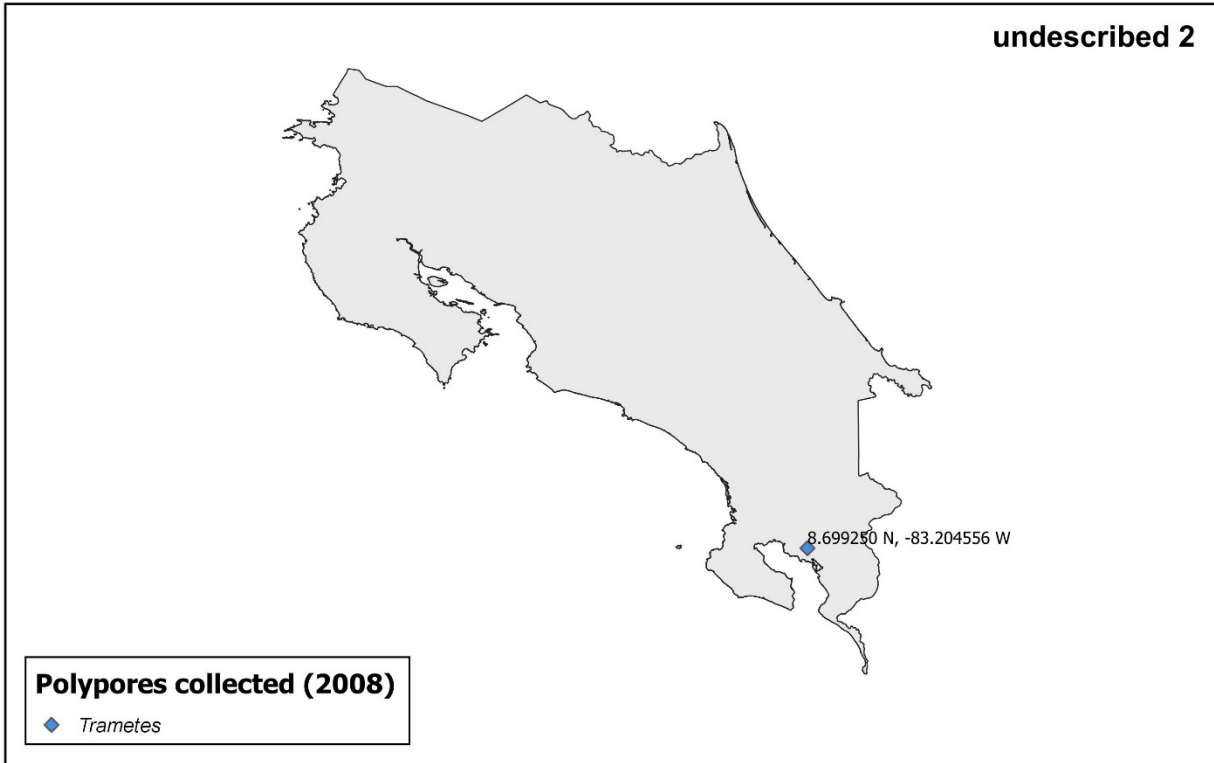
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Figure 2.8. Collection sites of polypore fungi (Basidiomycota: Agaricomycetes), which yielded beetles of the genus *Throscoptilium* (Coleoptera: Ptiliidae). Costa Rica. 2007.



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Figure 2.9. Collection site of polypore fungi (Basidiomycota: Agaricomycetes), which yielded an undescribed Ptiliidae (Coleoptera). Costa Rica. 2007.



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Figure 2.10. Collection site of polypore fungi (Basidiomycota: Agaricomycetes), which yielded a second undescribed Ptiliidae (Coleoptera). Costa Rica. 2008.

2.5 Discussion

We found 48 polypore fungi from which we extracted Ptiliidae beetles. The fungi belong to two different orders and at least four different families, and those that could be identified further were placed in 9 fungal genera. Those that could not be identified to genus were subsequently retained as identified to family. From these polypore fungi, we collected 9 genera of Ptiliidae from two different subfamilies and at least four different tribes (Table 2.1).

Trametes was the most abundant fungus in our collection, and in *Trametes* six of our nine genera of beetle were found. *Nanosella* was the most abundant beetle found in 10 different identified fungal types, which consisted of 39 of our 48 total fungal samples.

2.5.1 Co-occurrence

Co-occurrence by Nanosellini was thought to be rare (Hall 2007). Of the eight Nanosellini species collected on 12 different genera of polypore fungi, Polilov (2008) recorded two sets of co-occurring ptiliids: *Porophila lazovskii* Polilov and *Primorskiella anondonta* Polilov on fungus no.7, *Trichaptum biforme* (Hymenochaetales) on birch, and the other co-occurring pair, *Nanosella russica* Polilov and *Ussurilumpia trichaptumi* Polilov, on fungus no. 8, *T. biforme* on alder.

Our study had a higher level of co-occurrence than in Polilov's 2008 study with all nine ptiliids identified from the tribes Ptiliini, Nanosellini, and Acrotrichini coinhabiting six different polypore groups (genera or families) in various combinations of ptiliid genera. In 35 of our fungal samples, we recovered one ptiliid genus per fungus while ten fungal samples yielded two co-occurring beetle genera, and three fungal samples yielded three different genera of co-occurring ptiliids (Table 2.3).

Nanosella was the most widely distributed beetle among our fungal samples, occurring alone in nine different fungal types, while also co-occurring in three of those same fungal types with other ptiliids, in addition to co-occurring with other ptiliids in yet another fungal type, for a total of ten fungal types inhabited by *Nanosella*. *Cylindrosella* **sp. n.** occurred in four different fungal genera, co-occurring with three different other ptiliid genera.

In 13 polypore samples with two or three coinhabiting beetles, *Nanosella* spp. were found in 11 of the polypores with the polypore *Trametes* spp. accounting for six of the host fungi. In samples where two ptiliids from two tribes were coinhabiting, *Nanosella* (Nanosellini) and *Acrotrichis* (Acrotrichini) accounted for four of the pairings out of seven and for three coinhabiting ptiliids, *Nanosella* and *Acrotrichis* were recorded in all three of the fungi. Also, *Throscoptilium* was found with *Nanosella* and *Acrotrichis* in a fungus from family Polyporaceae in one sample, and in family Hymenochaetaceae in another sample.

The *Cylindrosella* **sp. n.** described in this publication was found alongside *Nanosella* in *Perenniporia* and *Trametes*, and also with *Nossidium* in *Phellinus*. *Nanosella* also shared *Trametes* with *Nephanes* and shared a fungus from family Hymenochaetaceae with *Ptilium*. A single sample of *Polyporus* yielded two new beetles to describe, our *Cylindrosella* **sp. n.** and another ptiliid, undescribed 1, to be described in a future publication. Undescribed 2 was extracted from a sample of *Trametes* along with *Acrotrichis* and *Nanosella*.

2.5.2 Fungal Host Specificity

Most species of derived Nanosellini inhabit fungal hosts, most notably Polyporaceae (Hall 1999). While Graves (1960) found no evidence of host specificity, he questioned if the development and decomposition stages of the conk might contribute to species attraction to polypores at different times of the season.

When Nanosellini is split into groups of basal genera versus derived genera, derived genera appear to be more specific regarding their polypore host, but basal genera are not (Hall 1999). Derived genera were defined as having certain reduced morphological characters and were from the Nearctic and Neotropical regions, including the United States, Mexico, Central America, and South America, while basal genera retained ancestral characters and are from only the southern hemisphere (Hall 1999).

Nanosella (Table 2.1), a derived genus from the tribe Nanosellini, was found on eight fungal genera distributed among *Ganoderma* (Ganodermataceae), *Irpex* (Irpicaceae, Steccherinaceae), *Phellinus* (Hymenochaetaceae), *Trichaptum* (family *incertae sedis*), and on *Earliella*, *Perenniporia*, *Pycnoporus*, and *Trametes* (Polyporaceae), plus other samples identified to family Polyporaceae and Hymenochaetaceae, supporting Hall's (1999) statement that the derived genera of Nanosellini inhabit a range of polypore species. All host fungi of *Nanosella* spp. are distinctly different in size, shape, color, spore type, overall shape, as well as shape of the pore structures and their dissepiments, indicating that *Nanosella* may be generalist feeders. Betz *et al.* (2003) stated that ptiliids could not digest large or heavy spores. Fungal genera cited as domicile for ptiliids were primarily from the family Polyporaceae and a few from family Hydnaceae (Dybas 1976), all being polypore fungi with thin single wall spores (Newton 1984, Hall 1999). The large number of ptiliids found on Polyporaceae might be attributed to spore anatomy and the ability to break open the spores. Spores from the Polyporaceae have a thin single wall and are easier to crack, while spores from Hymenochaetaceae have thicker walls and can be ornamented for strength or protection. Spores from Ganodermataceae are thicker yet, being double walled with structural support between the two walls. Literature examining the mouthparts of Ptiliidae have shown only small differences in the mandibles, mostly remarked to be a wider set of grooves in the soft tissue area posterior of the mola that would serve to guide the spores as they are pushed further into the pharynx (Betz *et al.* 2003).

In noting which families the fungi in our collection belong to, we found Ptiliidae in several different families of polypore fungi (Table 1.1). As we saw the spores in the gut of the beetles, we realize that ptiliids can consume spores of various construction. Here we provide evidence that Ptiliidae do at least attempt to consume heavier spores as a nutritional source from other host fungal families, Hymenochaetaceae and Ganodermataceae (Table 2.1).

We found Ptiliidae genera from tribes that are not Nanosellini in our fungal samples (Table 2.1). *Acrotrichis* (tribe Acrotrichini) and *Nephanes* (tribe Nephanini) are both from subfamily Acrotrichinae. *Ptilium* and *Nossidium* are from tribe Ptiliini in subfamily Ptiliinae. A character previously used to define Nanosellini as distinct from other tribes was that Nanosellini inhabited fungi (Hall 2007). Polilov (2008) described a Nanosellini, *Primorskiella anodonata* Polilov, on *Oxyporus* sp., (Schizoporaceae: Hymenochaetales) and remarked that this was the first Nanosellini to be associated with Schizoporaceae. We show that other tribes also inhabit polypore fungi, and so this may not be a good character by which to place a ptiliid into the tribe Nanosellini.

As our collection protocol was to collect any polypore that we encountered, we cannot assign a particular beetle genus only to the fungi in which we found them. Also, as we did not follow a particular sampling method (Thunes and Willassen 1997) that could have yielded equal numbers or types of samples from each location, we cannot draw statistical conclusions as to comparing the abundance of the ptiliid genera in any region or fungal type.

Our fungal genera are not equal in number of samples examined and other beetle genera that are less represented in our collection may be due to the paucity and diversity of fungi collected. While collecting, a large number of fungal samples found were *Trametes*, which were abundant and easy to identify as polypore, and so is disproportionately represented among our samples. Six of our nine Ptiliidae genera were found in this abundant fungal type, indicating it is a common successful host. *Cylindrosella* **sp. n.** was found in four different genera of fungi with two different spore wall types (Table 2.1). We also consider it fortunate that one single sample of *Polyporus* was encountered and collected because this sample contained an additional possible undescribed ptiliid.

Investigating and recording biodiversity of any taxa is a worthy cause. Knowledge of the life that exists and interacts with each other can help us make decisions on how to best interact with our own environment while keeping it healthy. Creating a public record of the wildlife we share space with can hopefully encourage respect from people who may otherwise be unaware,

especially when so many organisms are so hidden from our eyes. Building the foundation of knowledge is always important to help provide observations and inspiration for researchers who pursue more application-based experiments.

2.5.3 Future Research Questions

Many questions arise from this study. Some Ptiliidae species have been shown to be specialized to termite nests, but it has yet to be demonstrated if other Ptiliidae species are similarly specialized to polypore host species. An inventory of other organisms associated with Ptiliidae and polypore fungi could reveal additional guild relationships. With our conclusions of how often ptiliids co-occur on a polypore host, we should ask why there would be more than one species of Ptiliidae on a single fungus and if they are cohabitating, or if they are merely co-existing. It also has yet to be shown, if Ptiliidae target specific fungal species, how do ptiliids locate polypores to inhabit? How do they reach that destination if they can only flap and slap some, but primarily balloon? Assuming there is an olfactory response that helps the ptiliids locate fungal hosts, perhaps there a correlation between species of ptiliid and the type of rot caused by the fungus, or it is possible that the state of fungal decomposition or damage plays a role in host finding.

2.6 Taxonomy: A New Species of *Cylindrosella* Barber (Coleoptera: Ptiliidae) From Polypore Fungus (Basidiomycetes: Polyporaceae) in Costa Rica

Cylindrosella costaricensis Topolski and Oseto, sp. n.

Abstract

A new species of *Cylindrosella costaricensis* (Coleoptera: Ptiliidae) from Costa Rica is described from polypore fungi (Basidiomycetes: Polyporaceae).

Key Words: Ptiliidae, *Cylindrosella*, taxonomy, featherwing beetles

2.6.1 Introduction

Cylindrosella (Coleoptera: Ptiliidae) is a monotypic genus with *Cylindrosella dampfi* Barber the only described species (Barber 1924). Barber (1924) erected Nanosellinae as a new subfamily of Ptiliidae and placed *C. dampfi* within that subfamily. *C. dampfi* was collected by Dr.

A. Dampf in Mexico from a polypore fungus on the sacred fir, *Abies religiosa* (Pinaceae). Paquin *et al.* (1999), in a study of biodiversity in black spruce forests of Quebec, mentioned a new species of *Cylindrosella* associated with the research but no such description can be found.

Cylindrosella is currently placed in the Nanosellini, but the taxonomic position of *Cylindrosella* remains unresolved. Dybas (1976) postulated that Nanosellinae represented tribal ranking within Ptiliinae, and Sörensson (1997) suggested that Nanosellinae be reduced to tribal rank within Ptiliinae. Hall (1999) tentatively retained Nanosellini in his generic revision of Ptiliidae until a detailed phylogenetic analysis could be performed. Polilov *et al.* (2019) performed morphological and molecular data analyses and retained Nanosellini in the Ptiliinae. Polilov *et al.* (2019) proposed that Ptiliidae be divided into two subfamilies: Nossidiinae and Ptiliinae, and Ptiliinae is regarded as the most poorly defined group of ptiliid genera.

Ptiliidae, according to the dichotomous keys by Hall (2001), is currently split into three subfamilies. Ptiliinae differs from other subfamilies having an elongate body, 10 antennal segments, and an elaborate arrowhead shaped mesoventral process. For comparison, the Acrotrichinae are larger and have an oval body shape, 11 antennal segments, truncated elytra, and a mesoventral process that is weakly developed. The Cephaloplectinae have a limuloid body shape, 8 to 10 antennal segments, truncated elytra, lack hindwings and eyes and associate with ants.

Nanosellini, which is placed within the subfamily Ptiliinae, is believed to be a defined group, to which our new species of *Cylindrosella* belongs (Hall 1999, Sörensson 1997). Nanosellini are associated with a fungal host and have a closed procoxal cavity, elaborate mesoventral process, and contiguous or nearly contiguous coxae. Also diagnostic of Nanosellini is the apical setal field on the elytra.

2.6.2 Materials and Methods

Specimens used in this study were obtained as part of an overall study of the occurrence of Ptiliidae on selected polypore fungi throughout Costa Rica in 2007-2009. Additional details on polypore collection sites, preparation, and identification are given at the start of this publication as are data on ptiliid preparation and identification procedures. The following abbreviations are used for measurements (in mm) and ratios: BW – width of body at metaventer; BL – length of body from apex of labrum to posterior end of abdomen, excluding spine; BL/BW – ratio of body length to body width; EL – elytral length along midline; EW – greatest width of elytron; HL – head length

from tip of labrum to posterior margin of head; HW – head width posterior to compound eye; L_1 and L_2 – lengths of structures 1 and 2; L_1/L_2 – ratio of length 1 to length 2; L/W – ratio of length to width; PL – pronotal length at midline; PWA – pronotal width at anterior margin; PWP – pronotal width at posterior margin. Abbreviation for scientific collection is PERC: Purdue Entomological Research Collection (Purdue University, Smith Hall, West Lafayette, Indiana, 47907, USA, Aaron Smith).

2.6.3 Results

2.6.3.1 Type Locality

Costa Rica, Heredia Province, Braulio Carrillo National Park.

2.6.3.2 Type Material

Holotype female, deposited at Purdue Entomological Research Collection.

Locality: Costa Rica, 10.200444 N, -84.049306 W. Host: *Polyporus* (Basidiomycetes: Polyporaceae). Slide no. CR-14-1.

2.6.3.3 Other Materials Examined

Paratype females, deposited at Purdue Entomological Research Collection.

Locality: Costa Rica: Limon Province, 5 km south Cahuita on Highway 36. 9.736500 N, -82.838917 W. 30:V:2008, C. Oseto leg. Host: *Phellinus* (Basidiomycetes: Polyporaceae). Slide nos. 30-6-1 and 30-6-4.

Locality: Costa Rica: Puntarenas Province, Esquinas Lodge, 1.2 mi North Golfito. 8.699250 N, -83.204556 W. 6:VI:2008, C. Oseto leg. Host: *Trametes* (Basidiomycetes: Polyporaceae). Slide no. E-1-1.

Locality: Costa Rica: Puntarenas Province, Calle Blanca. 8.398972 N, -83.308500 W. 10:VI:2008, C. Oseto leg. Host: *Perenniporia* (Basidiomycetes: Polyporaceae). Slide no. J-10-6.

2.6.3.4 Etymology

The species is named for Costa Rica to honor the country's dedication to protecting its biodiversity.

2.6.3.5 Diagnosis

C. dampfi has an emarginate pygidial tooth, and *C. costaricensis* has a singular acute spine. *C. dampfi* is more elongate than *C. costaricensis*, as *C. dampfi* has a length between 0.6-0.7 mm and a width to length ratio of about 1:5 (Barber 1924), and *C. costaricensis* has measurements of 0.40 mm long and 0.11 mm wide, with a width to length ratio of 1:3.64. *C. dampfi* elytra extend nearly to the posterior apex, whereas elytra of *C. costaricensis* cover abdominal tergites 1 through 6 and partially tergite 7. The spermatheca of *C. dampfi* is J-shaped with spermathecal pump located at the apex, and the spermatheca of *C. costaricensis* is globular with an anterior pump. Note: The original description of *C. dampfi* provided by Barber in 1924 contained an error corrected by Hall (1999) from 11 antennal segments to 10 antennal segments, as *Cylindrosella* **sp. n.**

2.6.3.6 Description of Holotype, Female

Body: (Fig. 2.11) Uniformly pigmented, light reddish-brown, elongate, slender; setae on thorax and elytra, sparse evenly spaced. Measurements: BL = 0.403 mm, BW = 0.110 mm, BL/BW = 3.66.

Head: (Fig. 2.13) Head retracted 0.013 mm into prothorax, HL = 0.077 mm, HW = 0.078 mm; tentorium reduced lacking projections, corporotentorium present, eyes lateral, heavily pigmented; (Fig. 2.14) labrum prominent, LL = 0.022 mm, LW = 0.024 mm, apical edge of epipharynx with cluster of four dorsal and four ventral setae, two long setae posterior to apical setal cluster, two long setae situated mesally and extending well beyond lateral margin of labium, two shorter setae flank mesal setae, two setae situated distally at anterior margin of head capsule; series of gustatory pores. Submentum fused with head capsule; mentum large, rectangular, widest at middle, MW = 0.009 mm, ML = 0.014 mm, two pairs of setae; prementum membranous, labial palp two-segmented minute; maxillary palpi segment III subglobular, largest of 4 segments; segment IV slender almost as long as segment III; segment II unisetose; segment I small; galea fimbriate with

rows of microsetae; apical part of lacinia with series of teeth and short setae; mandible retracted, stout, slightly longer than wide, $L/W = 1.12$, apex with spine, mola pronounced. (Fig. 2.13) Antennae 10-segmented, 2-jointed club with whorls of apical setae on club segments; segment I subglobular, $L/W = 0.69$; segment II trapezoidal, wide proximally and narrow distally, anterior $L/W = 0.07$, posterior $L/W = 0.013$, longer than segment I; segment III $L/W = 2.21$, length equal to IV + V + VI, and less than half as wide as segment II; segments IV and V subglobular, segment IV $L/W = 0.75$, segment V $L/W = 0.75$; segments IV, V, VI, VII, and VIII nearly equal in length; segments IV and V equal in width; segment VI $L/W = 0.57$; segment VII $L/W = 0.42$; segment VIII $L/W = 0.38$; segment IX $L/W = 0.74$; segment X rounded apically, with inverted cone distally, $L/W = 1.0$.

Thorax. Prothorax: (Fig. 2.18) Pronotum cylindrical, sides nearly parallel, tapering slightly from anterior to posterior, $L/W = 0.91$, prothoracic glands absent. Proventral length 0.056 mm. Anterior proventrum longer before acetabulum, posterior short, proventrum closed, acetabulum of procoxae contiguous, nearer to posterior margin of proventrum. Procoxal pockets present at anterolateral corners of procoxal acetabulum. (Fig. 2.12) Prothoracic trochanter unisetose, prothoracic claws subequal in size, $L_1/L_2 = 1.5$, tarsal empodium with 1 long seta with truncated tip; four anterior femoral setae located distally; five anterior tibial setae, four posterior tibial setae, two median ventral setae, apex of tibia with three setae and one long tubular seta half the length of tarsomere III, L/W tarsomere III = 11.5.

Mesothorax: (Figs. 2.11, 2.15) Elytra covering abdominal tergites 1 to 6 and part of tergite 7, ventral surface with elytral stridulatory file, series of longitudinal striations resembling rectangle or parallelogram. Apical setal field of fine setae typical of Nanosellini, elytral apex rounded, smooth, with fine setae. (Fig. 2.16) Transverse sulcus separates basal rectangular mesoscutellum from triangular distal part with slender posteroapical tip, double tip. (Fig. 2.18) Median mesoventral process overall shape similar to arrowhead, wide at mesoventral collar, slightly narrowed posteriorly, then widened anterior to mesocoxae, rounded at side margins, then narrowed again between mesocoxae, slightly overlapping inner margins of mesocoxae, not extending onto metaventrum, apical tooth or process absent. (Fig. 2.12) Mesocoxae contiguous, mesotrochanter bisetose, femur with 3 dorsal and 3 ventral setae, tibia with 11 setae, most anterior apical setae

long reaching middle of tarsus III, 2 large apical spurs, small spinelets located at junction of tibia and tarsi I, mesothoracic claws subequal in size, tarsal empodium with 1 long seta.

Metathorax: (Fig. 2.16) Metascutellum long, narrow, with longitudinal groove extending posteriorly, begins near metathoracic wing attachment point and ends at middle of abdominal segment II. Anterolateral metendoventrite arms reduced, metacoxae nearly contiguous with intermetacoxal condyle bifid, hind angles acute. (Fig. 2.18) Metaventral lines extend from posterolateral corners of metacoxae, fades before reaching the metacoxae. Lateral metaventral suture directed laterally from mesocoxae, curved near pleural region, then directed posteriorly along lateral margin of metaventrum. (Fig. 2.15) Hindwing with single wing strut, wing membrane long and narrow, setal formula 3 + (6-7) + (23-25). Metatrochanter bisetose (Fig. 2.12) with series of pores, 2 dorsal and 1 ventral femoral setae, 4 anterior setae and 7 posterior setae. Metathoracic claws subequal in size, tarsal empodium with 1 long seta.

Abdomen: (Fig. 2.18) Single row of setae on the posterior margin of each abdominal ventrite, first visible ventrite has fewer, finer, shorter hairs, and segment IX lacks setae. Setae are shorter in length than abdominal segment, and increase in length in posterior segments. (Fig. 2.17) Abdominal tergites II, III, IV, and V with strigula. Abdominal tergite VII with wing folding fringe along posterior margin. Thick setae in single row on abdominal tergites II through VIII, line located centrally and running across the tergites laterad. Setae longer in posterior segments. Tergites VIII, IX, and X have thick setae. Spiracles, six, present on abdominal segments I to VI, spiracular setae present. Pygidium with spine unidentate. (Fig. 2.16) Spermatheca round sac with pump, thick tube extends off laterally.

2.6.3.7 Discussion

Relationships among the ptiliids are poorly understood, as a phylogenetic analysis of the entire family has not been completed, and Ptiliinae is regarded as the most poorly defined group of genera. Within the subfamily Ptiliinae is found the tribe Nanosellini, which was once considered a subfamily itself, Nanosellinae, and is believed to be a defined group, to which our new species of *Cylindrosella* belongs (Hall 1999, Sorenson 1997). Nanosellini are characterized by an association with a fungal host, a closed procoxal cavity, elaborate mesoventral process, and

contiguous or nearly contiguous coxae. Also diagnostic of Nanosellini is the apical setal field on the elytra.

Cylindrosella, *Nanosella*, and *Paratuposa*, as derived genera, have been proposed to be closer in relationship than other genera of subfamily Ptiliinae by a limited phylogenetic analysis performed using morphological features to establish clearer boundaries for the tribe Nanosellini (Hall 1999). *Baranowskiella* is less certain in its relationship to the group, but still appears to be in close relation as it shares many characters with other Ptiliinae. *Cylindroselloides* is a more recently named genus that would also fall into this group. Dichotomous keys of Ptiliidae reveal that these genera share a number of morphological features. (Dybas 1990, Hall 2001) with each having 10 antennal segments, head and thorax of similar width ratios, and similar metaventral lines ending anterior to the metacoxae or at the intermetacoxal condyle.

Within the current Nanosellini: *Cylindrosella*, *Cylindroselloides*, *Nanosella*, and *Paratuposa* share autapomorphies, with anterolateral pockets at their procoxal acetabulum, while *Baranowskiella* does not. *Cylindroselloides* has a mesoventral process that extends onto the metaventrum and possesses a fringe at the apex of the elytra, which are absent in *Cylindrosella costaricensis* **sp. n.** The apex of the *Cylindrosella* elytra is smooth with only small, fine setae and lack the distinct, large fringes such as also seen in *Baranowskiella* (Sörensson 1997). *Nanosella* also has a mesoventral process that extends onto the metaventrum as an acute tip, and *Nanosella*'s elongate-oval body has a width to length ratio of no more than 1:3 (Dybas 1990), whereas *Cylindrosella costaricensis* **sp. n.** is more than 1:3.6. The elongate-oval body and a prothorax that widens posteriorly serves to exclude *Nanosella* and *Paratuposa* as a potential genus of our undescribed specimen because *Cylindrosella costaricensis* **sp. n.** has an elongate body and a prothorax that is nearly parallel sided and longer than it is wide. The side margins of the prothorax of *C. dampfi* also are nearly parallel, and the pronotum is longer than it is wide (Barber 1924), and so our new ptiliid best fits into *Cylindrosella*.

The conclusion of placing this new beetle into *Cylindrosella* also makes sense geographically, given the dispersal information known for these genera of Ptiliidae to this point. *Baranowskiella* and *Paratuposa* are reported to be geographically located in Sweden (Sörensson 1997) and New Guinea (Deane 1931), respectively. *Cylindroselloides* is reported from northeast USA (Hall 1999) and southeast Canada (Paquin and Dupérré 2000). *Nanosella* is represented around the globe (Hall 2007) including Africa, Australia, Japan, eastern and southern USA, Central

and South America, but *Nanosella* and *Cylindrosella* are located in overlapping areas of Mexico and southwest USA (Barber 1924). This is first report of *Cylindrosella* in Central America.

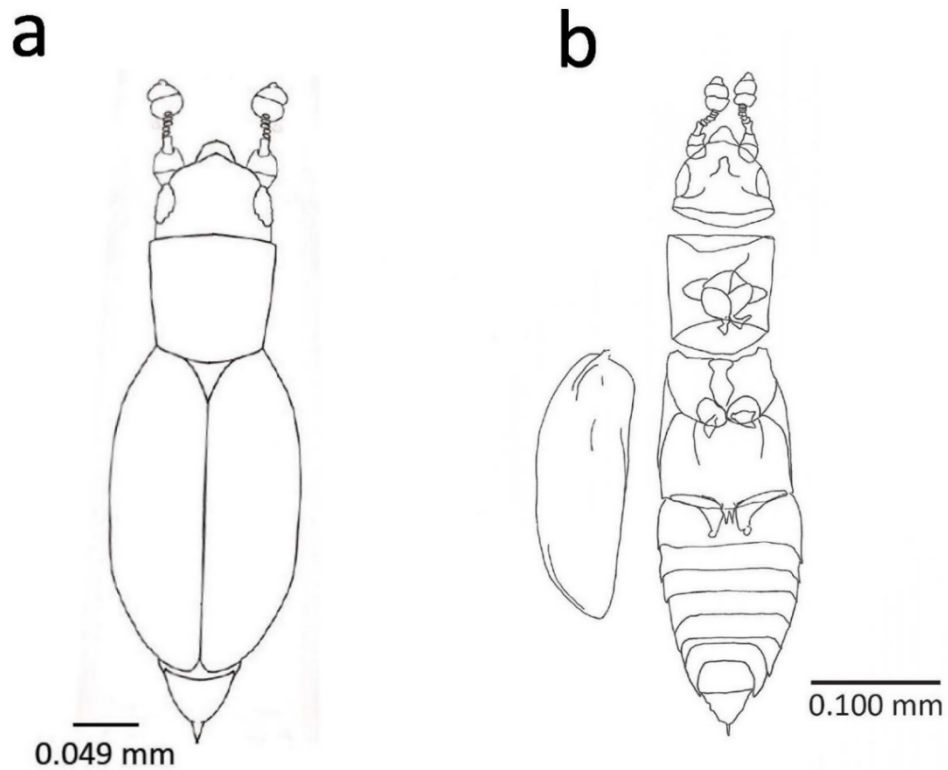


Figure 2.11. *Cylindrosella costaricensis*, whole body without legs. Female. 40x, scale in mm. a) Dorsal view. b) Ventral view.

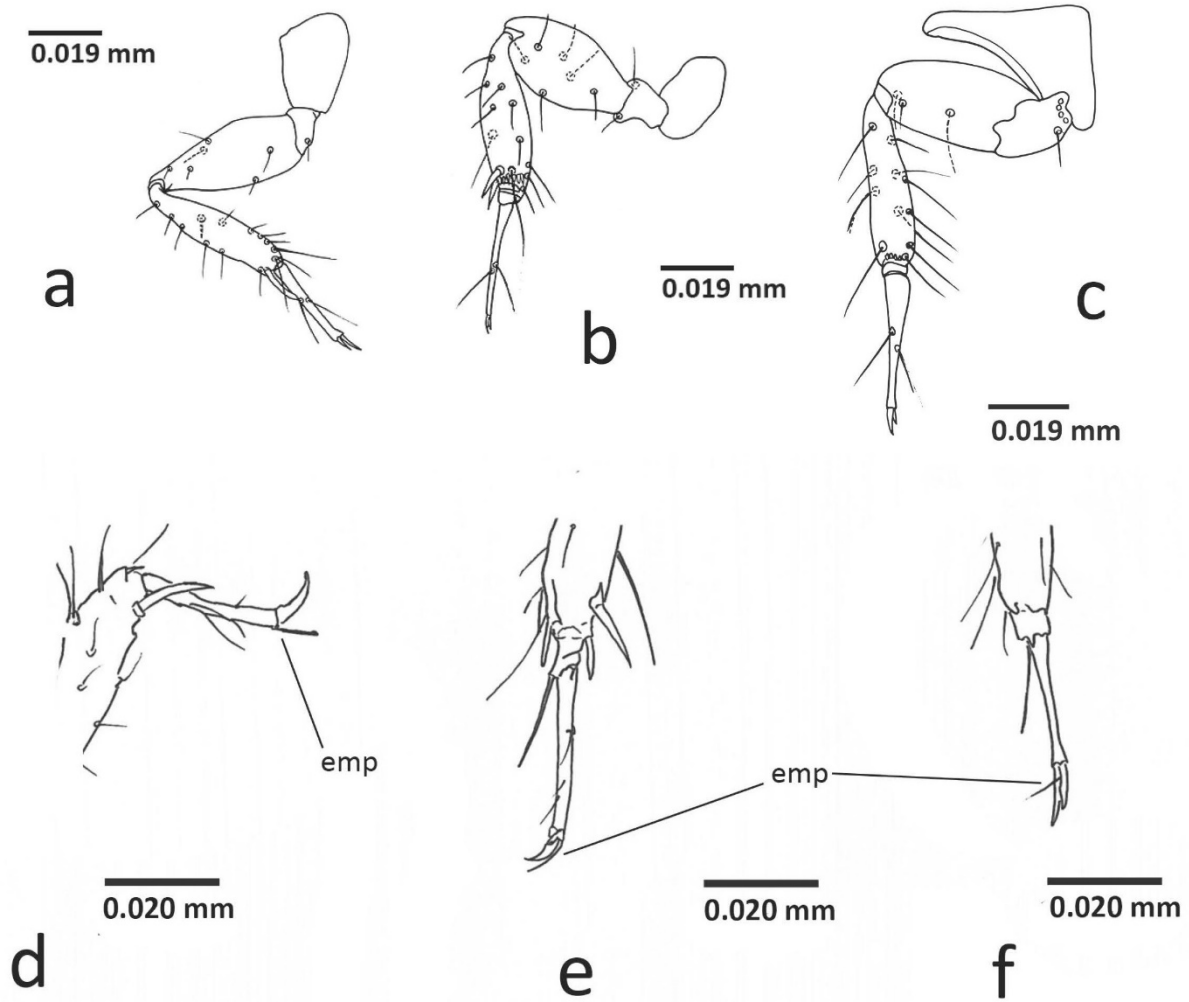


Figure 2.12. *Cylindrosella costaricensis*, prothoracic, mesothoracic, and metathoracic legs. Female. Oil, scale in mm, ventral view. a) Prothoracic leg, right. b) Mesothoracic leg, right, c) Metathoracic leg, right, d) Prothoracic tarsi, left, e) Mesothoracic tarsi, left, f) Metathoracic tarsi, left. emp, empodium with tarsal seta.

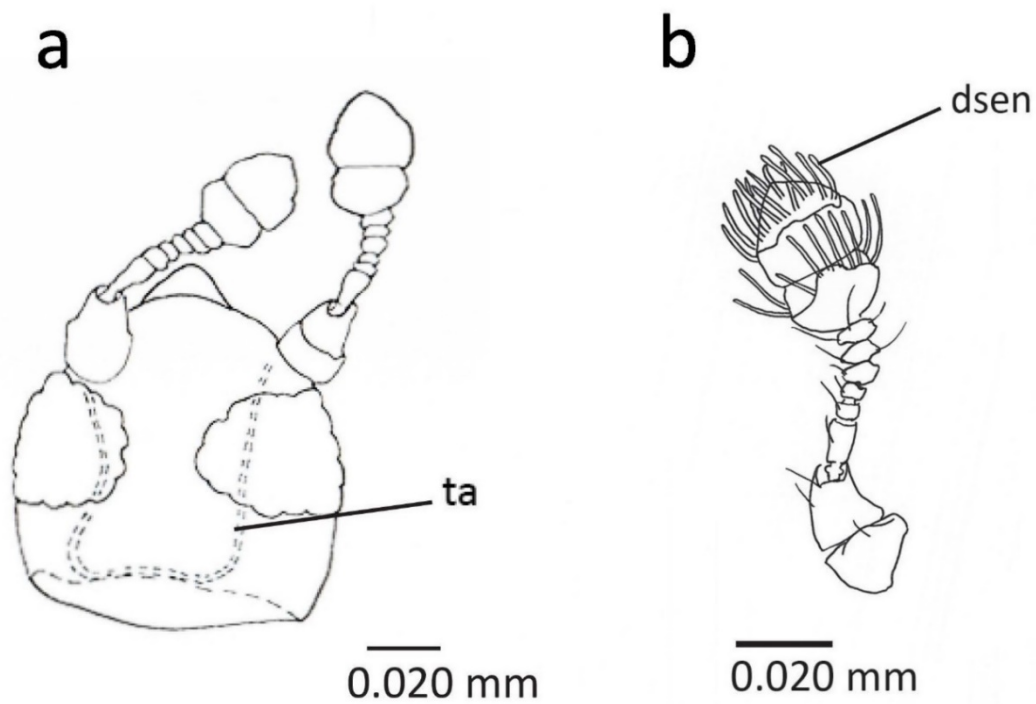


Figure 2.13. *Cyldrosella costaricensis*, head and antenna, ventral view. Oil, scale in mm. a) Head morphology. b) Antenna, left. dsen, digitiform sensilla; ta, tentorial arms.

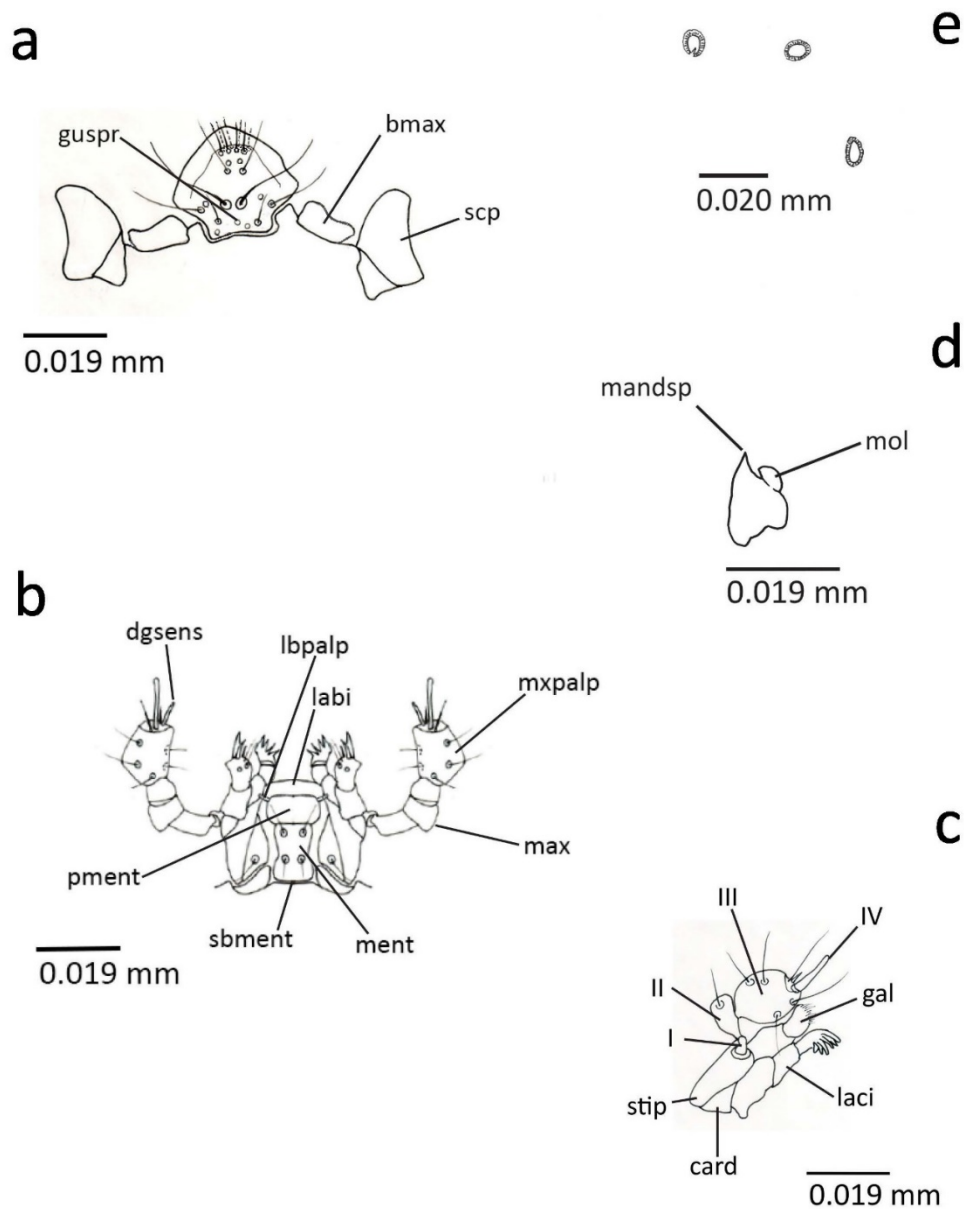


Figure 2.14. *Cylindrosella costaricensis*, mouthparts and spores. Oil, scale in mm. a) Labrum, dorsal view. b) Labium and maxilla, ventral view. c) Maxilla, ventral view. d) Mandible, right, ventral view. e) spores, found in gut content of *Cylindrosella costaricensis*. bmax, base maxilla; card, cardo; dgsens, digitiform sensilla; gal, galea; guspr, gustatory pore; labi, labium; laci, lacinia; lbpalp, labial palp; mandsp, mandibular spine; max, maxilla; ment, mentum; mol, mola; mxpalp, maxillary palp; pment, prementum; sbment, submentum fused with head capsule; scp, antennal scape; segments I, II, III, and IV of maxillary palpus; stip, stipes.

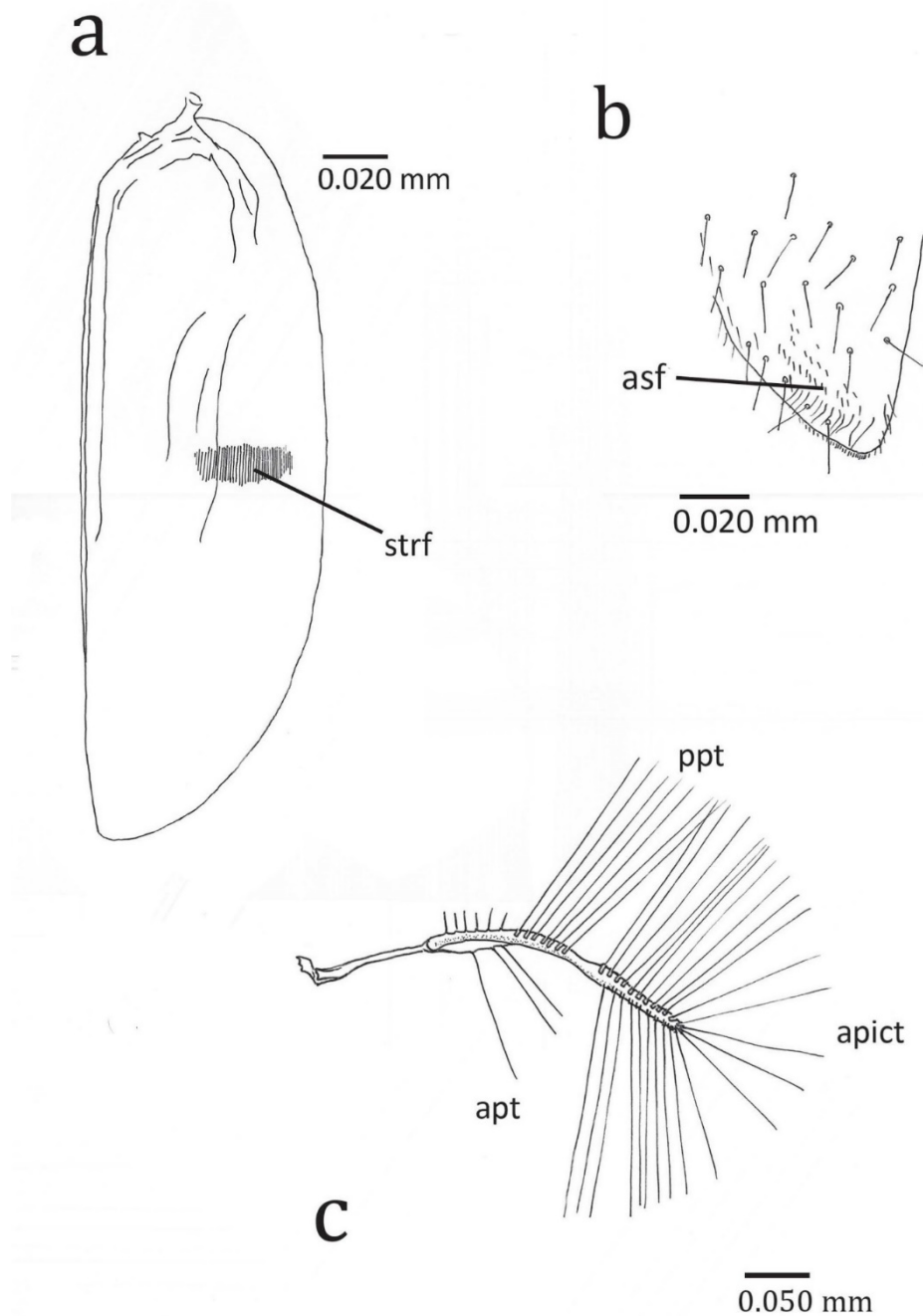


Figure 2.15. *Cylindrosella costaricensis*, mesothoracic and metathoracic wings. Scale in mm. a) Mesothoracic wing, left elytra, ventral view, oil. b) Elytral apex, right wing, ventral view, oil. Fine setae typical of Nanosellini. c) Metathoracic wing. 40x. Left featherwing, single wing strut, wing membrane long and narrow, setal formula 3 + (6-7) + (23-25). apict, apical subgroup of trichia; apt, anteroproximal subgroup of trichia; asf, apical setal field; ppt, posteroproximal subgroup of trichia; strf, stridulatory file.

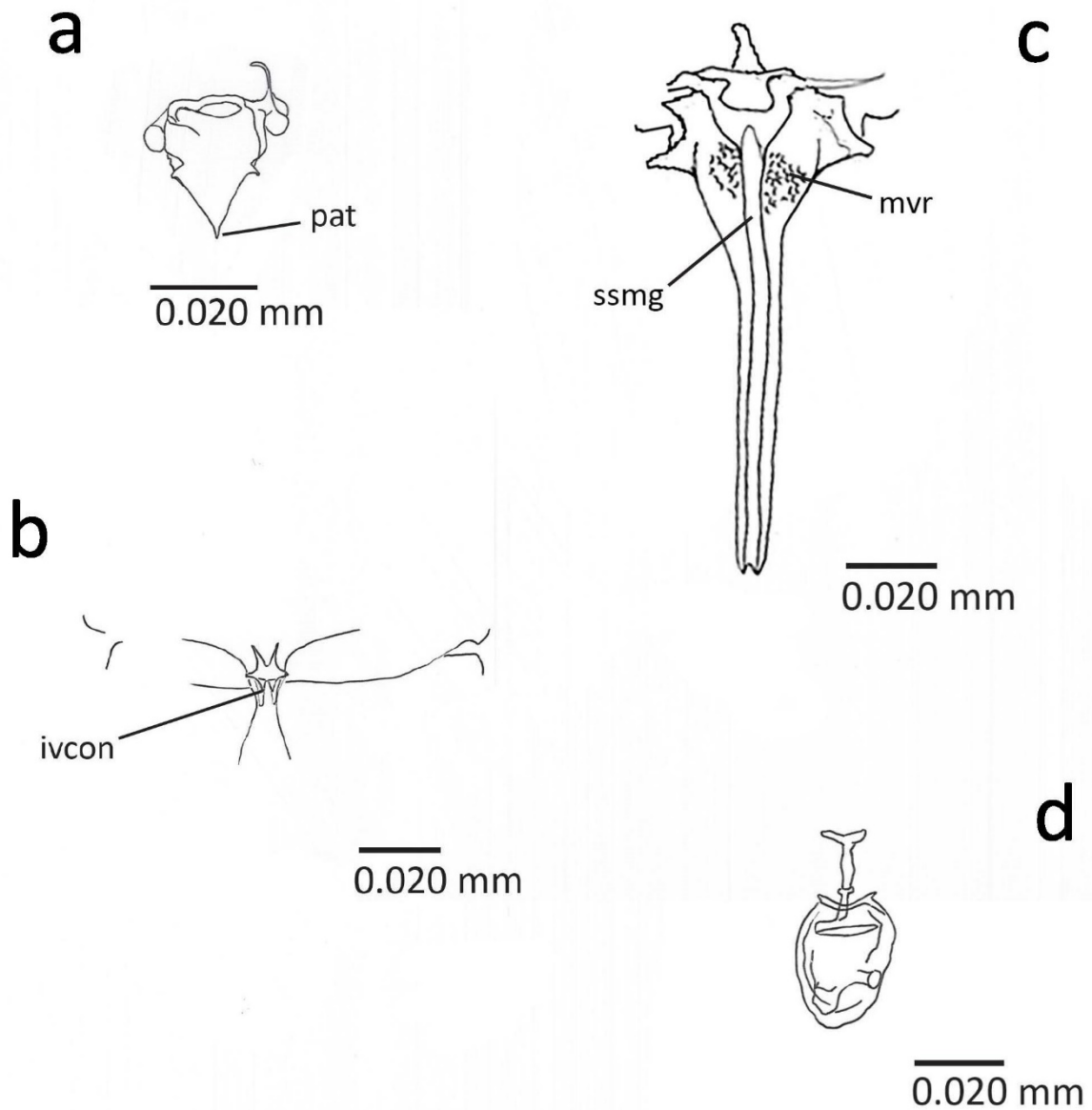


Figure 2.16. *Cylindrosella costaricensis*, oil, scale in mm. a) Mesoscutellum, dorsal view. b) Metendoventrite, ventral view. c) Metascutellum, with texture sampled in small area, dorsal view. d) Spermatheca, globular with anterior pump. ivcon, intermetacoxal condyle; mvr, ventral ridge of metanotum; pat, posteroapical tip; ssmg, scutoscutellar median groove.

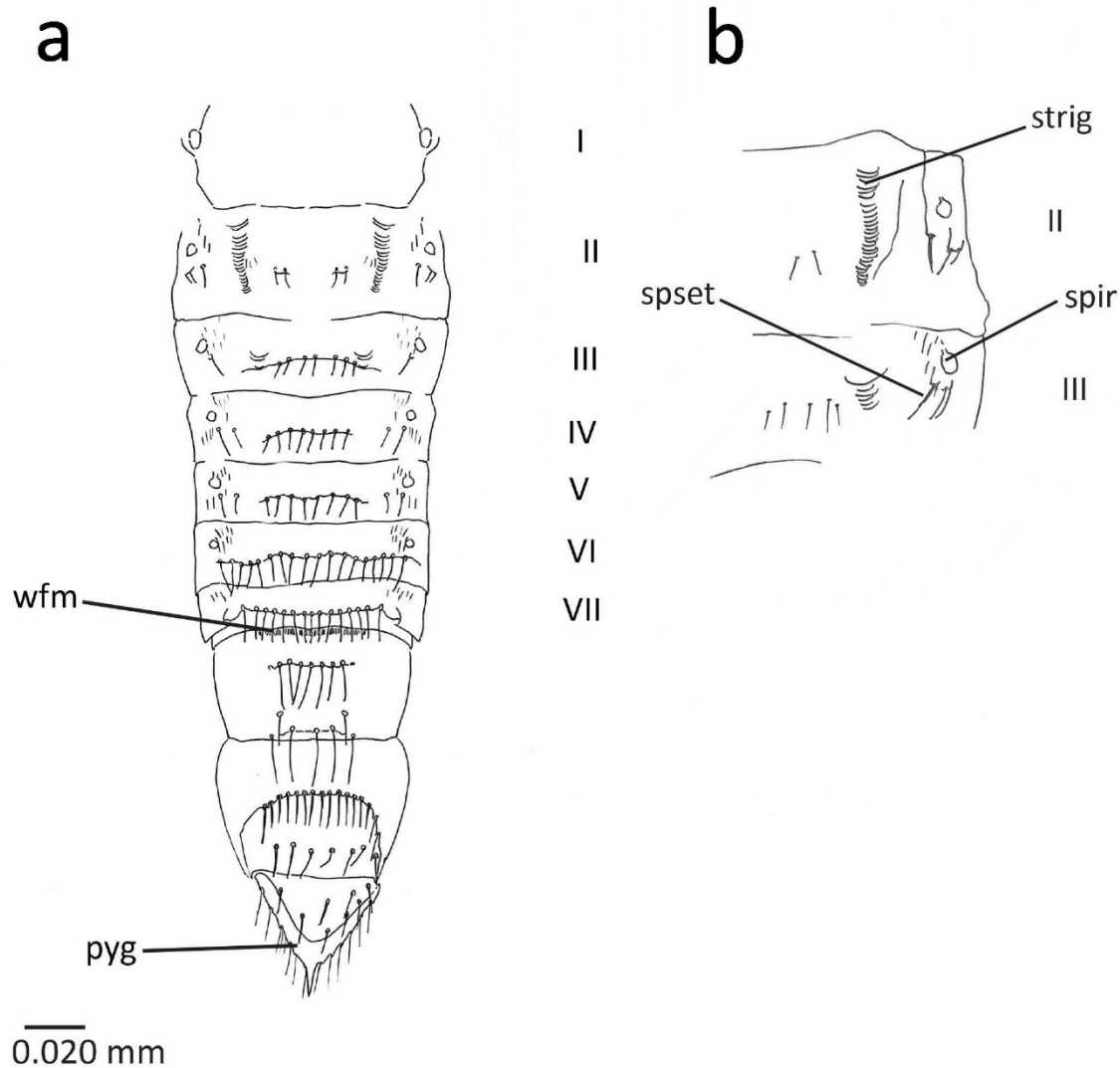


Figure 2.17. *Cylindrosella costaricensis*, abdominal tergites, composite drawing. Oil, scale in mm. a) Abdominal segments, abdominal tergite VII has wingfolding fringe along posterior margin. b) magnification of abdominal segments II and III. pyg, pygidium; spir, spiracle; spset, spiracular seta, strig, strigula; wfm, wing folding mechanism.

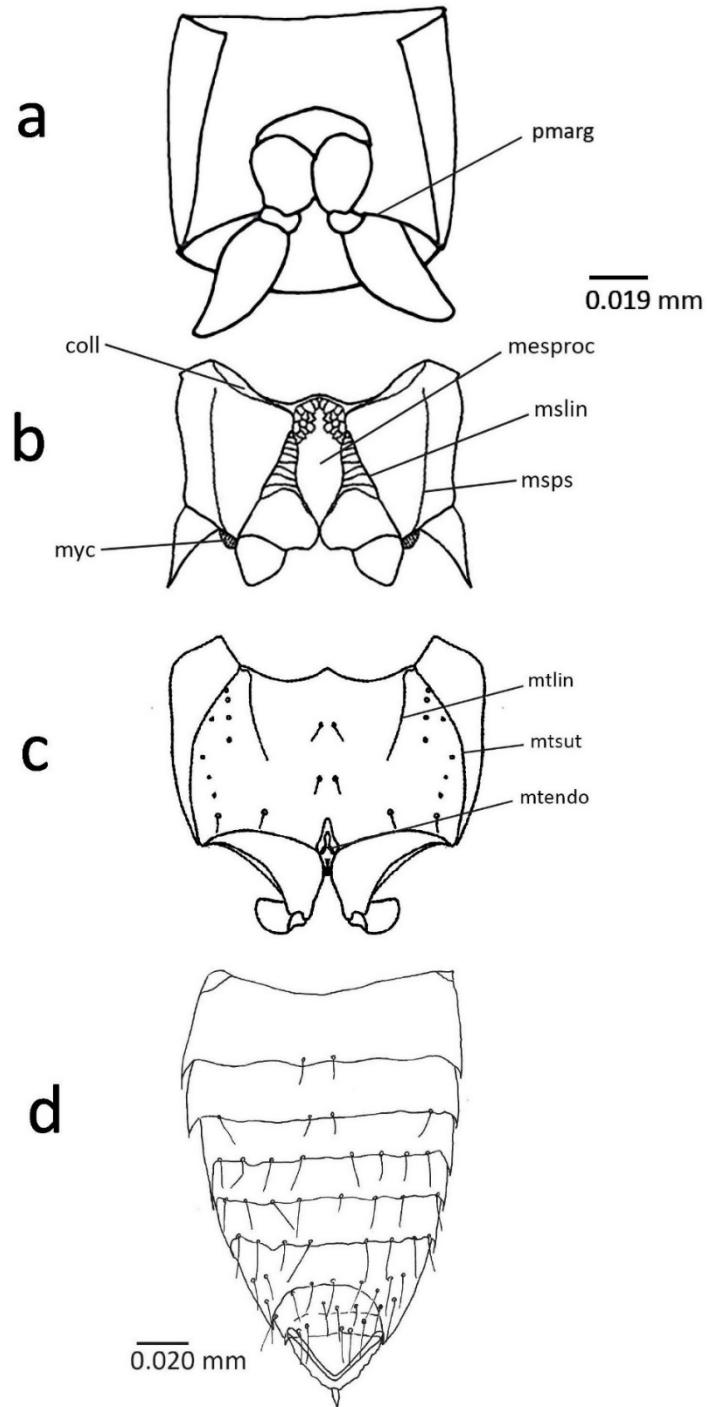


Figure 2.18. *Cylindrosella costaricensis*, ventral view, composite, oil, scale in mm. a) Proventrum. b) Mesoventrum. c) Metaventrum. d) Abdominal ventrites. coll, mesoventral collar; mesproc, mesoventral process; mslin, mesoventral line; msps, mesopleural suture; mtendo, metendoventrite; mtlin, metaventral line; mtsut, metaventral suture; myc, mycangium; pmarg, posterior margin.

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