TAXONOMY OF THE PROTURAN IN DOI INTHANON NATIONAL PARK, CHIANG MAI PROVINCE

NATDANAI LIKHITRAKARN

MASTER OF SCIENCE
(AGRICULTURE)
IN ENTOMOLOGY

THE GRADUATE SCHOOL
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FEBRUARY 2008

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN
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7 February 2008

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ABSTRACT

Soil samples were collected on 30 January 2007 along an altitudinal gradient in Doi Inthanon National Park, Chiang Mai province, Thailand. Five different forest types were chosen at 500 meters intervals: dry deciduous dipterocarp forest; mixed deciduous forest; lower evergreen forest; upper evergreen forest; and cloud forest, respectively. At each site, 10 soil samples were collected using a 15 × 15 centimeters quadrate to a depth of 5 centimeters. The soil samples were then transferred to Berlese funnels for 72 hours for the extraction of soil arthropods. The proturan specimens were separated and permanent slides were made for each sample.

After specimen preparation and identification, it was determined that eleven species and two subspecies of proturans were collected. These 11 species and 2 subspecies consist of 3 described species (*Condeellum regale* (Condé), *C. ishiianum ishiianum* Imadaté, *Silvestridia keijiana* (Imadaté)), one a newly recorded subspecies for Thailand (*C. ishiianum setosum* Imadaté), and 8 undescribed species (*Australentulus* sp., *Baculentulus* sp., *Kenyentulus* sp. 1, *Kenyentulus* sp. 2, *Eosentomon* sp. 1, *Eosentomon* sp. 2, *Eosentomon* sp. 3, and *Eosentomon* sp. 4). These 8 undescribed species have a high probability of being new species. This research demonstrates the potential richness of proturan fauna in Thailand, then additional studies should be continued and expanded.

ชื่อเรื่องวิทยานิพนธ์ อนุกรมวิธานของเสี้ยนนมในอุทยานแห่งชาติดอยอินทนนท์ จังหวัดเชียงใหม่

ผู้เขียน นายณัฐดนัย ลิขิตตระการ

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ดร. องุ่น ลิ่ววานิช กรรมการ

บทคัดย่อ

เก็บตัวอย่างดินในวันที่ 30 มกราคม 2550 ตามระดับความสูงของพื้นที่ป่าในอุทยานแห่งชาติดอยอินทนนท์ จังหวัดเชียงใหม่ โดยแบ่งป่าตามระดับความสูงทุก ๆ 500 เมตร รวม 5 ประเภทได้แก่ ป่าผลัดใบแล้ง ป่าผลัดใบผสม ป่าดิบเขาระดับล่าง ป่าดิบเขาระดับบน และป่าเมฆ ตามลำดับ ในแต่ละชนิดป่าเก็บดินป่าละ 10 ตัวอย่าง ซึ่งมีขนาด 15 × 15 เซนติเมตร ลึก 5 เซนติเมตร นำตัวอย่างดินมาใส่ในกรวยเบอร์ลิสทิ้งไว้ 72 ชั่วโมง จากนั้นนำมาคัดเลือกเสี้ยนนม เพื่อนำไปทำสไลด์ถาวร

หลังจากเตรียมตัวอย่างเสี้ยนนมและทำการจำแนกชนิดเป็นที่เรียบร้อย พบเสี้ยนนม 11 ชนิด 12 ชนิดย่อยซึ่งประกอบไปด้วย 3 ชนิดที่เคยมีการรายงาน (*Condeellum regale* (Condé), *C. ishiianum ishiianum* Imadaté, *Silvestridia keijiana* (Imadaté)) หนึ่งชนิดย่อยพบครั้งแรกในประเทศไทย (*C. ishiianum setosum* Imadaté) และที่เหลืออีก 8 ชนิดที่ยังไม่มีรายงาน (*Australentulus* sp., *Baculentulus* sp., *Kenyentulus* sp. 1, *Kenyentulus* sp. 2, *Eosentomon* sp. 1, *Eosentomon* sp. 2, *Eosentomon* sp. 3, และ *Eosentomon* sp. 4) ซึ่งมีความเป็นได้สูงที่ทั้งแปดชนิดจะเป็นชนิดใหม่ที่ยังไม่มีใครค้นพบมาก่อน งานวิจัยนี้ชี้ให้เห็นถึงความเป็นไปได้ที่จะพบความหลากหลายของเสี้ยนนมเพิ่มขึ้นอีกมากในประเทศไทย ดังนั้นควรที่จะมีการศึกษาอย่างจริงจังและต่อเนื่องต่อไป

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CHAPTER 1
INTRODUCTION

1.1 General

The proturans are minute whitish hexapods ranging from less than 0.5 mm to 2 mm in length. They occur in all regions of the world in forest litter and humus, in tree cavities, under bark on dead trees, under stones, in peat bogs, in pastures, cultivated fields, grassland soils, on moss and lichens, underground in small mammal nests, and in caves (Copeland and Imadaté, 1990). They feed on decomposing organic matter, fungal spores and mycorrhizal fungi (Sturm, 1959; Machida and Takahashi, 2004; Triplehorn and Johnson, 2005). In general, most species can be found in soil surfaces but some are also found 15-25 centimeters at subsoil levels (Bernard and Tuxen, 1991; Copeland and Imadaté, 1990; Krauss and Funke, 1999).

Any studies concerning biology, ecology, karyology, biochemical taxonomy, embryology or anatomy of proturans can provide new, very important and interesting results. However, morphologically based taxonomy is a necessary base (Szeptycki, 2002; Yin, 1999).

1.2 Historical background in Thailand

Szeptycki (2002) reported that there are 688 proturan species in 71 genera worldwide. Europe has 166 described species in 17 genera (Imadaté, 1989; Szeptycki, 2002). In Austria 32 species, in 10 genera, and 3 families are known (Department of the Environment and Heritage, 2006; Tuxen, 1964). In Japan 68 species, 25 genera, and 4 families have been found (Imadaté, 1974; Nakamura, 2003). China has 156 species, 34 genera, and 10 families. The survey in Southeast Asia by Imadaté (1989) found 42 species in 7 genera.

In Thailand, Imadaté (1989) conducted a study concerning the taxonomy and distribution of proturans which found 25 species in 7 genera and 3 families (Condé,1961; Imadaté, 1965, 1989). Most of them are known from Northern Thailand. Only 3 species were found in south (Imadaté, 1965). In the survey, the proturans which were found in Thailand consisted of 15 new species and few of these species were widely distributed.

A study in Doi Suthep-Pui National Park, Chiang Mai province, Northern Thailand found 11 species in 4 genera and 3 families (Likhitrakarn, 2004). Three of the species are new and are pending publication (Nakamura, pers. comm.). A study on collembolan, which are similar to proturan in habitat and ecology, found that there are 130 species of collembolan in Doi Inthanon National Park (Deharveng *et al.*, 1989). These findings suggest that the study of proturan in Thailand and Southeast Asia should be continued and expanded.

1.3 Objectives

The objectives of this study are:

1. To study the taxonomy of proturan in Doi Inthanon National Park, Chiang Mai province
2. To construct pictorial keys of proturan in Doi Inthanon National Park, Chiang Mai province

CHAPTER 2
LITERATURE REVIEW

Proturans are very small, with a length ranging in size from 0.5 to 2 millimeters. Proturans have three distinct body regions (head, thorax, and abdomen). The head displays entognathous mouthparts, but without eyes, or antennae. The thorax is divided into three segments with locomotory appendages and without wings. The forelegs assume sensory function, and are furnished with sensory hairs (sensilla), the shape, number, and arrangement of sensilla are of great systematic importance. The abdomen is divided into twelve segments with abdominal appendages on the first three segments. Proturans are the only insects with anamorphosis, they add body segments during development (Copeland and Imadaté, 1990; Nosek, 1973; Nosek *et al.*, 1978; Szeptycki, 2002; Tuxen, 1964).

2.1 Reproductive characteristics and postembryonic development

Proturans are the only insects with anamorphosis development, meaning during their post-embryonic development the abdomen increases in the number of segments from nine to twelve. They sequentially divide to 6 stages; egg, prelarva, larva I, larva II, maturus junior, and adult (Yin, 1999). Bernard (1976, 1979) show the prelarva as the first stage after eclosion from the egg.

Prelarva (Fig. 1A and B). The mouthparts, foretarsi, and abdominal appendages are not well developed. Foretarsal claws and empodia are absent in suborder Eosentomoidea but present in suborder Acerentomoidea. The abdomen consists of 9 segments.

Larva I (Fig. 1C and D). The mouthparts, abdominal appendages, and claws are developed as in the adult, but the abdomen has only 9 segments. The shape and position of the foretarsal sensilla are only slightly different from adult. During development from larva I to adult, the chaetotaxy evolves progressively. Body setae number usually increases with each molt by adding new setae to those existing in the previous stage. This occurs in every developmental stage.

Larva II (Fig. 1E and F). A new segment emerges between the eighth and terminal segments, giving ten segmented abdomen.

Maturus Junior (Fig. 1G). Two additional segments appear, therefore, the abdomen now possesses twelve segments as in the adult stage. Genitalia in both sexes are still absent.

Adult (Fig. 1H and I). The adult is the final stage of development with twelve segments and well developed outer genitalia.

2.2 Ecology

Proturans occur in all regions of the world where sufficient moisture supports plant growth except in the true arctic and Antarctic. They are among the most abundant soil arthropods. Proturans are to be found in forest litter and humus, in tree cavities, under bark on dead tree, under stones, in peat bogs, in pasture, cultivated field, and grassland soils, on moss and lichens, in underground, small mammal nests, and in caves (Imadaté and Copeland, 1990; Eisenbeis and Wichard, 1985). In Thailand proturan can be found in forest soil and high mountain (Likhitrakarn, 2004).

Likhitrakarn and Chaichana (in press) reported a total proturan population density of 1,031 individuals per square meter (depth 5 centimeters) in Queen Sirikit Botanic Garden, Mae Rim District, Chiang Mai province in Northern Thailand. Proturans were fourth in density behind acari (mites), formicids (ants) and collembolans.

Studies in Europe and Japan have shown that some species are ecologically tolerant and consequently have a wide distributional range, whereas others are intolerant and have more restricted ranges. These studies also indicate that some species with wide ranges are generally abundant, while others with equally broad ranges are less frequently encountered. The limited information available on North American forms makes generalizations hazardous. However, from what we known, a few species occur in both Europe and America or in both Asia and America (Copeland and Imadaté, 1990). Most other species have limited distributions.

They feed on decomposing organic matter, fungal spores and mycorrhizal fungi (Sturm, 1959; Machida and Takahashi, 2004; Triplehorn and Johnson, 2005). Tuxen (1977) suggested to look for proturans at the roots of mycorrhiza-bearing trees.

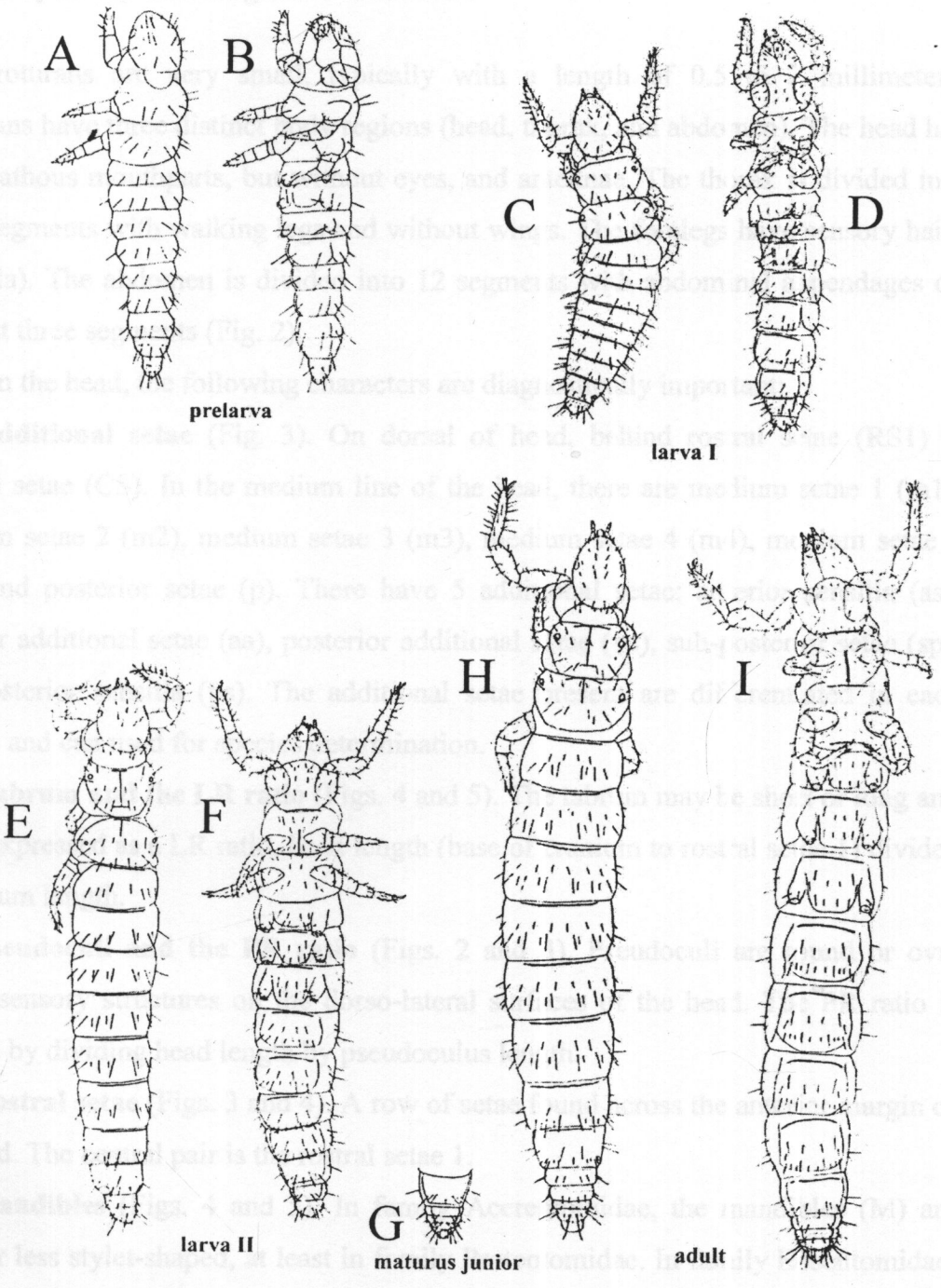


Figure 1 Postembryonic development of proturan, family Eosentomidae, *Eosentomon transitorium* Berlese.

A-B, prelarva dorsal and ventral; C-D, larva I dorsal and ventral; E-F, larva II dorsal and ventral; G, maturus junior abdomen VIII-XII, ventral view; H-I, adult dorsal and ventral (Nosek, 1973).

2.3 Morphology and diagnostic characters

Proturans are very small, typically with a length of 0.5 to 2 millimeters. Proturans have three distinct body regions (head, thorax, and abdomen). The head has entognathous mouthparts, but without eyes, and antennae. The thorax is divided into three segments with walking legs and without wings. The forelegs have sensory hairs (sensilla). The abdomen is divided into 12 segments with abdominal appendages on the first three segments (Fig. 2).

On the head, the following characters are diagnostically important:

Additional setae (Fig. 3). On dorsal of head, behind rostral setae (RS1) is clypeal setae (CS). In the medium line of the head, there are medium setae 1 (m1), medium setae 2 (m2), medium setae 3 (m3), medium setae 4 (m4), medium setae 5 (m5) and posterior setae (p). There have 5 additional setae: anterior sensilla (as), anterior additional setae (aa), posterior additional setae (pa), sub-posterior setae (sp), and posterior sensilla (ps). The additional setae present are differentiated in each species and can used for species determination.

Labrum and the LR ratio (Figs. 4 and 5). The labrum may be short or long and it can expressed as a LR ratio, head length (base of cranium to rostral setae 1) divided by labrum length.

Pseudoculi and the PR ratio (Figs. 2 and 3). Pseudoculi are round or oval paired sensory structures on the dorso-lateral surfaces of the head. The PR ratio is derived by dividing head length by pseudoculus length.

Rostral setae (Figs. 3 and 4). A row of setae found across the anterior margin of the head. The central pair is the rostral setae 1.

Mandibles (Figs. 4 and 5). In family Acerentomidae, the mandibles (M) are more or less stylet-shaped, at least in family Protentomidae. In family Eosentomidae, they may be very long and extremely narrow, very long and more broad, intermediate, or broad and short.

Maxilly palp (Figs. 2, 4, and 5). Family Eosentomidae have the maxillary palp (MP) with three-segments ending in a tuft of setae, a few setae situated more proximally. On the second segment lateral sensillum *s* is present. In family Protentomidae and family Acerentomidae on the second segment with two sensilla.

Labial palps (Figs. 5 and 6). They usually display one segment, ending in a tuft of setae like the maxillary palp (Fig. 6A) or reduced (Figs. 6B and C), with three or four setae and often sausage-like sensillum.

Canal of maxillary gland (Figs. 2 and 5). There is a single tube in suborder Eosentomoidea but is varied and systematically very important in suborder Acerentomoidea. The canal of maxillary gland (CMG) usually has a heart-shaped widening (calyx) with or without peculiar appendices. Sometimes they are obscured or damaged during the mounting process.

On the thorax, the most important characteristics are:

Thoracic legs (Fig. 2). All three legs normally consist of six segments; coxa, trochanter, femur, tibia, tarsus and pre-tarsus. The middle and hind legs were walking legs but the forelegs use as sensory functions, replacing the missing antennae and the tarsus is very useful systematically.

Abdominal appendages (Figs. 2 and 7). In family Eosentomidae (Fig. 7A-C) all three pairs are similar, each appendage bearing five setae and a terminal vesicle. In family Acerentomidae, the abdominal appendages show differentiation and provide very useful taxonomic characters, especially between the genera. For example, genus *Australentulus* (Fig. 7D-F) has abdominal appendage I with four setae and a terminal vesicle but abdominal appendages II-III with 3 setae without terminal vesicles. Family Protentomidae (Fig. 7G-I) are characterized by the reduction of the third pair which has no terminal vesicle. Three setae are found on the abdominal appendage III in genus *Condeellum*.

Foretarsus (Figs. 2, 8-10).

This character is importance taxonomically and essential for species determination. The foretarsus can be visualized as a four-sided structure with an anterior view (dorsal) surface containing the alpha (α) setae, the posterior view (ventral) with the beta (β) setae, the exterior view with the gamma (γ) setae, and the interior view with the delta (δ) setae. The setae surround the sensilla and serve to locate them. The size, shape, and position of the sensilla in relation to the setae are constant within the species but vary inter-specifically.

In family Acerentomidae (Fig. 8), there are three anterior foretarsal sensilla, *t*-1, *t*-2, *t*- 3; seven exterior sensilla, *a*-*g* ; and three interior sensilla, *a'*, *b'* ,c' ; seven anterior setae, α1-7; seven posterior setae, β1-7; five exterior setae, γ 1-5; and six interior setae; δ 1-6.

In family Eosentomidae (Fig. 9), there finds eight α, nine β, eight δ, and five γ setae. On the anterior surface, the claviform *t*-1 is easily identified. It is located near the center of the tarsus on the level of seta α3' or between it and α3. The *t*-1, *t*-2, and *t*-3 form a straight line along the tarsus. The pre-tarsal sensillum *s* is just beyond the *t*-3.

In family Protentomidae (Fig. 10), the reduction of sensilla and setae is not rare. An extreme reduction is found in the genus *Condeellum*, which has only seven foretarsal sensilla.

The BS ratio. The distance of sensillum *t*-1 to the base of tarsus divided by the distance of sensillum *t*-1 to apex of tarsus.

The TR ratio. The tarsal length divided by claw length.

Empodium (Figs. 8-10). It may be short or long. In family Eosentomidae (Fig. 9) it is long, in family Acerentomidae (Fig. 8) and the Protentomidae (Fig. 10), it is relatively short.

The EU ratio. The empodium length divided by claw length.

Spiracles (Fig. 11). It is situated at mesonotum and metanotum. They are present in suborder Eosentomoidea. These lead to the tracheal system, with longitudinal tracheae to the head, prothorax and mesothorax from mesothoracic spiracle, and to metathorax and abdomen from the metathoracic spiracle (Berlese, 1909). The tracheae from the different spiracles are not connected with each other, neither in the longitudinal nor the transverse direction (Prell, 1911). The spiracles are situated dorsolaterally and protected by a group of bristles. In suborder Acerentomoidea, the spiracles, as well as tracheal system, are wholly absent (Nosek, 1973).

Chaetotaxy (Fig. 12). The system for naming the setae was devised by Tuxen (1949) and slightly modified in 1964. The thoracic and abdominal setae generally occur in two rows, are numbered tergals. Setae in the anterior row are prefixed with the capitals letter A (A1, A2, A3, A4, A5) and those in the posterior row with P plus the numeral. In the posterior rows, there are the accessory setae, and these are

identified with a letter (P1a, P2a, P3a, P4a, P5a). It start count in the center of each row.

Comb (Figs. 2 and 13). The eighth abdominal segment carries posteriorly on either side the opening of the large abdominal glands. This opening is always covered by a "lid", which in family Eosentomidae is undifferentiated but in family Acerentomidae is diverse, with or without teeth differing in number and length; it is often called comb VIII.

Striate band (Figs. 2 and 13). In family Acerentomidae, they have a characteristic, so-called striate band, on the proximal part of the eighth abdominal segment. It consists of two lines, with or without striate in between. In the Protentomidae the band is represented by a single line. In family Eosentomidae it is missing. The striate may have the character of a regular grate, called "striate band well developed", if no striate are visible, it is termed "reduced".

Genitalia (Fig. 14). The external genitalia differ from those of all other insects. In both sexes they open ventrally between the eleventh segments and telsons (the gonotreme). In both sexes there are a pair of basal arms and two styli. The male arms, or periphallus, carry setae but the female arms, perigynium, never do. The gonopore is not the styli, and thus double, in the male but between the styli, and thus single, in the female. The male genitalia are generally alike in all species, though differing between suborder Eosentomoidea and suborder Acerentomoidea, where the genitalia show distinct specific differences in the female. In suborder Eosentomoidea the styli most often carries a curious structure, called the processus sternalis (plural: processus sternales), which is of a characteristic shape between species and thus of great taxonomic importance. In suborder Acerentomoidea there is no such structure; each of the styli ends in an acrostylus, the shape of which may also be of taxonomic value (Tuxen, 1985).

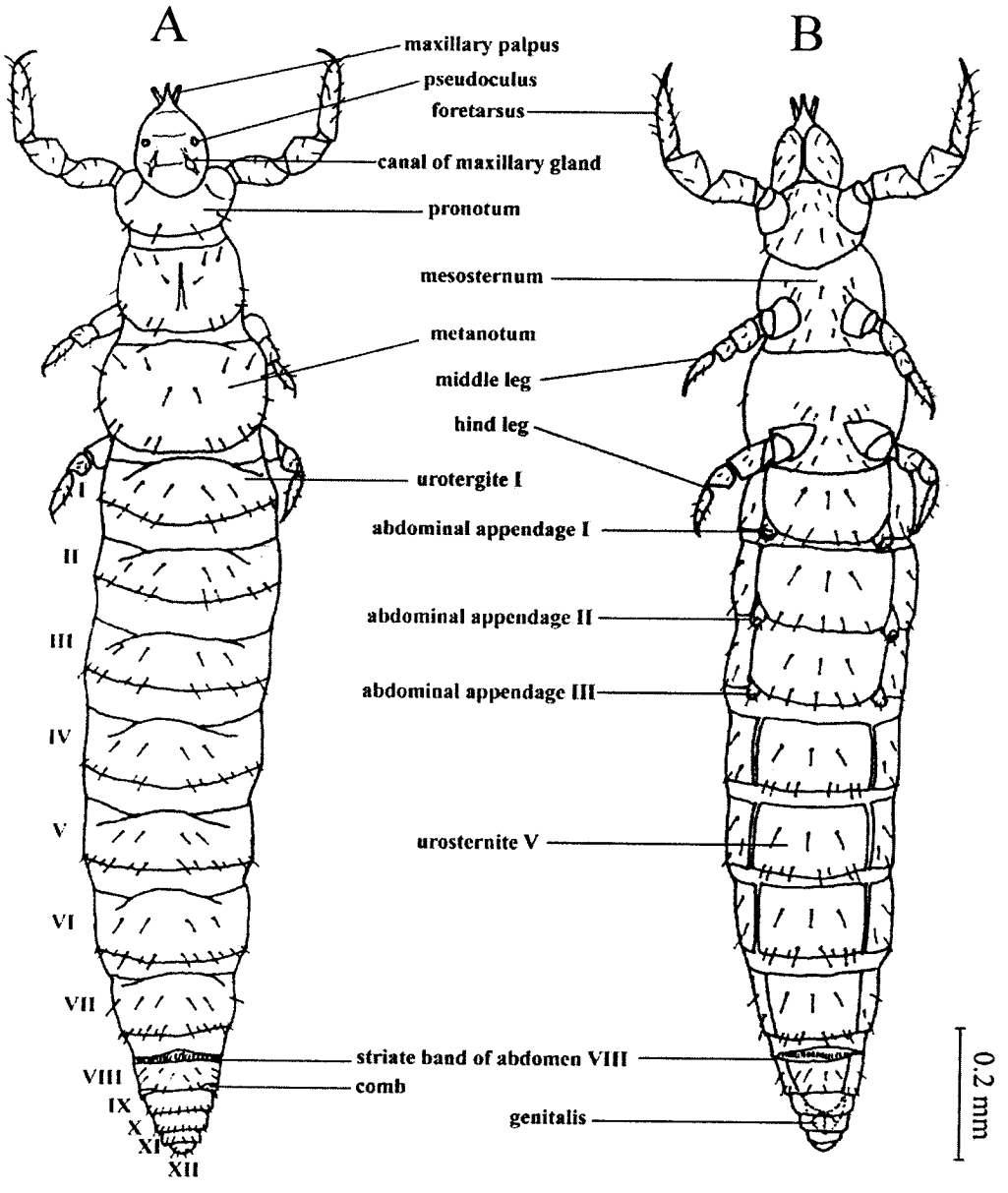


Figure 2 Morphological features of proturan, family Acerentomidae, genus *Australentulus*.

A, dorsal view; B, ventral view.

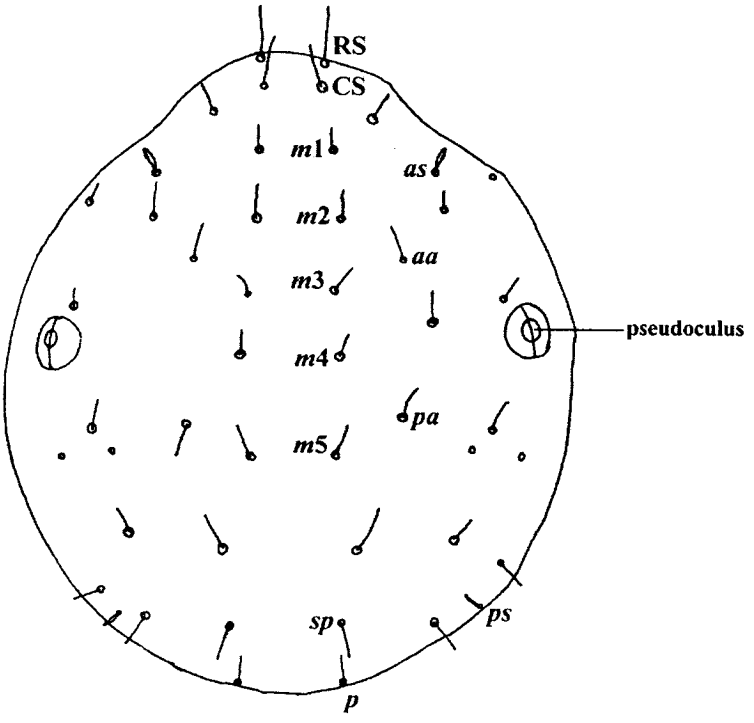


Figure 3 Additional setae on dorsal of head.

RS1, rostral setae; CS, clypeal setae; m1, medium setae 1; m2, medium setae 2; m3, medium setae 3; m4, medium setae 4; m5, medium setae 5; sp, subposterior setae; p, posterior setae; ps, posterior sensilla; pa, posterior additional setae; aa, anterior additional setae; as, anterior sensilla.

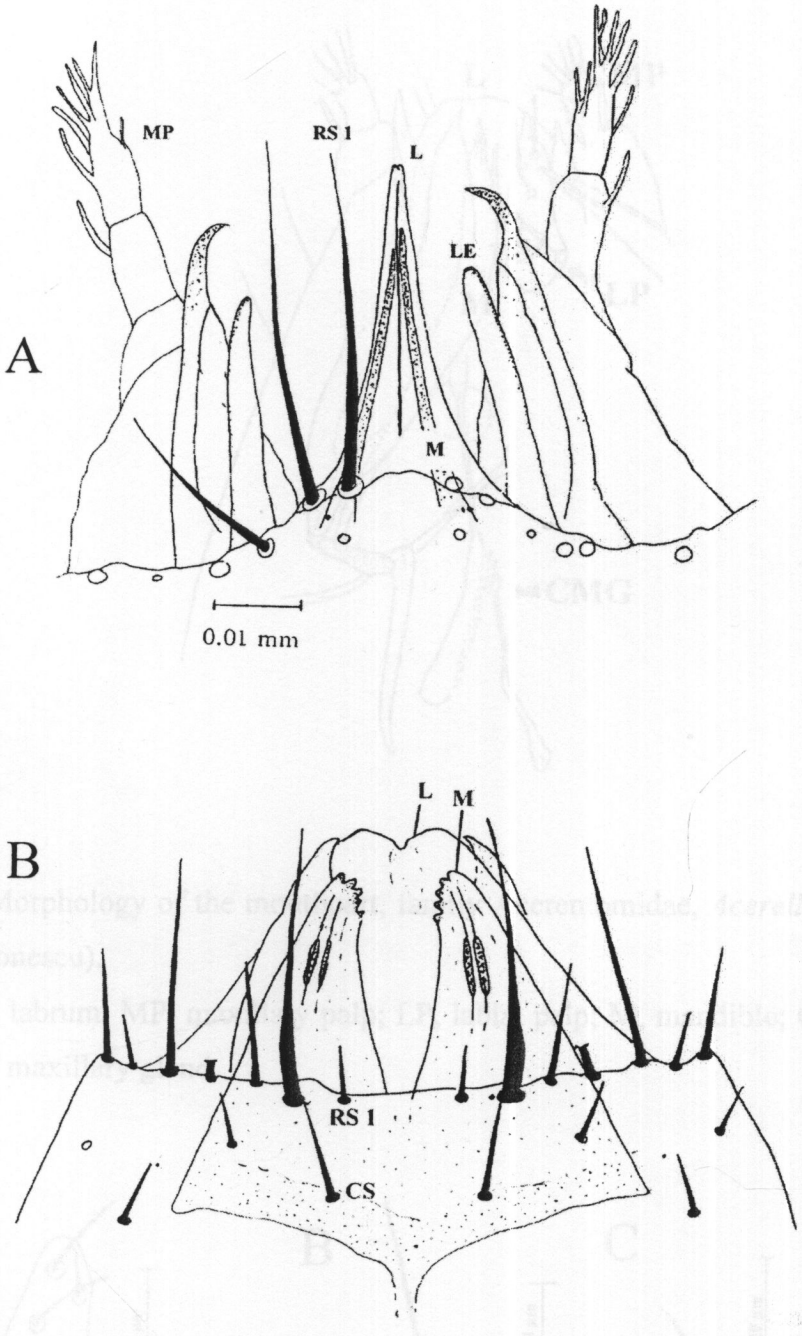


Figure 4 Morphology of the mouthparts, family Acerentomidae, genus *Styletoentomon* and family Eosentomidae, genus *Eosentomon*.

A, genus *Styletoentomon*, anterior of head; B, genus *Eosentomon*, anterior of head; MP, maxillary palp; RS1, rostral setae 1; L, labrum; LE, lobi externi of maxilla; M, mandible; CS, clypeal setae (Nosek, 1973).

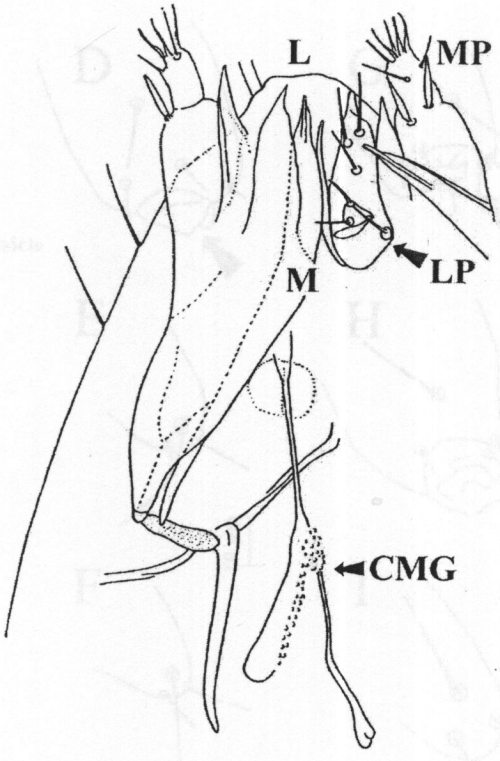


Figure 5 Morphology of the mouthpart, family Acerentomidae, *Acerella muscorum* (Ionescu).

L, labrum; MP, maxillary palp; LP, labial palp; M, mandible; CMG, Canal of maxillary gland.

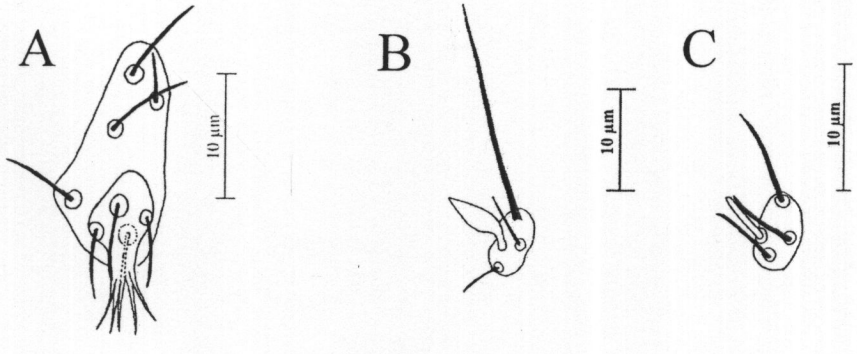


Figure 6 Labial palps of proturans.

A, genus *Condeellum*; B, genus *Australentulus*; C, genus *Baculentulus*.

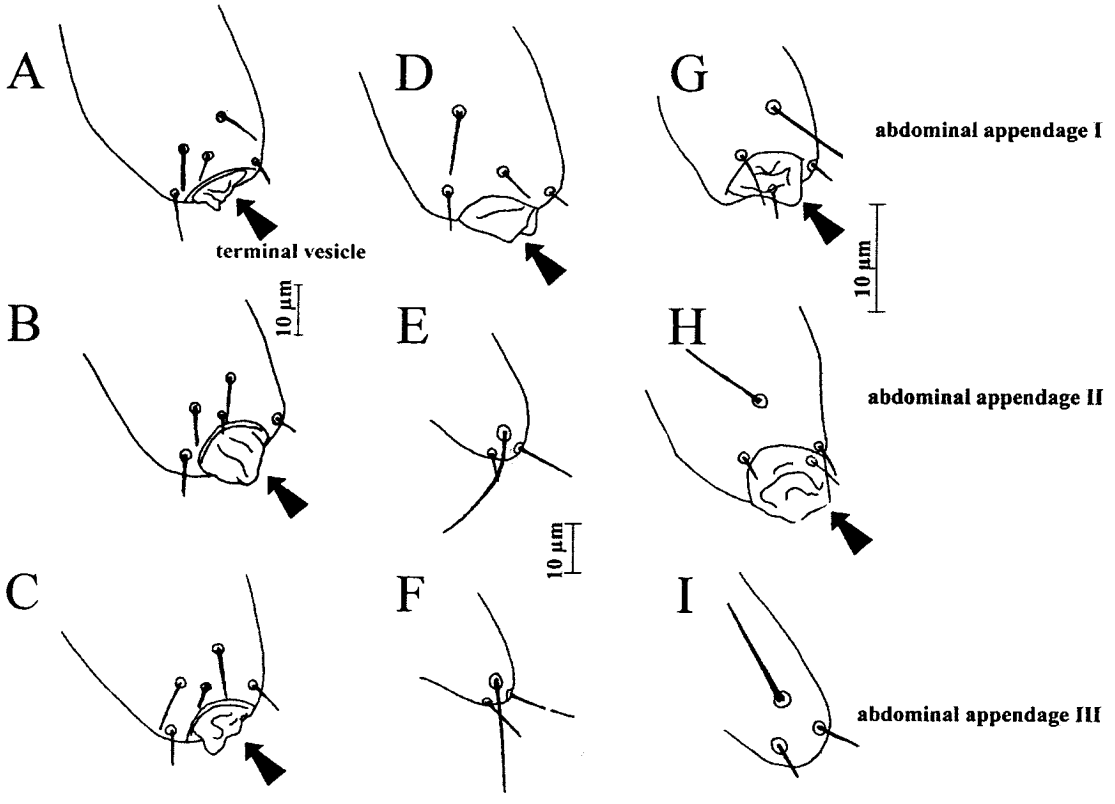


Figure 7 Abdominal appendages of proturans.

A-C, family Eosentomidae, genus *Eosentomon*; D-F, family Acerentomidae, genus *Australentulus*; G-I, family Protentomidae, genus *Condeellum*.

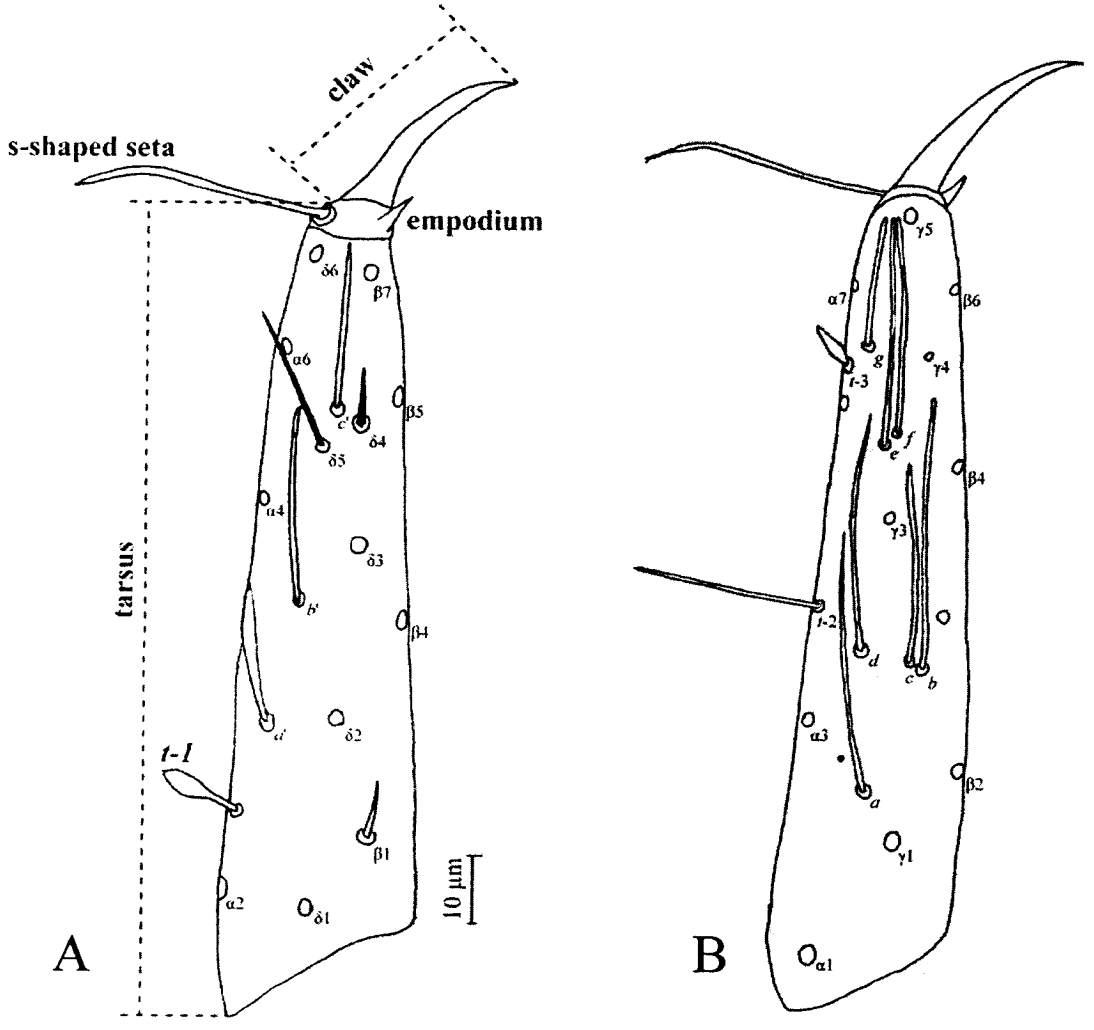


Figure 8 Foretarsus of family Acerentomidae, genus *Australentulus*.
A, interior view; B, exterior view.

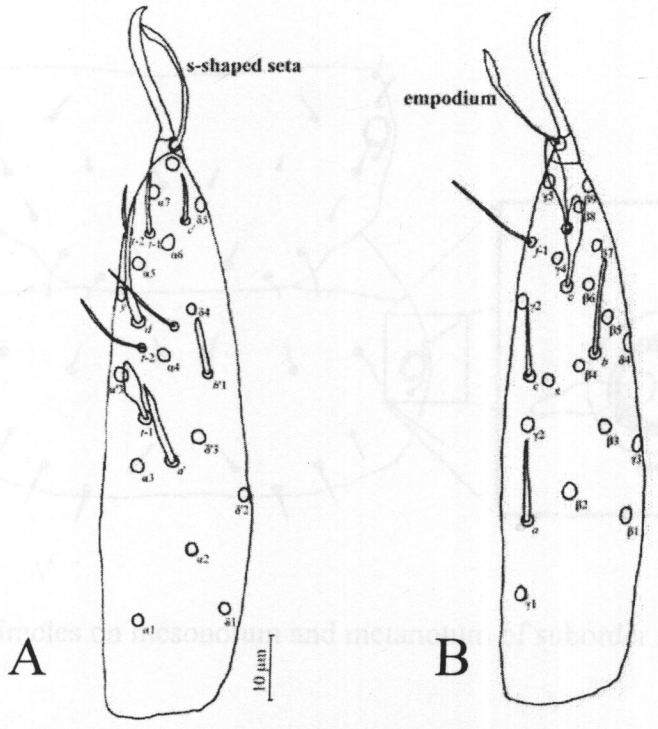


Figure 9 Foretarsus of family Eosentomidae, genus *Eosentomon*.
A, anterior view; B, posterior view.

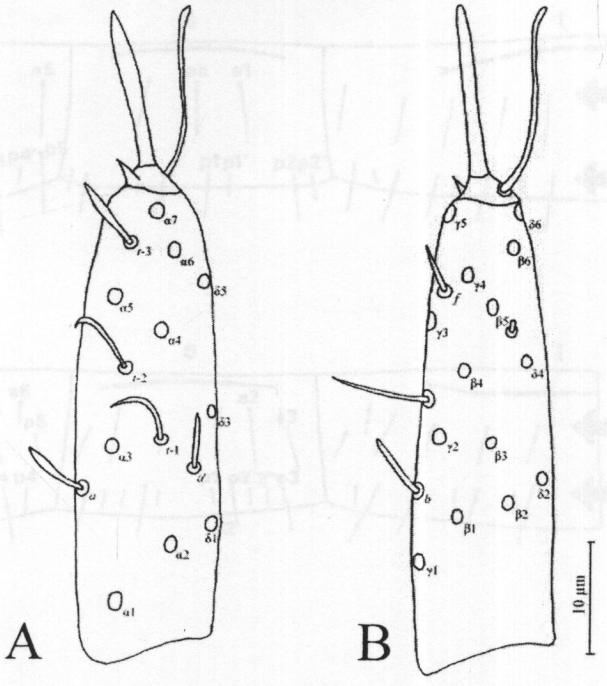


Figure 10 Foretarsus of family Protentomidae, genus *Condeellum*.
A, anterior view; B, posterior view.

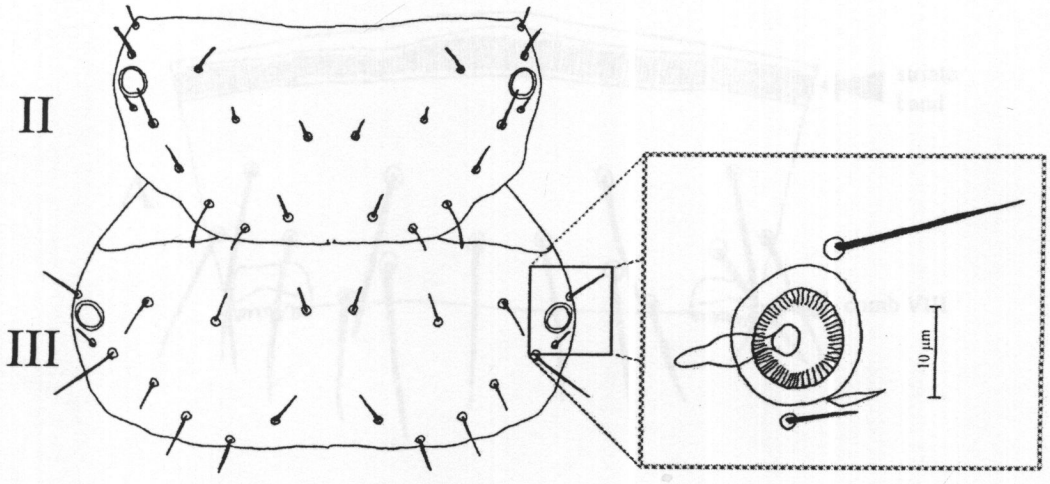


Figure 11 Spiracles on mesonotum and metanotum of suborder Eosentomoidea.

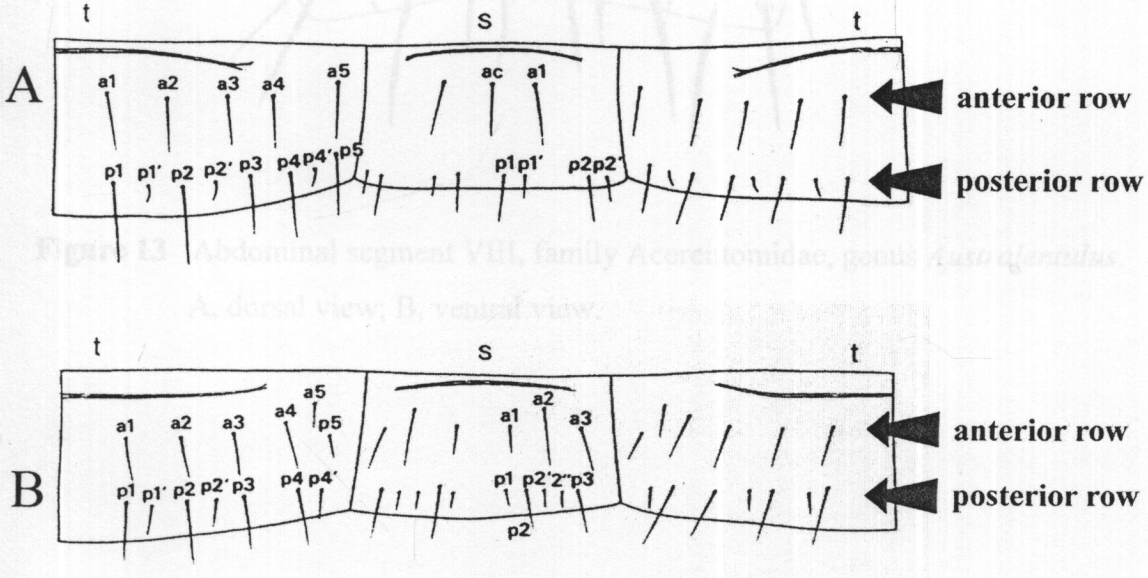


Figure 12 Chaetotaxy of abdominal segment IV.

A, family Eosentomidae; B, family Acerentomidae; s, sternum; t, tergum (Tuxen, 1985).

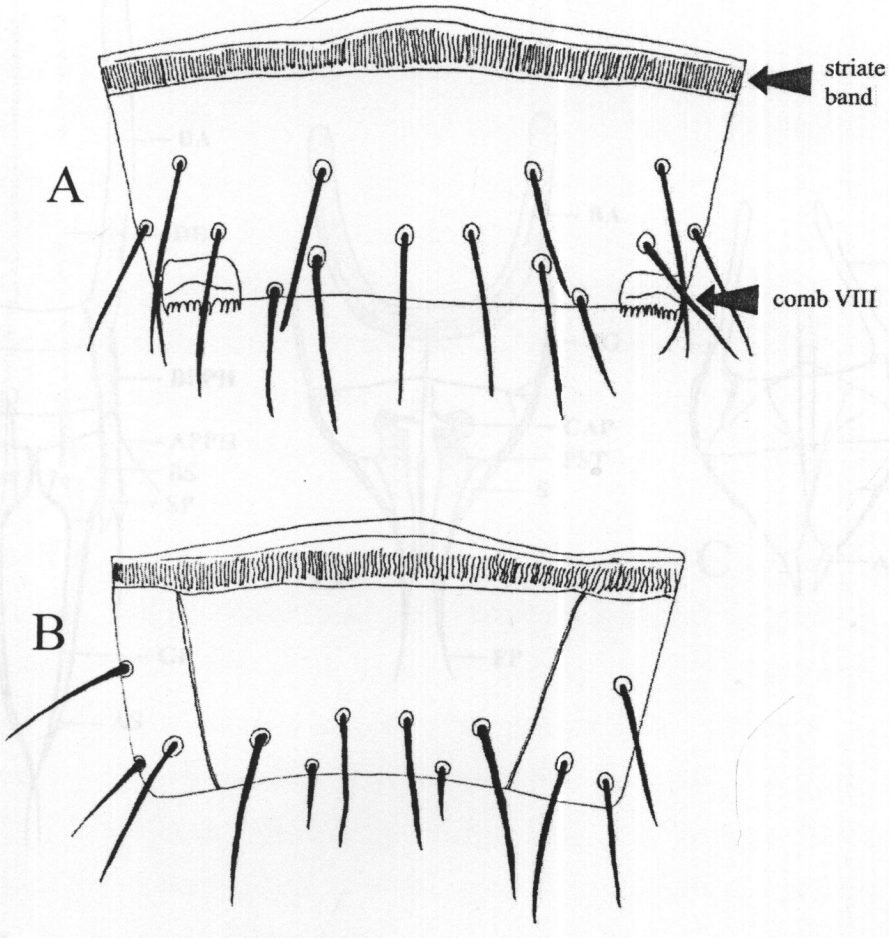


Figure 13 Abdominal segment VIII, family Acerentomidae, genus *Australentulus*. A, dorsal view; B, ventral view.

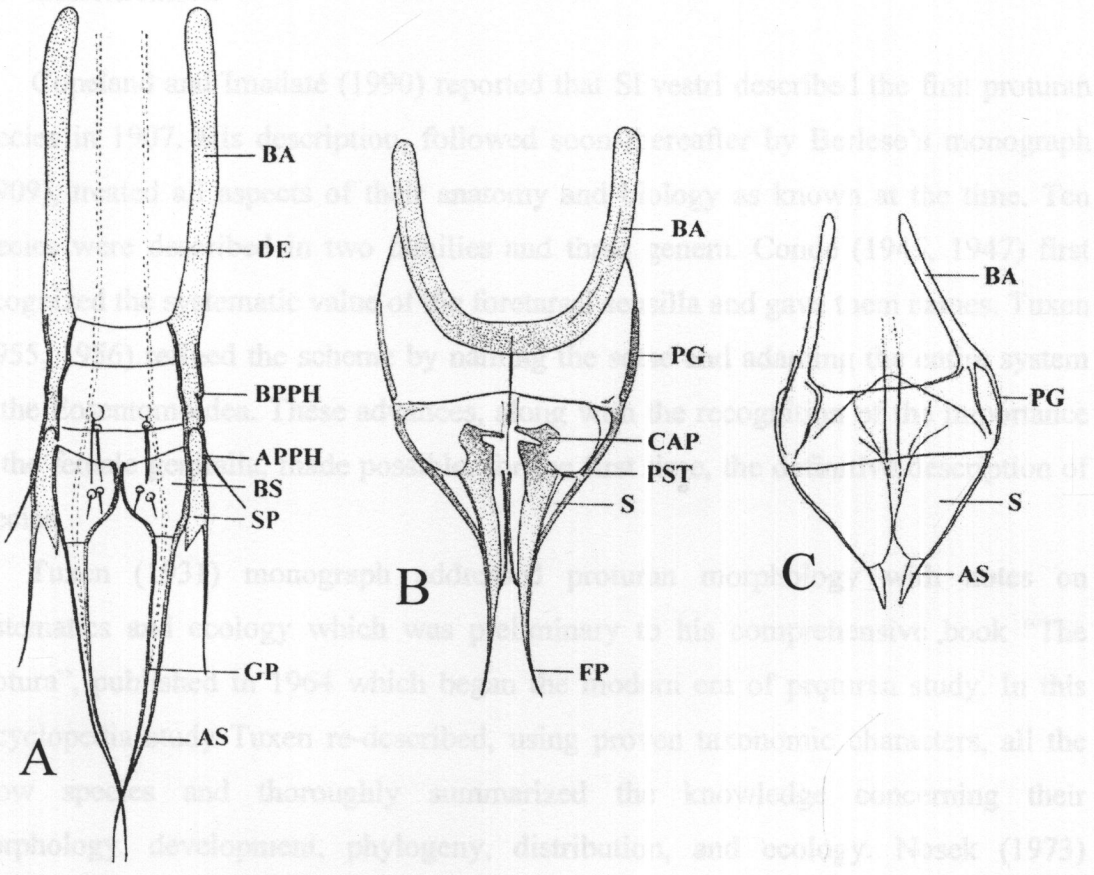


Figure 14 Genitalia of proturans.

A, male squama genitalia, family Eosentomidae, *Eosentomon transitorium* Berlese; BA, basal apodeme; DE, ductus ejaculatorius; BPPH, basiperiphallus; APPH, acroperiphallus; BS, basistylus; SP, side plates; GP, gonopore; AS, acrostylus; B, female squama genitalia, family Eosentomidae, *Eosentomon transitorium* Berlese; C, female squama genitalia, family Acerentomidae, *Acerentomon imadatei* Nosek; BA, basal apodeme; PG, perigynium; CAP, caput processus; PST, processus sternalis; S, stylus (basistylus); FP, filum processus; AS, acrostylus.

2.4 Classification

Copeland and Imadaté (1990) reported that Slivestri described the first proturan species in 1907. His description, followed soon thereafter by Berlese's monograph (1909), treated all aspects of their anatomy and biology as known at the time. Ten species were described in two families and three genera. Condé (1945, 1947) first recognized the systematic value of the foretarsal sensilla and gave them names. Tuxen (1955, 1956) refined the scheme by naming the setae and adapting the entire system to the Eosentomoidea. These advances, along with the recognition of the importance of the female genitalia, made possible, for the first time, the definitive description of species.

Tuxen (1931) monograph addressed proturan morphology with notes on systematics and ecology which was preliminary to his comprehensive book "The Protura", published in 1964 which began the modern era of proturan study. In this encyclopedia study Tuxen re-described, using proven taxonomic characters, all the know species and thoroughly summarized the knowledge concerning their morphology, development, phylogeny, distribution, and ecology. Nosek (1973) followed with his monograph on "The European fauna". Most of our knowledge of Asiatic and Pacific Island proturan has been derived from the many publications and the book by Imadaté and from the papers of Yin (Copeland and Imadaté, 1990). Finally Yin (1999) published the book of proturan in China "Fauna Sinica. Arthropoda Protura". The first survey in Thailand was done by Imadaté (1989). He described 25 species which were only found in Thailand. Later, Likhitrakarn (2004) surveyed the Doi Suthep-Pui National Park, Chiang Mai province, in Northern Thailand. There he found 11 species of which 6 species had been described and another 5 species were new to science. There is little known about proturan in Thailand. Proturan taxonomy is the base from which to develop future studies in biology, distribution, ecology, behavior, and molecular genetics of this curious and fascinating group of insects.

The order Protura contains 4 families: Protentomidae, Acerentomidae, Eosentomidae, and Sinentomidae. In Thailand, 3 families have been found: Protentomidae, Acerentomidae, and Eosentomidae. The taxonomic status follows Tuxen (1985):

2.4.1 Family Protentomidae

The abdominal appendages I-II with terminal vesicle and 4 setae. The abdominal appendage III without vesicle and 3 setae. Eighth abdominal segment with a serrated line. Sternum XII with 8 setae. Female squama genitalis broad, with bud-like, occasionally pointed acrostyli and short basal apodemes.

Genus found in Thailand is *Condeellum*.

2.4.2 Family Acerentomidae

The abdominal appendage I with a terminal vesicle and 4 setae, the the abdominal appendages II-III without a vesicle and each with 3, 2, or 1 seta. Abdominal tergum VIII with a striate band consisting of 2 lines, with or without striate in between. Female squama genitalis more or less pointed, bipartite or, together with distal part of stylus, forming a tripartite structure. Sternum XII with 6 setae.

Genera found in Thailand are *Australentulus, Kenyentulus, Gracilentulus, Baculentulus, and Silvestridia.*

2.4.3 Family Eosentomidae

Mesonotum and metanotum with spiracles. The abdominal appendages I-III each with a terminal vesicle and 5 setae. Mandible rather broad and stout ending mostly in three small teeth. Abdominal tergum VIII without a striate band or serrate line. Female squama genitalis mostly with processus sternalis but without acrostyli. Sternum XII with 12 setae.

Genus found in Thailand is *Eosentomon.*

2.5 Proturans in Thailand

The first survey in Thailand was done by Imadaté (1989). He described 25 indigenous species to Thailand. Later Likhitrakarn (2004) surveyed Doi Suthep-Pui National Park, Chiang Mai province, Northern Thailand. There he found 11 species of which 6 species had been previously described and five were *novo* species. This was the species checklist prior to this thesis research.

2.6 Checklist of proturans in Thailand

Suborder **Acerentomoidea** Condé, 1951

Family **Protentomidae**, Ewing, 1936

Genus ***Condeellum*** Tuxen, 1963

Condeellum regale (Condé, 1958)

Condeellum ishiianum ishiianum Imadaté, 1965

Family **Acerentomidae** Silvestri, 1907

Genus ***Australentulus*** Tuxen, 1967

Australentulus prachedee (Imadaté, 1965)

Genus ***Silvestridia*** Bonet, 1942

Silvestridia keijiana (Imadaté, 1965)

Genus ***Baculentulus*** Tuxen, 1977

Baculentulus morikawai (Imadaté & Yosii, 1956)

Baculentulus duongkeoi (Imadaté, 1965)

Baculentulus bervinguis (Condé, 1961)

Baculentulus umesaoi (Imadaté, 1965)

Baculentulus matsuokai (Imadaté, 1965)

Baculentulus lanna (Imadaté, 1965)

Baculentulus ogawai (Imadaté, 1965)

Baculentulus oginoi (Imadaté, 1965)

Genus ***Gracilentulus*** Tuxen,1963

Gracilentulus sachikoae Imadaté, 1965

Genus ***Kenyentulus*** Tuxen, 1981

Kenyentulus ohyamai (Imadaté, 1965)

Suborder **Eosentomoidea** condé, 1951

Family **Eosentomidae** Berlese, 1909

Genus ***Eosentomon*** Berlese, 1909

Eosentomon kloomi Imadaté, 1965

Eosentomon paktai Imadaté, 1965

Eosentomon thamnooni Imadaté, 1965

Eosentomon imbutum Imadaté, 1965

Eosentomon yanaka Imadaté, 1965

Eosentomon sawasdi Imadaté, 1965

Eosentomon sayani Imadaté, 1965

Eosentomon pairathi Imadaté, 1965

Eosentomon hyatti Condé, 1958

Eosentomon torbongsi Imadaté, 1965

Eosentomon udorni Imadaté, 1965

CHAPTER 3
MATERIALS AND METHODS

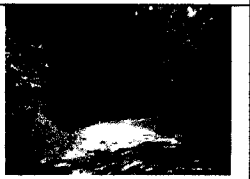
3.1 Collecting methodology

Soil samples were collected along an altitudinal gradient in Doi Inthanon National Park, Chiang Mai province which is the highest montane region in Thailand, at 2465 meters, located at 18°31′ N - 18°34′ N and 98°28′ E - 98°38′ E, possessing 482 kilometer^2, and includes amphoe Chom Thong, San Pa Tong, and Mae Chaem districts. This region possesses a high biodiversity of plants and animals including insects (Thienhirun, 2002). Five different forest types (Table 1) were chosen at 500 meters intervals: dry deciduous dipterocarp forest; mixed deciduous forest; lower evergreen forest; upper evergreen forest; and cloud forest, respectively. At each site, 10 soil samples were collected using a 15 × 15 centimeters quadrat with a depth of 5 centimeters in each forest type. The soil samples were then transferred to Berlese funnels for 72 hours for soil arthropod extraction. Proturans were separated from the other specimens and were preserved in 70 % ethanol.

3.2 Identification and constructing the pictorial key

Specimens were mounted to slides for identification under a microscope. Then, these specimens were observe under 1000 x. Only the adult stage was identified to genus and species by using published keys in combination with necessary newly constructed keys. The concept of genera groups primarily follows the classification of Tuxen (1964, 1985). Morphological identifications were base on descriptions by Imadaté (1989), Nakamura (2003), Szeptycki (1988, 2001), and Bu and Yin (2007). Some specimens were sent to specialists for further confirmation. Procedures for slide mounting are detailed in Appendix. Appropriate specimens for each species were selected for photographing and for line drawings in order to construct the most salient morphological features for keys to genera and species.

Table 1 Description of collection sites in Doi Inthanon National Park, Chiang Mai province.

Site	Image of site	Latitude/Longitude	Plant communities	Altitude (m)
1. Vachiratharn waterfall		18° 31′ N, 98° 29′ E	Bamboo stands	700
2. Ban Pha Mon		18° 33′ N, 98° 28′ E	Mixed deciduous forest with pines	1000
3. Checkpoint to Mae Chaem		18° 34′ N, 98° 28′ E	Evergreen hill forest (1650 m)	1650
4. Kiew Mae Pan		18° 33′ N, 98° 28′ E	Evergreen hill forest	2100
5. Evergreen summit forest		18° 34′ N, 98° 28′ E	Evergreen hill forest	2450

CHAPTER 4
RESULTS

Proturan taxonomy and description

4.1 Summary and checklist of proturan in Doi Inthanon National Park, Chiang Mai province

Soil samples were collected on 30 January 2007 along an altitudinal gradient in Doi Inthanon National Park, Chiang Mai province, Thailand. Five different forests were chosen at 500 meters intervals: dry deciduous dipterocarp forest; mixed deciduous forest; lower evergreen forest; upper evergreen forest; and cloud forest, respectively. At each site, 10 soil samples were collected using a 15 × 15 centimeters quadrat with a depth of 5 centimeters.

After specimen preparation and identification, it was determined that eleven species and two subspecies of proturans were collected. These 11 species and 2 subspecies consist of 3 described species (*Condeellum regale* (Condé), *C. ishiianum ishiianum* Imadaté, *Silvestridia keijiana* (Imadaté)), one newly recorded subspecies for Thailand (*C. ishiianum setosum* Imadaté, 1991), and 8 undescribed species (*Australentulus* sp., *Baculentulus* sp., *Kenyentulus* sp. 1, *Kenyentulus* sp. 2, *Eosentomon* sp. 1, *Eosentomon* sp. 2, *Eosentomon* sp. 3, and *Eosentomon* sp. 4). The species collected belong to the genera *Condeellum* Tuxen (2 spp.), *Australentulus* Tuxen (1 sp.), *Silvestridia* Bonet (1 sp.), *Baculentulus* Tuxen, 1977 (1 sp.), *Kenyentulus* Tuxen (2 spp.), *Eosentomon* Berlese (4 spp.). The following analysis was based on morphological characteristics of proturan in the adult stage.

4.2 Checklist of proturans in Doi Inthanon National Park, Chiang Mai province

Suborder **Acerentomoidea** Condé, 1951

Family **Protentomidae**, Ewing, 1936

Genus ***Condeellum*** Tuxen, 1963

1. *Condeellum regale* (Condé, 1958)
2. *Condeellum ishiianum ishiianum* Imadaté, 1965
3. *Condeellum ishiianum setosum* Imadaté, 1991

Family **Acerentomidae** Silvestri, 1907

Genus ***Australentulus*** Tuxen, 1967

4. *Australentulus* sp.

Genus ***Silvestridia*** Bonet, 1942

5. *Silvestridia keijiana* (Imadaté, 1965)

Genus ***Baculentulus*** Tuxen, 1977

6. *Baculentulus* sp.

Genus ***Kenyentulus*** Tuxen, 1981

7. *Kenyentulus* sp. 1
8. *Kenyentulus* sp. 2

Suborder **Eosentomoidea** Condé, 1951

Family **Eosentomidae** Berlese, 1909

Genus ***Eosentomon*** Berlese, 1909

9. *Eosentomon* sp. 1
10. *Eosentomon* sp. 2
11. *Eosentomon* sp. 3
12. *Eosentomon* sp. 4

4.3 Key to genus of proturan in Doi Inthanon National Park, Chiang Mai Province

1. Thoracic tergites II-III without spiracle.....2

1′. Thoracic tergites II-III with a pair of spiracles (Fig. 11).....*Eosentomon*

2. Abdominal appendage II without terminal vesicle (Fig. 7E).....3

2′. Abdominal appendage II with a terminal vesicle (Fig. 7H) .....*Condeellum*

3. Striate band on abdomen VIII reduced, labrum not protruded (Fig. 27F).....4

3′. Striate band on abdomen VIII well developed (Fig. 23F), labrum strikingly protruded.....*Australentulus*

4. Abdominal appendage III without terminal vesicle and two setae (Fig. 27C), labial palpus with three setae.....5

4′. Abdominal appendage III without terminal vesicle and one seta (Fig. 25C), labial palpus with two setae.....*Silvestridia*

5. Canal of maxillary gland with two additional dilatations (Fig. 29E)...*Kenyentulus*

5′. Canal of maxillary gland simple without additional dilatation (Fig. 27E).....
.....*Baculentulus*

4.4 Key to species of proturan in Doi Inthanon National Park, Chiang Mai province

1. Thoracic tergites II-III without spiracle.....2

1′. Thoracic tergites II-III with a pair of spiracles (Fig. 11).....9

2. Abdominal appendage II without terminal vesicle (Fig. 7E).....3

2′. Abdominal appendage II with a terminal vesicle (Fig. 7H).....5

3. Urotergites II-VI with 3 pairs of anterior setae (A1, 2, 5).....4

3′. Urotergites II-VI with 2 pairs of anterior setae (A1, 5).....
.....*Condeellum regale* (Condé, 1958)

4. Urotergite VII with 2 pairs of anterior setae (A4, 5).....
.....*Condeellum ishiianum ishiianum* Imadaté, 1965

4′. Urotergite VII with 3 pairs of anterior setae (A1, 4, 5).....
.....*Condeellum ishiianum setosum* Imadaté, 1991

5. Striate band on abdomen VIII reduced (Fig. 27F), labrum not protruded.....6

5′. Striate band on abdomen VIII well developed or not reduced (Fig. 23F), labrum strikingly protruded.....*Australentulus* sp.

6′. Abdominal appendage III (Fig. 27C) without terminal vesicle and two setae, labial palpus with three setae.....7

6. Abdominal appendage III (Fig. 25C) without terminal vesicle and one seta, labial palpus with two setae.....*Silvestridia keijiana* (Imadaté, 1965)

7. Canal of maxillary gland with two additional dilatations (Fig. 29E).....8

7′. Canal of maxillary gland simple without additional dilatation (Fig. 27E).....
.....*Baculentulus* sp.

8. Urotergite IV with 3 pairs of anterior setae (A1, 2, 5).....*Kenyentulus* sp. 1

8′. Urotergite IV with 2 pairs of anterior setae (A2, 5).....*Kenyentulus* sp. 2

9. Urotergite V with 2 pairs of anterior setae (A4, 5).....10

9′. Urotergite V with 3 pairs of anterior setae (A1, 4, 5).....11

10. Urotergite VII with 2 pairs of anterior setae (A4, 5).....*Eosentomon* sp. 1

10′. Urotergite VII with a pairs of anterior setae (A5).....*Eosentomon* sp. 2

11. Urotergite VI with 3 pairs of anterior setae (A1, 4, 5).....*Eosentomon* sp. 3

11′. Urotergite VI with 2 pairs of anterior setae (A4, 5).....*Eosentomon* sp. 4

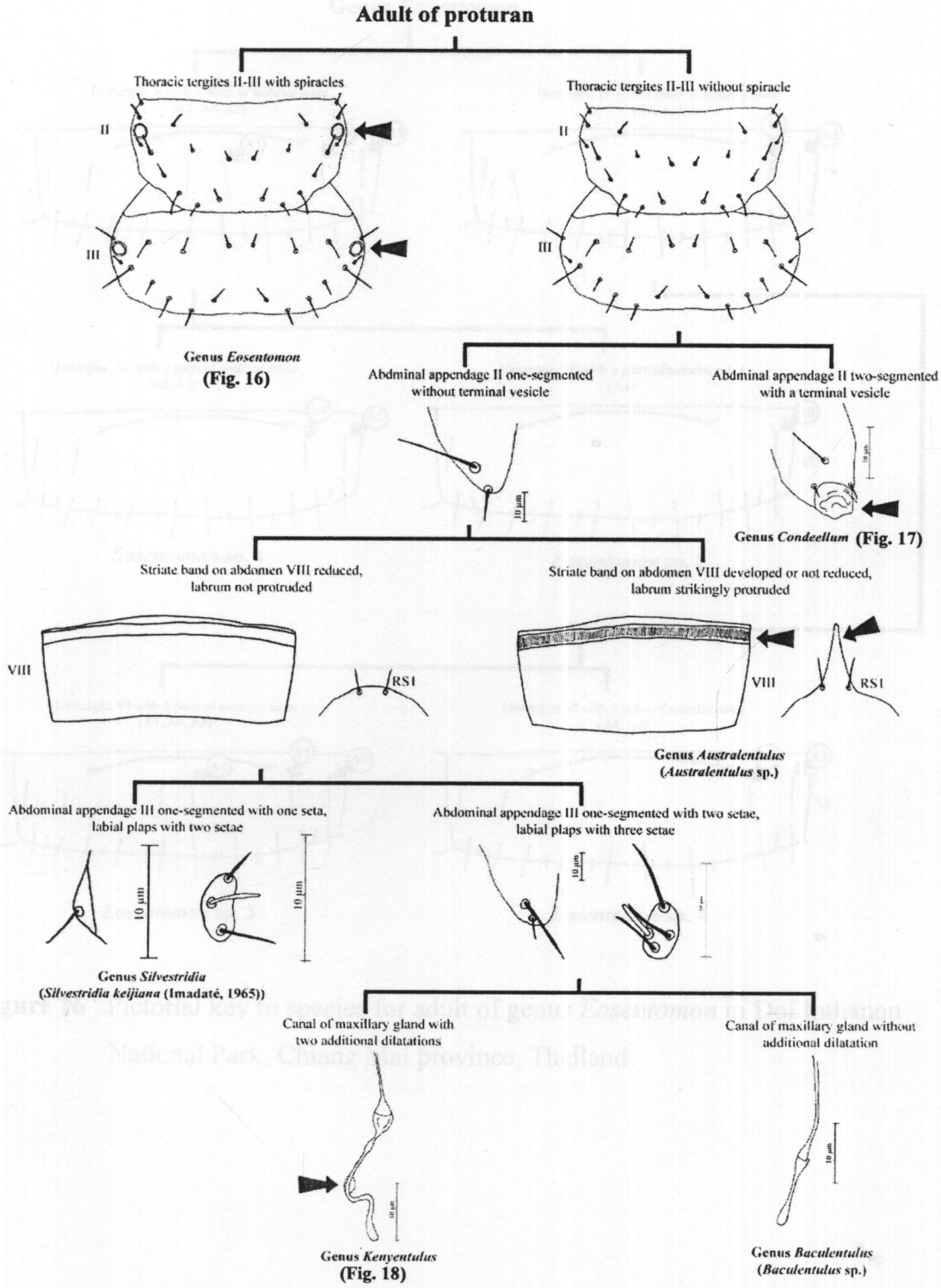


Figure 15 Pictorial key to genera for adult of proturan in Doi Inthanon National Park, Chiang Mai province, Thailand.

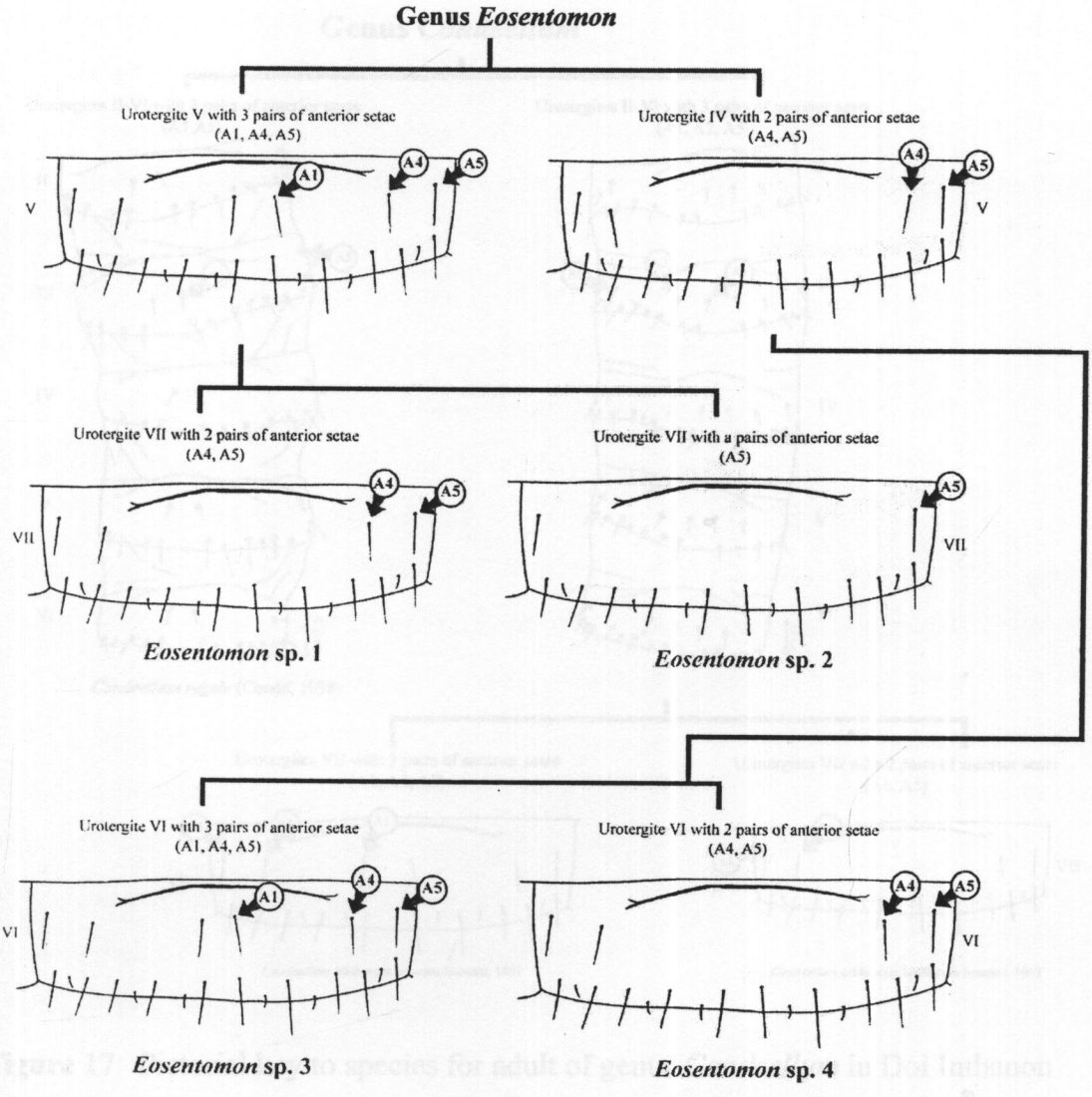


Figure 16 Pictorial key to species for adult of genus *Eosentomon* in Doi Inthanon National Park, Chiang Mai province, Thailand.

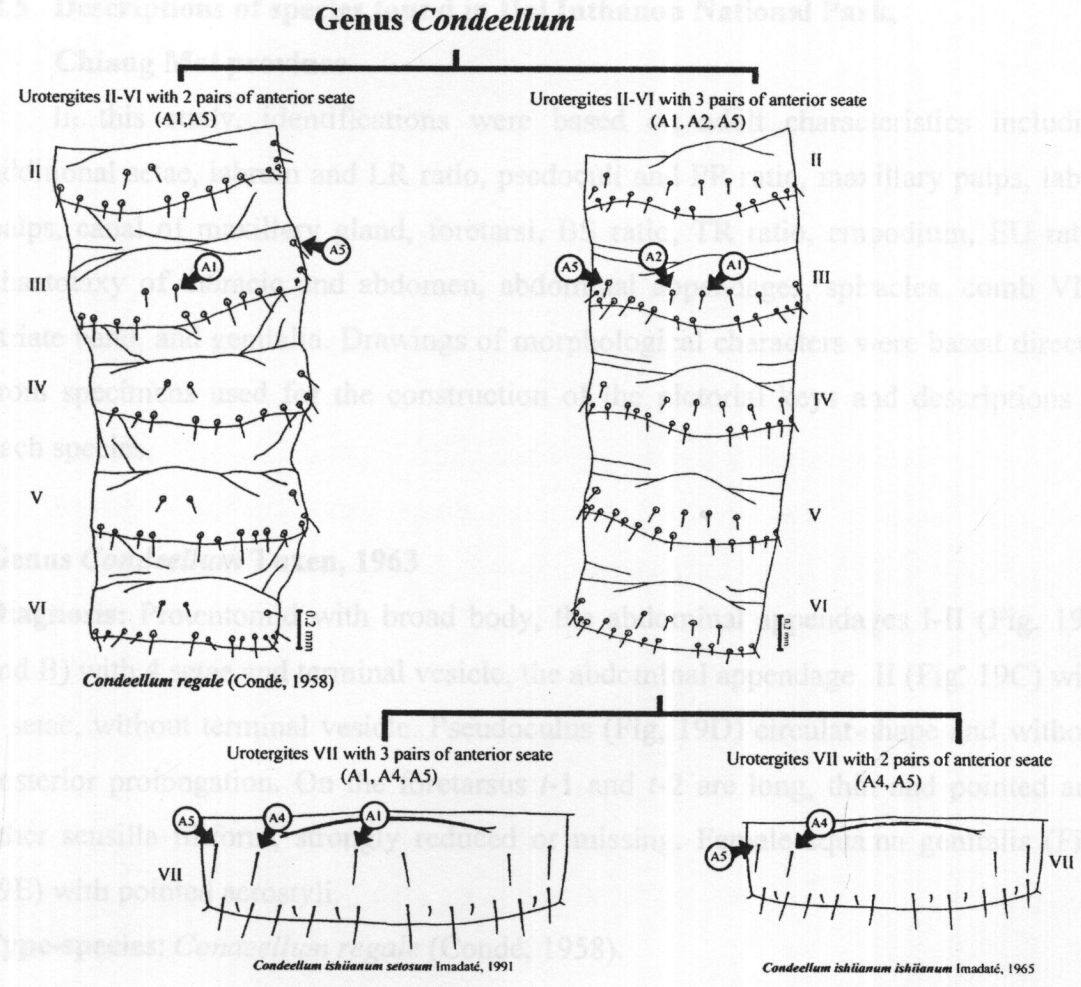


Figure 17 Pictorial key to species for adult of genus *Condeellum* in Doi Inthanon National Park, Chiang Mai province, Thailand.

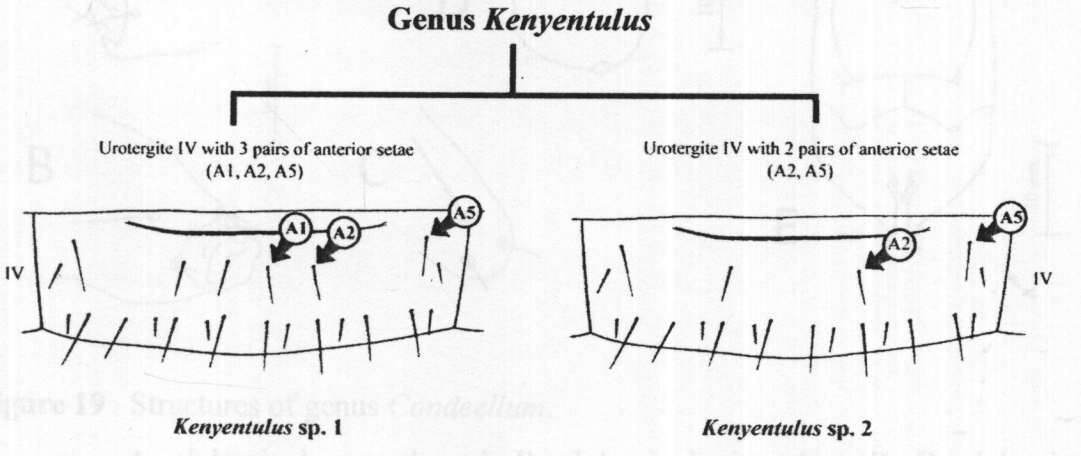


Figure 18 Pictorial key to species for adult of genus *Kenyentulus* in Doi Inthanon National Park, Chiang Mai province, Thailand.

4.5 Descriptions of species found in Doi Inthanon National Park, Chiang Mai province

In this study, identifications were based on adult characteristics including additional setae, labrum and LR ratio, psedoculi and PR ratio, maxillary palps, labial palps, canal of maxillary gland, foretarsi, BS ratio, TR ratio, empodium, EU ratio, chaetotaxy of thoracic and abdomen, abdominal appendages, spiracles, comb VIII, striate band, and genitalia. Drawings of morphological characters were based directly from specimens used for the construction of the pictorial keys and descriptions of each species.

Genus *Condeellum* Tuxen, 1963

Diagnosis: Protentomid with broad body, the abdominal appendages I-II (Fig. 19A and B) with 4 setae and terminal vesicle, the abdominal appendage III (Fig. 19C) with 3 setae, without terminal vesicle. Pseudoculus (Fig, 19D) circular-shape and without posterior prolongation. On the foretarsus *t*-1 and *t*-2 are long, thin and pointed and other sensilla filiform, strongly reduced or missing. Female squama genitalis (Fig. 19E) with pointed acrostyli.

Type-species: *Condeellum regale* (Condé, 1958).

Distribution: Madagascar, Nepal, China, Thailand, Borneo, and Taiwan.

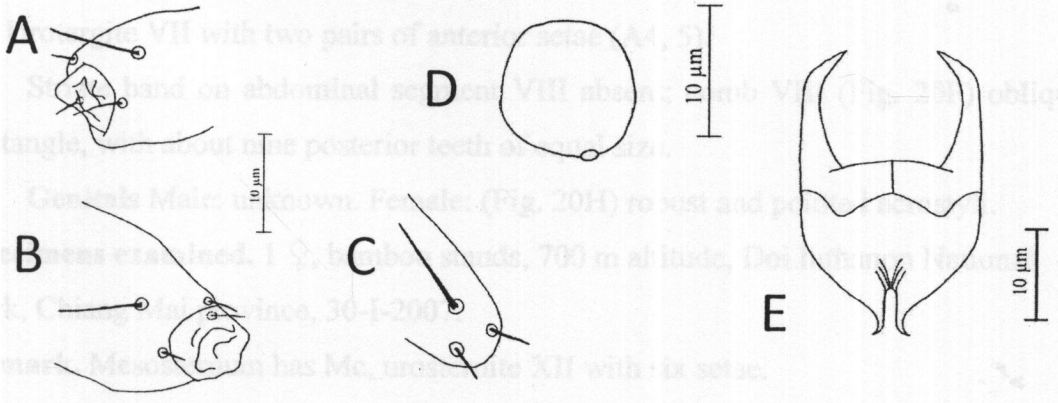


Figure 19 Structures of genus *Condeellum*.

A, abdominal appendage I; B, abdominal appendage II; C, abdominal appendage III; D, pseudoculus; E, female squama genitalis

***Condeellum regale* (Condé, 1958)**

(Fig. 20)

Diagnosis. Urotergites II–VII with two pairs of anterior setae (A4, 5).

Description. Body length 800 μm.

Head (Fig. 20A) Oval, length 90 μm, width 69 μm. Additional setae absent. Maxillary palps with two pointed sensilla. Labial palps with a tuft and 4 setae. Rostrum not protruded. Pseudoculus (Fig. 20B) almost circular, length 10 μm, width 9–11 μm, PR = 9. Canal of maxillary gland (Fig. 20C) with ball-shaped dilatation; proximal part forming sac-like dilation and terminal part globular dilatation.

Thorax (Table 2) Prosternum with two pairs of anterior setae (A1, M). Mesosternum and metasternum with four pairs of anterior part (A1, 2, 3, M).

Foretarsal (Fig. 20D and E) length 45 μm, claw length 16 μm, TR = 2.8; empodium length 2.9 μm, EU = 0.18, S-shaped setae length 18 μm. Dorsal sensilla *t*-1 and *t*-2 slim and long, BS = 0.88; *t*-3 spatulate, its apex surpassing tarsus. Exterior sensilla *a* spatulate, its apex reaching the base of α3; *b* normal, its apex reaching the base of γ2; *f* short, its apex surpassing the base of γ4. Interior sensilla *a'* spatulate, surpassing the base of *t*-1. Middle tarsal length 20–22 μm, claw length 13 μm. Hind tarsal length 23–25 μm, claw length 13 μm.

Abdomen (Table 2) Urotergite I with two pairs of anterior setae (A1, 2), with seven pairs of posterior setae. Urotergite II–VI with two pairs of anterior setae (A1, 5). Urotergite VII with two pairs of anterior setae (A4, 5).

Striate band on abdominal segment VIII absent; comb VIII (Fig. 20F) oblique rectangle, with about nine posterior teeth of equal size.

Genitals Male: unknown. Female: (Fig. 20H) robust and pointed acrostyli.

Specimens examined. 1 ♀, bamboo stands, 700 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. Mesosternum has Mc, urosternite XII with six setae.

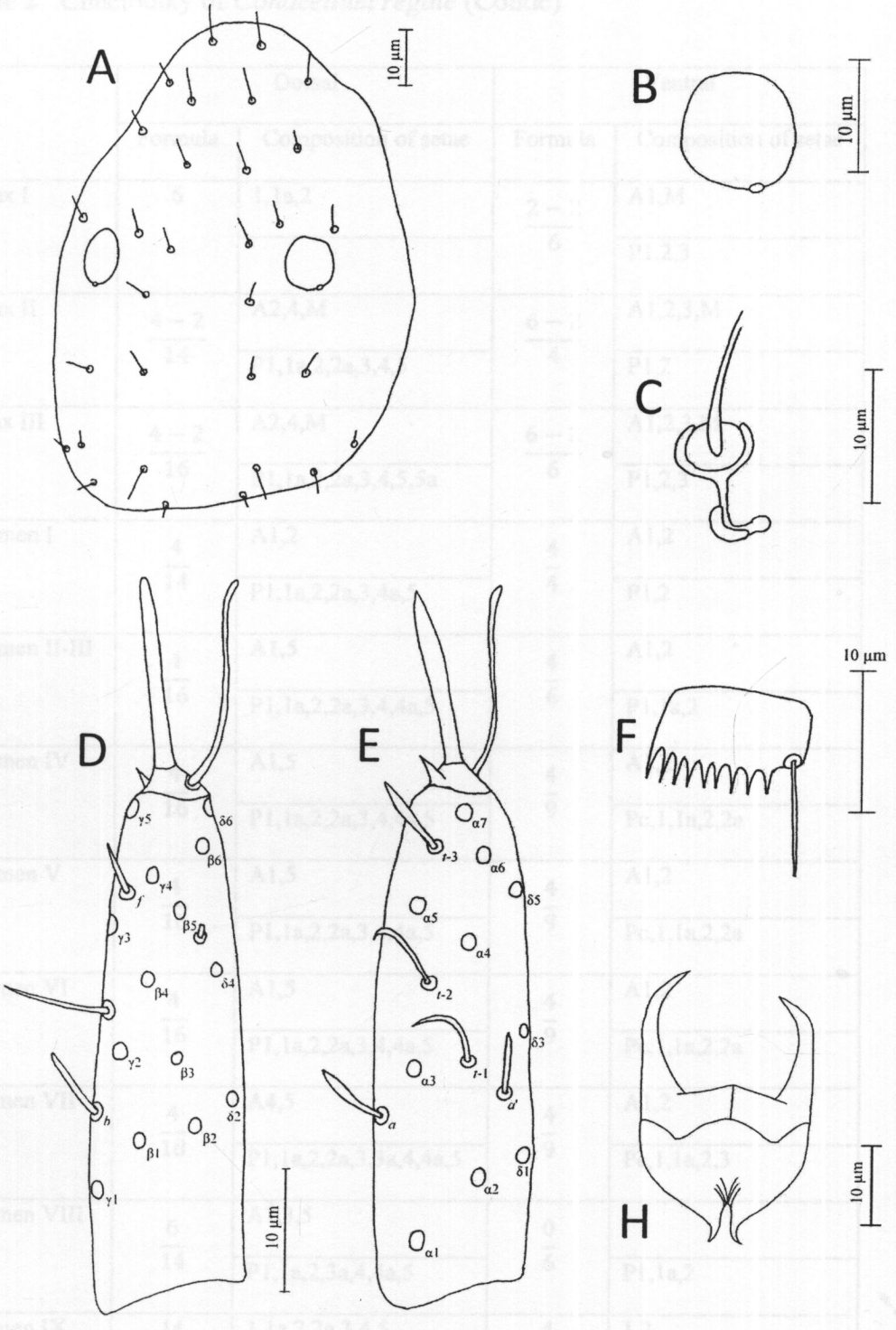


Figure 20 Structures of *Condeellum regale* (Condé).

A, head, dorsal view; B, pseudoculus; C, canal of maxillary gland; D, posterior view of foretarsus; E, anterior view of foretarsus; F, comb on abdominal VIII; H, female squama genitalis.

Table 2 Chaetotaxy of *Condeellum regale* (Condé)

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	6	1,1a,2	$\frac{2-2}{6}$	A1,M
				P1,2,3
Thorax II	$\frac{4-2}{14}$	A2,4,M	$\frac{6-2}{4}$	A1,2,3,M
		P1,1a,2,2a,3,4,5		P1,2
Thorax III	$\frac{4-2}{16}$	A2,4,M	$\frac{6-2}{6}$	A1,2,3,M
		P1,1a,2,2a,3,4,5,5a		P1,2,3
Abdomen I	$\frac{4}{14}$	A1,2	$\frac{4}{4}$	A1,2
		P1,1a,2,2a,3,4a,5		P1,2
Abdomen II-III	$\frac{4}{16}$	A1,5	$\frac{4}{6}$	A1,2
		P1,1a,2,2a,3,4,4a,5		P1,1a,2
Abdomen IV	$\frac{4}{16}$	A1,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,4,4a,5		Pc,1,1a,2,2a
Abdomen V	$\frac{4}{16}$	A1,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,4,4a,5		Pc,1,1a,2,2a
Abdomen VI	$\frac{4}{16}$	A1,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,4,4a,5		Pc,1,1a,2,2a
Abdomen VII	$\frac{4}{18}$	A4,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,3a,4,4a,5		Pc,1,1a,2,3
Abdomen VIII	$\frac{6}{14}$	A1,3,5	$\frac{0}{6}$	
		P1,1a,2,3a,4,4a,5		P1,1a,2
Abdomen IX	14	1,1a,2,2a,3,4,5	4	1,2
Abdomen X	12	1,2,2a,3,4,5	4	1,2
Abdomen XI	8	1,2,2a,3	6	1,2,3
Abdomen XII	9	Ac,1,2,3,4	8	1,2,3,4

***Condeellum ishiianum ishiianum* Imadaté, 1965**

(Fig. 21)

Diagnosis. Urotergite II–VI with three pairs of anterior setae (A1, 2, 5). Urotergite VII with two pairs of anterior setae (A4, 5).

Description. Body length 890, 960 μm.

Head (Fig. 21A) Oval, length 95, 115 μm, width 82, 90 μm. Additional setae absent. Maxillary palps with two pointed sensilla. Labial palps with a tuft and 4 setae. Rostrum not protruded. Pseudoculus (Fig. 21B) almost circular, length 10–11 μm, width 9–11 μm, PR = 9.5–10. Canal of maxillary gland (Fig. 21C) with ball-shaped dilatation; proximal part forming sac-like dilation and terminal part globular dilatation.

Thorax (Table 3) Prosternum with three pairs of anterior setae (A1, 2, M). Mesosternum with four pairs of anterior setae (A1, 2, 3, M). Metasternum with five pairs of anterior setae (A1, 2, 3, 4, M).

Foretarsal (Fig. 21D and E) length 51–59 μm, claw length 20–21 μm, TR = 2.4–2.81; empodium length 4 μm, EU = 0.19, S–shaped setae length 23 μm. Dorsal sensilla *t*-1 and *t*-2 slim and long, BS = 0.89–0.97; *t*-3 spatulate. Exterior sensilla *a* spatulate, its apex reaching the base of α3; *b* normal, its apex surpassing the base of γ2; *f* short, its apex surpassing the base of γ4. Interior sensilla *a'* spatulate, its apex surpassing the base of *t*-1. Middle tarsal length 24–29 μm, claw length 13–17 μm. Hind tarsal length 28–35 μm, claw length 14–18 μm.

Abdomen (Table 3) Urotergite I with two pairs of anterior setae (A1, 2), with seven pairs of posterior setae. Urotergite II–VI with three pairs of anterior setae (A1, 2, 5). Urotergite VII with two pairs of anterior setae (A4, 5).

Striate band on abdominal segment VIII absent; comb VIII (Fig. 21F) consisting of about eight posterior teeth of irregular size.

Genitals Male: unknown. Female: (Fig. 21H) robust and pointed acrostyli.

Specimens examined. 1 ♀, bamboo stands, 700 m altitude; 1 ♀, evergreen hill forest, 1650 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. 1 ♀, bamboo stands, P3 on left–hand on prosternum is missing, A3 on right–hand on metasternum is missing.

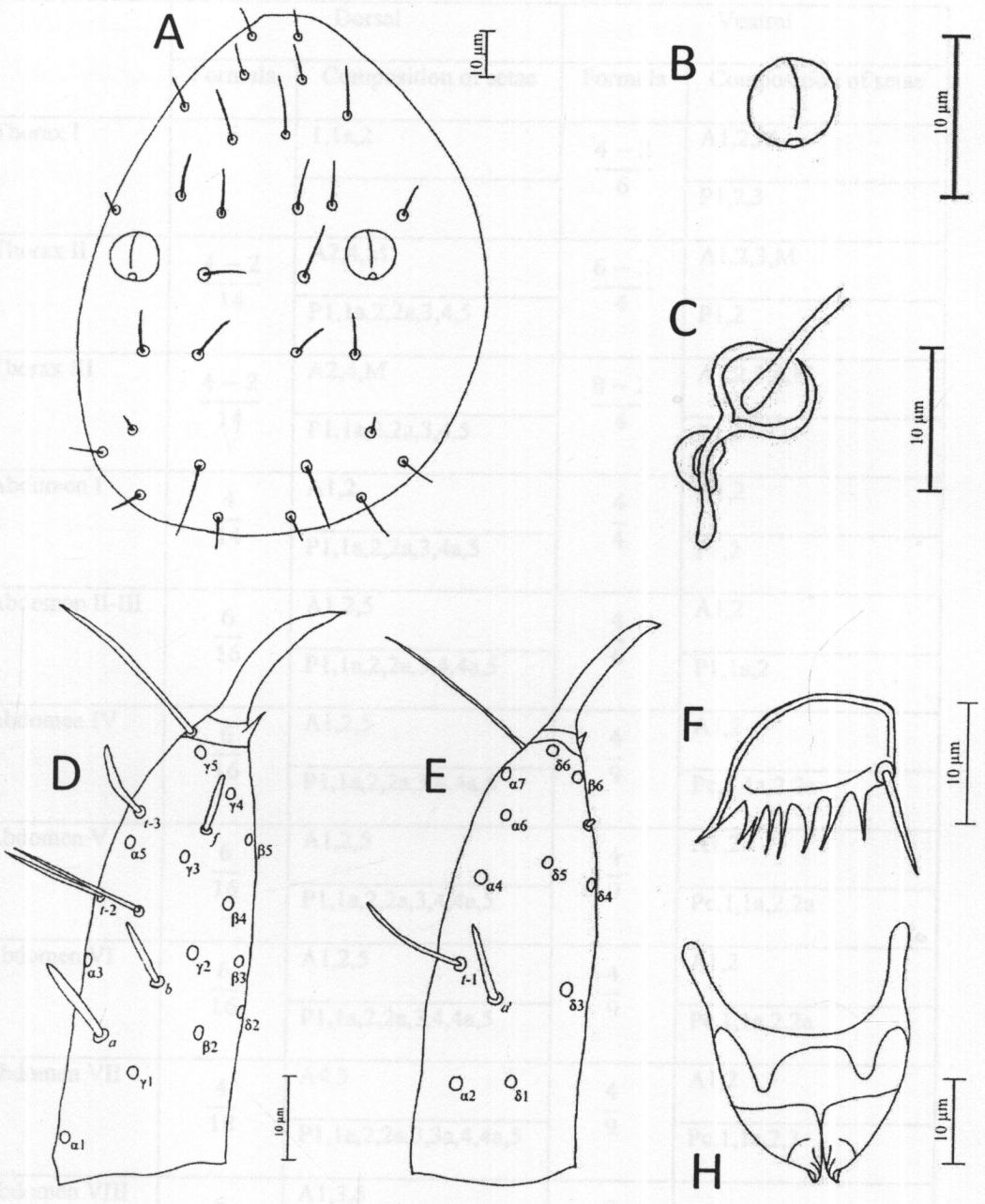


Figure 21 Structures of *Condeellum ishiianum ishiianum* Imadaté.

A, head, dorsal view; B, pseudoculus; C, canal of maxillary gland; D, exterior view of foretarsus; E, interior view of foretarsus; F, comb on abdominal VIII; H, female squama genitalis.

Table 3 Chaetotaxy of *Condeellum ishiianum ishiianum* Imadaté.

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	6	1,1a,2	$\frac{4-2}{6}$	A1,2,M
				P1,2,3
Thorax II	$\frac{4-2}{14}$	A2,4,M	$\frac{6-2}{4}$	A1,2,3,M
		P1,1a,2,2a,3,4,5		P1,2
Thorax III	$\frac{4-2}{14}$	A2,4,M	$\frac{8-2}{4}$	A1,2,3,4,M
		P1,1a,2,2a,3,4,5		P1,2
Abdomen I	$\frac{4}{14}$	A1,2	$\frac{4}{4}$	A1,2
		P1,1a,2,2a,3,4a,5		P1,2
Abdomen II-III	$\frac{6}{16}$	A1,2,5	$\frac{4}{6}$	A1,2
		P1,1a,2,2a,3,4,4a,5		P1,1a,2
Abdomen IV	$\frac{6}{16}$	A1,2,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,4,4a,5		Pc,1,1a,2,2a
Abdomen V	$\frac{6}{16}$	A1,2,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,4,4a,5		Pc,1,1a,2,2a
Abdomen VI	$\frac{6}{16}$	A1,2,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,4,4a,5		Pc,1,1a,2,2a
Abdomen VII	$\frac{4}{18}$	A4,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,3a,4,4a,5		Pc,1,1a,2,3
Abdomen VIII	$\frac{6}{14}$	A1,3,5	$\frac{0}{6}$	
		P1,1a,2,3a,4,4a,5		P1,1a,2
Abdomen IX	14	1,1a,2,2a,3,4,5	4	1,2
Abdomen X	12	1,2,2a,3,4,5	4	1,2
Abdomen XI	8	1,2,2a,3	6	1,2
Abdomen XII	9	Ac,1,2,3,4	8	1,2,3,4

***Condeellum ishiianum setosum* Imadaté, 1991**

(Fig. 22)

Diagnosis. Urotergite I–VII with three pairs of anterior setae (A1, 2, 5).

Description. Body length 780–850 μm.

Head (Fig. 22A) Oval, length 82–94 μm, width 70–75 μm. Additional setae absent. Maxillary palps with two pointed sensilla. Labial palps with a tuft and 4 setae. Rostrum not protruded. Pseudoculus (Fig. 22B) almost circular, length 9 μm, width 8.5 μm, PR = 10–10.4. Canal of maxillary gland (Fig. 22C) with ball-shaped dilatation; proximal part forming sac-like dilation and terminal part globular dilatation.

Thorax (Table 4) Prosternum with four pairs of anterior setae (A1, 2, M1, 2). Mesosternum with four pairs of anterior setae (A1, 2, 3, M) and metasternum with five pairs of anterior setae (A1, 2, 3, 4, M).

Foretarsal (Fig. 22D and E) length 41–51 μm, claw length 14–18 μm, TR = 2.89–2.9; empodium length 4–5 μm, EU = 0.22–0.29, S-shaped setae length 13–14 μm. Dorsal sensilla *t*-1 and *t*-2 slim and long, BS = 0.82–0.92; *t*-3 spatulate, its apex surpassing the base of α7. Exterior sensilla *a* spatulate, its apex reaching the base of α3; *b* normal, its apex surpassing the base of γ2; *f* short, its apex reaching the base of γ4. Interior sensilla *a'* spatulate, surpassing the base of *t*–1. Middle tarsal length 17–23 μm, claw length 10–12 μm. Hind tarsal length 20–27 μm, claw length 11–14 μm.

Abdomen (Table 4) Urotergite I with two pairs of anterior setae (A1, 2), with seven pairs of posterior setae. Urotergite II–VI with three pairs of anterior setae (A1, 2, 5). Urotergite VII with three pairs of anterior setae (A1, 4, 5). Urosternite IX with seven setae.

Striate band on abdominal segment VIII absent; comb VIII (Fig. 22F) consisting of about ten posterior teeth of irregular size.

Genitals Male: (Fig. 22G) robust, basistylus with short setae. Female: (Fig. 22H) pointed acrostyli.

Specimens examined. 2 ♂, bamboo stands, 700 m altitude; 1 ♂, evergreen hill forest, 2100 m altitude; 1 ♀, evergreen hill forest, 1650 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. 1 ♂, evergreen hill forest, prosternum with two pairs of anterior setae (A1, M1) and urotergite IX with 16 setae.

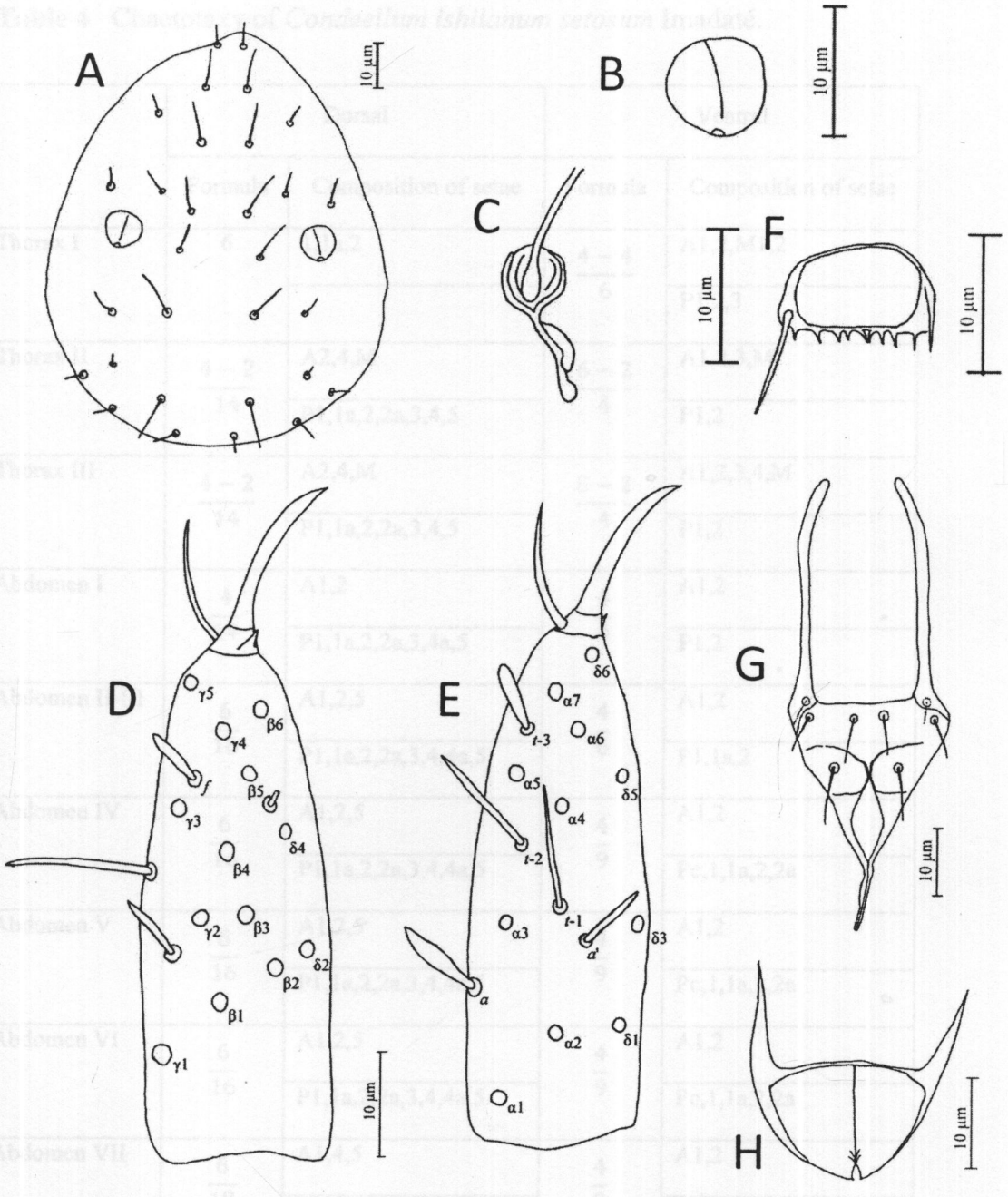


Figure 22 Structures of *Condeellum ishiianum setosum* Imadaté.

A, dorsal view of head; B, pseudoculus; C, canal of maxillary gland; D, posterior view of foretarsus; E, anterior view of foretarsus; F, comb on abdominal VIII; G, male genitalis; H, female squama genitalis.

Table 4 Chaetotaxy of *Condeellum ishiianum setosum* Imadaté.

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	6	1,1a,2	$\frac{4-4}{6}$	A1,2,M1,2
				P1,2,3
Thorax II	$\frac{4-2}{14}$	A2,4,M	$\frac{6-2}{4}$	A1,2,3,M
		P1,1a,2,2a,3,4,5		P1,2
Thorax III	$\frac{4-2}{14}$	A2,4,M	$\frac{8-2}{4}$	A1,2,3,4,M
		P1,1a,2,2a,3,4,5		P1,2
Abdomen I	$\frac{4}{14}$	A1,2	$\frac{4}{4}$	A1,2
		P1,1a,2,2a,3,4a,5		P1,2
Abdomen II-III	$\frac{6}{16}$	A1,2,5	$\frac{4}{6}$	A1,2
		P1,1a,2,2a,3,4,4a,5		P1,1a,2
Abdomen IV	$\frac{6}{16}$	A1,2,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,4,4a,5		Pc,1,1a,2,2a
Abdomen V	$\frac{6}{16}$	A1,2,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,4,4a,5		Pc,1,1a,2,2a
Abdomen VI	$\frac{6}{16}$	A1,2,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,4,4a,5		Pc,1,1a,2,2a
Abdomen VII	$\frac{6}{18}$	A1,4,5	$\frac{4}{9}$	A1,2
		P1,1a,2,2a,3,3a,4,4a,5		Pc,1,1a,2,3
Abdomen VIII	$\frac{6}{14}$	A1,3,5	$\frac{0}{6}$	
		P1,1a,2,3a,4,4a,5		P1,1a,2
Abdomen IX	14	1,1a,2,2a,3,4,5	6	1,1a,2
Abdomen X	12	1,2,2a,3,4,5	4	1,2
Abdomen XI	8	1,2,2a,3	6	1,2,3
Abdomen XII	9	Ac,1,2,3,4	8	1,2,3,4

Genus *Australentulus* Tuxen, 1967

Diagnosis: The abdominal appendage I (Fig. 23A) with 4 setae and terminal vesicle, and with 3 setae on the abdominal appendages II–III (Fig. 23B and C). Labial palps (Fig. 23D) more or less reduced. Canal of maxillary gland (Fig 23E) simple. Sensilla *t*-3 in foretarsus not willow-leaf-like, but shaped as a longer or shorter bud, from 2–5 times as long as broad, rounded at apex, and mostly parallel-sided; *t*-1 claviform. Striate band on abdomen VIII (Fig. 23F) developed or not reduced. Urosternite VIII with 4 setae and no posterior setae near the hind border.

Type-species: *Australentulus australensis* (Condé, 1957).

Distribution: Thailand, Cambodia, Singapore, Vietnam, Java, and Australia.

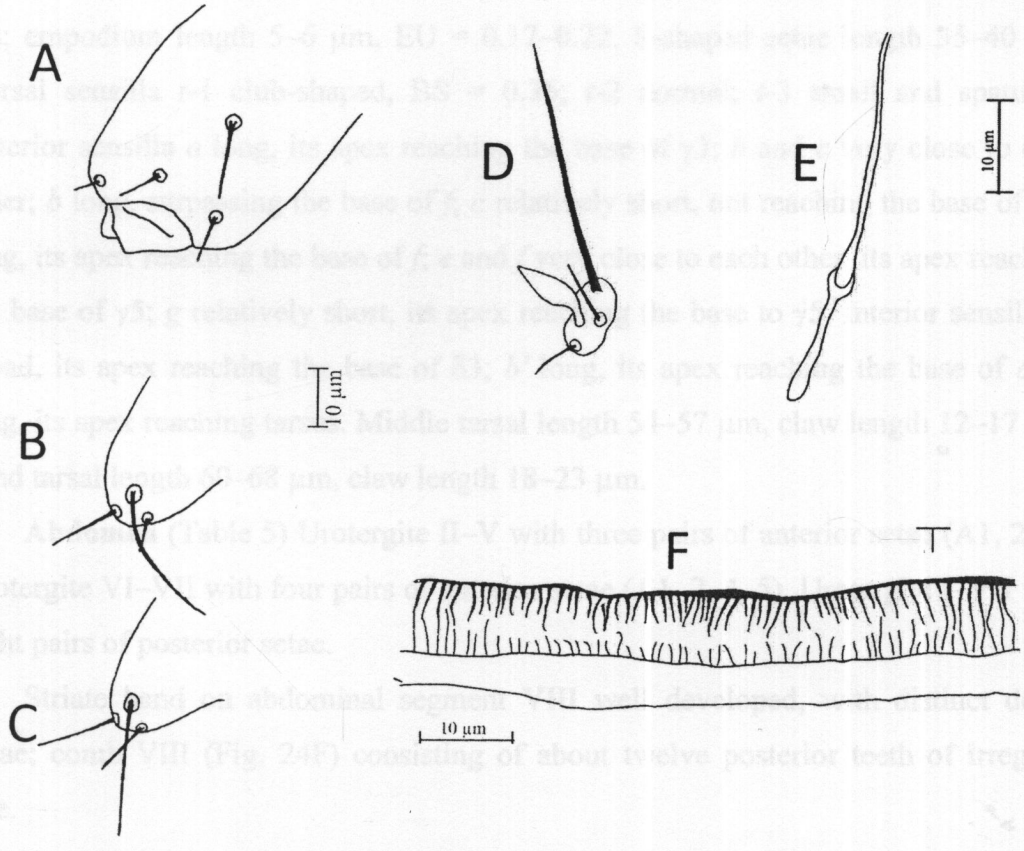


Figure 23 Structures of genus *Australentulus*.

A, abdominal appendage I; B, abdominal appendage II; C, abdominal appendage III; D, labial palpus; E, canal of maxillary gland; F, striate band.

***Australentulus* sp.**

(Fig. 24)

Diagnosis. Striate band on abdominal segment VIII well developed. Urotergite V with three pairs of anterior setae (A1, 2, 5).

Description. Body length 1575–1775 μm.

Head (Fig. 24A) Oval, length 145–147 μm, width 118–120 μm. Labrum distinctly protruded, 28–29 μm, LR = 4.83–4.92. Additional setae absent. Pseudoculus (Fig. 24B) almost circular, length 12.5 μm, width 12.5 μm, PR = 13.3–14.5. Canal of maxillary gland (Fig. 24C) simple.

Thorax (Table 5) Mesonotum and metanotum with three pairs of anterior setae (A2, 4, M).

Foretarsal (Fig. 24D and E) length 115–125 μm, claw length 30 μm, TR = 3.8–4.2; empodium length 5–6 μm, EU = 0.17–0.22, S-shaped setae length 35–40 μm. Dorsal sensilla *t*-1 club-shaped, BS = 0.36; *t*-2 normal; *t*-3 small and spatulate. Exterior sensilla *a* long, its apex reaching the base of γ3; *b* and *c* very close to each other; *b* long, surpassing the base of *f*; *c* relatively short, not reaching the base of *e*; *d* long, its apex reaching the base of *f*; *e* and *f* very close to each other, its apex reaching the base of γ5; *g* relatively short, its apex reaching the base to γ5. Interior sensilla *a'* broad, its apex reaching the base of δ3; *b'* long, its apex reaching the base of *c'*; *c'* long, its apex reaching tarsus. Middle tarsal length 54–57 μm, claw length 12–17 μm. Hind tarsal length 60–68 μm, claw length 18–23 μm.

Abdomen (Table 5) Urotergite II–V with three pairs of anterior setae (A1, 2, 5). Urotergite VI–VII with four pairs of anterior setae (A1, 2, 4, 5). Urotergite I–VII with eight pairs of posterior setae.

Striate band on abdominal segment VIII well developed, with distinct dense striae; comb VIII (Fig. 24F) consisting of about twelve posterior teeth of irregular size.

Genitals Male: unknown. Female: (Fig. 24H) with pointed acrostyli.

Specimens examined. 3 ♀, evergreen hill forest, 2100 m altitude; Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. 1 ♀, Evergreen hill forest, pronotum with two pairs of anterior setae (A1, M) and A4 in the right on urotergite V is lacking.

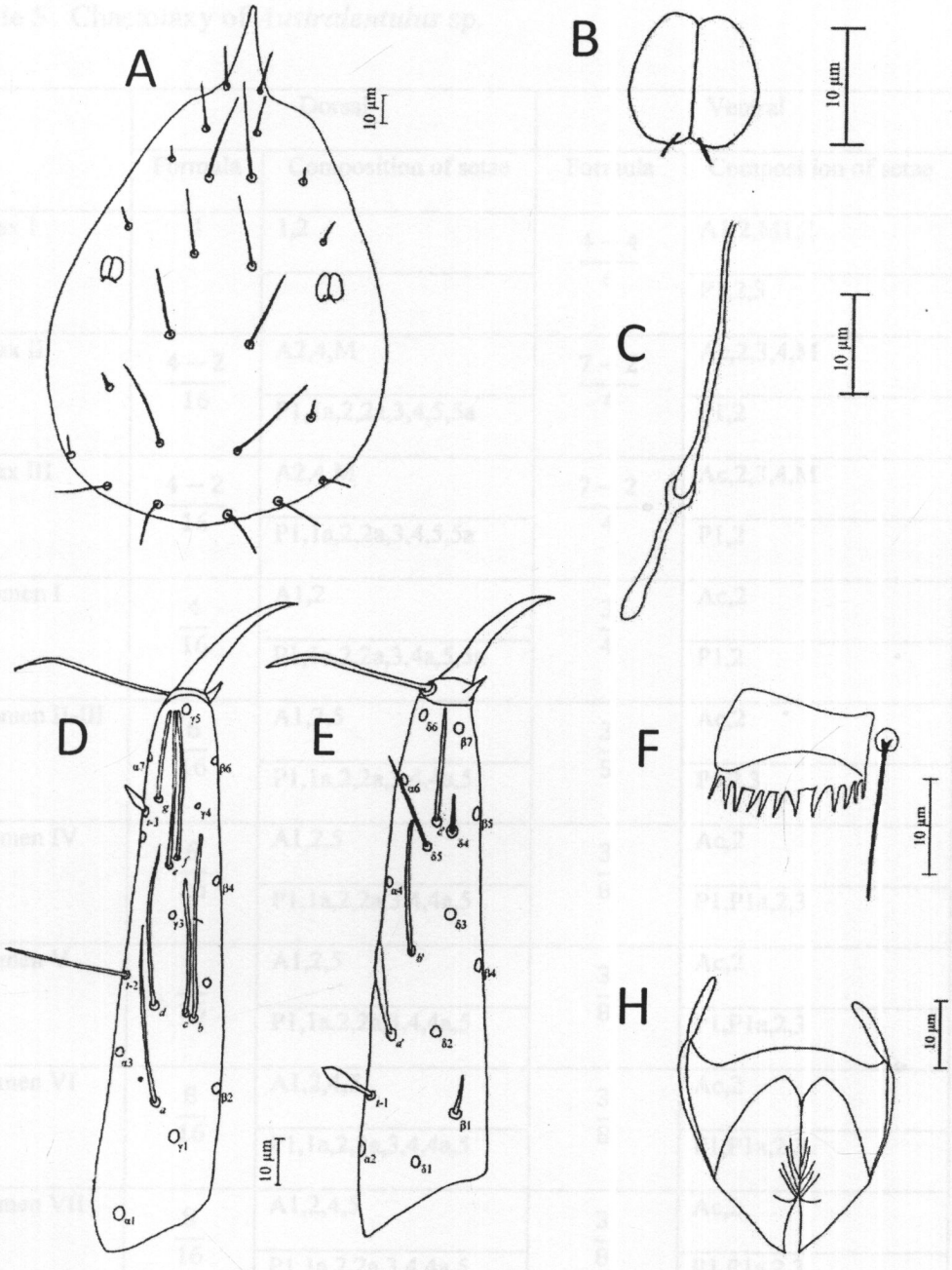


Figure 24 Structures of *Australentulus* sp.

A, dorsal view of head; B, pseudoculus; C, canal of maxillary gland; D, exterior view of foretarsus; E, interior view of foretarsus; F, comb on abdominal VIII; H, female squama genitalis.

Table 5 Chaetotaxy of *Australentulus* sp.

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	4	1,2	$\frac{4-4}{6}$	A1,2,M1,2
				P1,2,3
Thorax II	$\frac{4-2}{16}$	A2,4,M	$\frac{7-2}{4}$	Ac,2,3,4,M
		P1,1a,2,2a,3,4,5,5a		P1,2
Thorax III	$\frac{4-2}{16}$	A2,4,M	$\frac{7-2}{4}$	Ac,2,3,4,M
		P1,1a,2,2a,3,4,5,5a		P1,2
Abdomen I	$\frac{4}{16}$	A1,2	$\frac{3}{4}$	Ac,2
		P1,1a,2,2a,3,4a,5,5a		P1,2
Abdomen II-III	$\frac{6}{16}$	A1,2,5	$\frac{3}{5}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		Pc,2,3
Abdomen IV	$\frac{6}{16}$	A1,2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen V	$\frac{6}{16}$	A1,2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen VI	$\frac{8}{16}$	A1,2,4,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen VII	$\frac{8}{16}$	A1,2,4,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen VIII	$\frac{6-8}{8}$	A1,3,5,M1,2,3,5	$\frac{4}{2}$	A1,2
		P2,3,4,5		P1
Abdomen IX	14	1,1a,2,2a,3,4,5	4	1,2
Abdomen X	12	1,2,2a,3,4,5	4	1,2
Abdomen XI	6	1,2,3	6	1,2,3
Abdomen XII	9	Ac,1,2,3,4	6	1,2,3

Genus *Silvestridia* Bonet, 1942

Diagnosis: Acerentomids with the abdominal appendage I (Fig. 25A) with 4 setae and terminal vesicle, and with usually one sub apical seta on the abdominal appendages II–III (Fig. 25B and C). Labial palps (Fig. 25D) reduced with only two setae and a sensillum. Mouthparts small. Canal of Maxillary gland (Fig. 25E) simple. Sensillum *b* in foretarsus much longer than *c* and broad, spindle-shaped. Striate band on abdominal segment VIII (Fig. 25F) reduced, dispersed striae in the band area proceeding from the proximal border. Comb VIII concave, with small teeth. Hind tarsus at most one and a half times the length of its claw.

Type-species: *Silvestridia artiochaeta* (Bonet, 1942).

Distribution: Mexico, Brazil, Madagascar, Seychelles, Reunion, Thailand, Java, Borneo, Taiwan, and Japan.

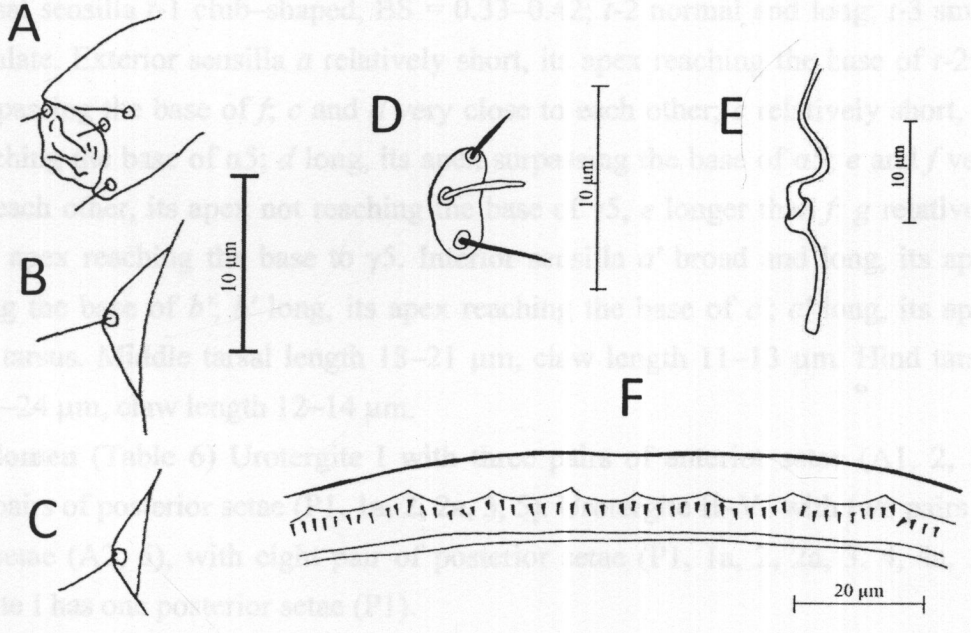


Figure 25 Structures of genus *Silvestridia*.

A, abdominal appendage I; B, abdominal appendage II; C, abdominal appendage III; D, labial palpus; E, canal of maxillary gland; F, striate band.

***Silvestridia keijiana* (Imadaté, 1965)**

(Fig. 26)

Diagnosis. Mesonotum and metanotum with three pairs of anterior setae (A2, 4, M). Urotergite I with three pairs of anterior setae (A1, 2, 5).

Description. Body length 600–780 μm.

Head (Fig. 26A) Oval, length 68–76 μm, width 63–68 μm. Maxillary palps with two slender sensilla on penultimate segment. Labium palps with two setae and a sausage-shaped sensillum. Additional setae absent. Rostrum not protruded. Pseudoculus (Fig. 26B) almost circular, length 6 μm, width 6 μm, PR = 12.0–12.7. Canal of maxillary gland (Fig. 26C) simple.

Thorax (Table 6) Mesonotum and metanotum with three pairs of anterior setae (A2, A4, M), with seven pairs of posterior setae (P1, 1a, 2, 2a, 3, 4, 5).

Foretarsal (Fig. 26D and E) length 43–45 μm, claw length 15–16 μm, TR = 2.7–3.0; empodium length 3–4 μm, EU = 0.19–0.25, S–shaped setae length 16–23 μm. Dorsal sensilla *t*-1 club–shaped, BS = 0.33–0.42; *t*-2 normal and long; *t*-3 small and spatulate. Exterior sensilla *a* relatively short, its apex reaching the base of *t*-2; *b* long, surpassing the base of *f*; *c* and *d* very close to each other; *c* relatively short, its apex reaching the base of α5; *d* long, its apex surpassing the base of α5; *e* and *f* very close to each other, its apex not reaching the base of γ5, *e* longer than *f*; *g* relatively short, its apex reaching the base to γ5. Interior sensilla *a'* broad and long, its apex surpassing the base of *b'*; *b'* long, its apex reaching the base of *c'*; *c'* long, its apex reaching tarsus. Middle tarsal length 18–21 μm, claw length 11–13 μm. Hind tarsal length 21–24 μm, claw length 12–14 μm.

Abdomen (Table 6) Urotergite I with three pairs of anterior setae (A1, 2, 5), with six pairs of posterior setae (P1, 1a, 2, 2a, 3, 5). Urotergite II–VI with two pairs of anterior setae (A2, 5), with eight pair of posterior setae (P1, 1a, 2, 2a, 3, 4, 4a, 5). Urosternite I has one posterior setae (P1).

Striate band on abdominal segment VIII reduced, with wedge-shaped dispersed at the anterior margin; comb VIII (Fig. 26F) consisting of about seven posterior teeth of small size.

Genitals Male: unknown. Female: (Fig. 26H) with pointed acrostyli.

Specimens examined. 9 ♀, evergreen hill forest, 1650 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. 1 ♀, evergreen hill forest, Ac on urosternite I is lacking.

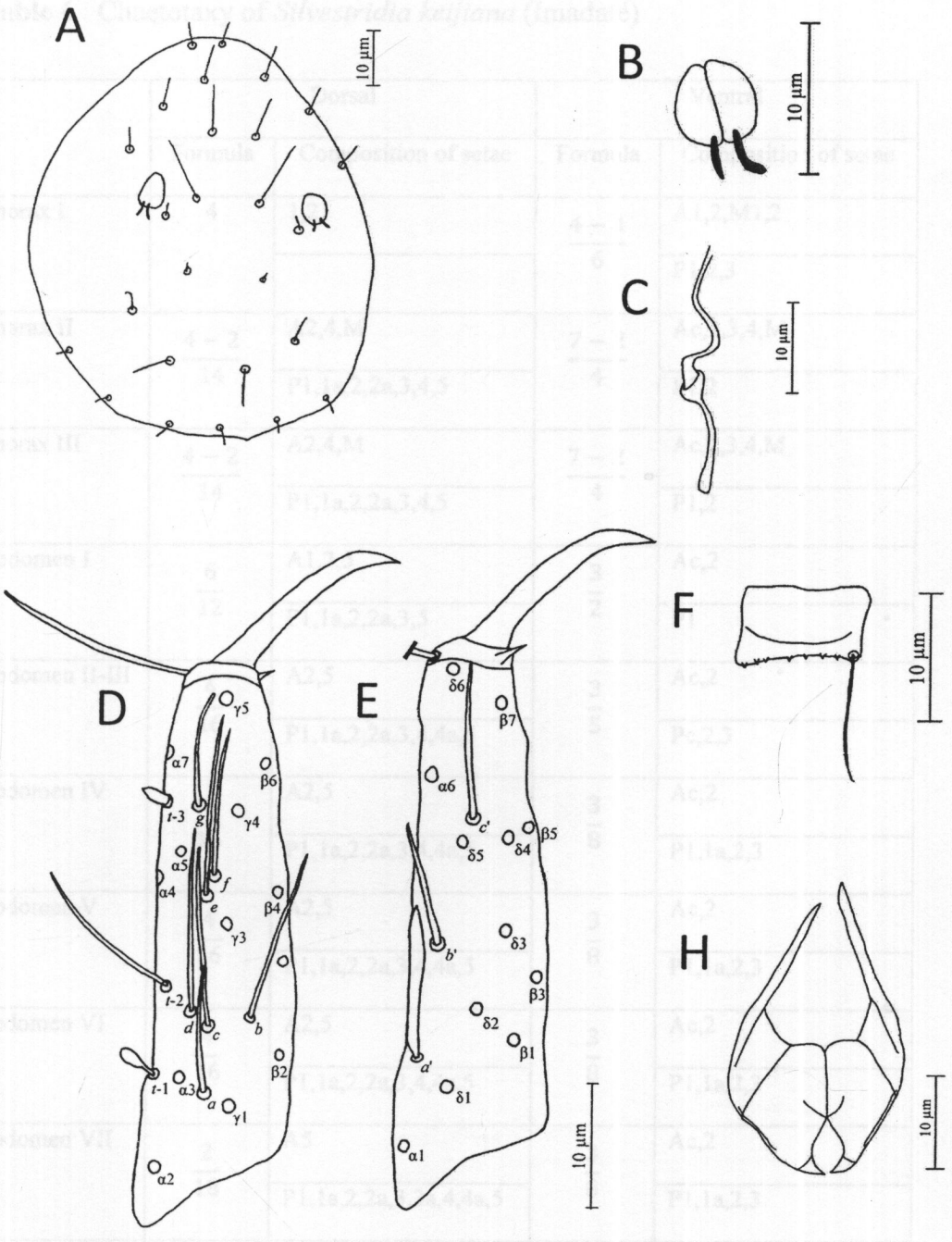


Figure 26 Structures of *Silvestridia keijiana* (Imadaté).

A, dorsal view of head; B, pseudoculus; C, canal of maxillary gland; D, exterior view of foretarsus; E, interior view of foretarsus; F, comb on abdominal VIII; H, female squama genitalis.

Table 6 Chaetotaxy of *Silvestridia keijiana* (Imadaté)

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	4	1,2	$\frac{4-4}{6}$	A1,2,M1,2
				P1,2,3
Thorax II	$\frac{4-2}{14}$	A2,4,M	$\frac{7-2}{4}$	Ac,2,3,4,M
		P1,1a,2,2a,3,4,5		P1,2
Thorax III	$\frac{4-2}{14}$	A2,4,M	$\frac{7-2}{4}$	Ac,2,3,4,M
		P1,1a,2,2a,3,4,5		P1,2
Abdomen I	$\frac{6}{12}$	A1,2,5	$\frac{3}{2}$	Ac,2
		P1,1a,2,2a,3,5		P1
Abdomen II-III	$\frac{4}{16}$	A2,5	$\frac{3}{5}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		Pc,2,3
Abdomen IV	$\frac{4}{16}$	A2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,1a,2,3
Abdomen V	$\frac{4}{16}$	A2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,1a,2,3
Abdomen VI	$\frac{4}{16}$	A2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,1a,2,3
Abdomen VII	$\frac{2}{18}$	A5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,3a,4,4a,5		P1,1a,2,3
Abdomen VIII	$\frac{4-7}{8}$	A3,5,Mc,2,3,4	$\frac{0}{4}$	
		P2,3,4,5		P1,2
Abdomen IX	12	1,2,3,3a,4,5	4	1,2
Abdomen X	12	1,2,3,3a,4,5	4	1,2
Abdomen XI	6	1,2,3	4	1,2
Abdomen XII	9	Ac,1,2,3,4	6	1,2,3

Genus *Baculentulus* Tuxen, 1977

Diagnosis: Acerentomids with the abdominal appendage I (Fig. 27A) with 4 setae and terminal vesicle, and the abdominal appendages II–III (Fig. 27B and C) with one long and one very short setae. Labial palps (Fig. 27D) reduced with 2–3 setae. Canal of maxillary gland (Fig. 27E) simple. Foretarsus sensillum *t*-1 baculiform. The striate band (Fig. 27F) reduced. Comb VIII more or less oblique.

Type-species: *Baculentulus becki* (Tuxen, 1976)

Distribution: North and South America, East Africa, Southwest Asia, India, Thailand, Japan, and Australia.

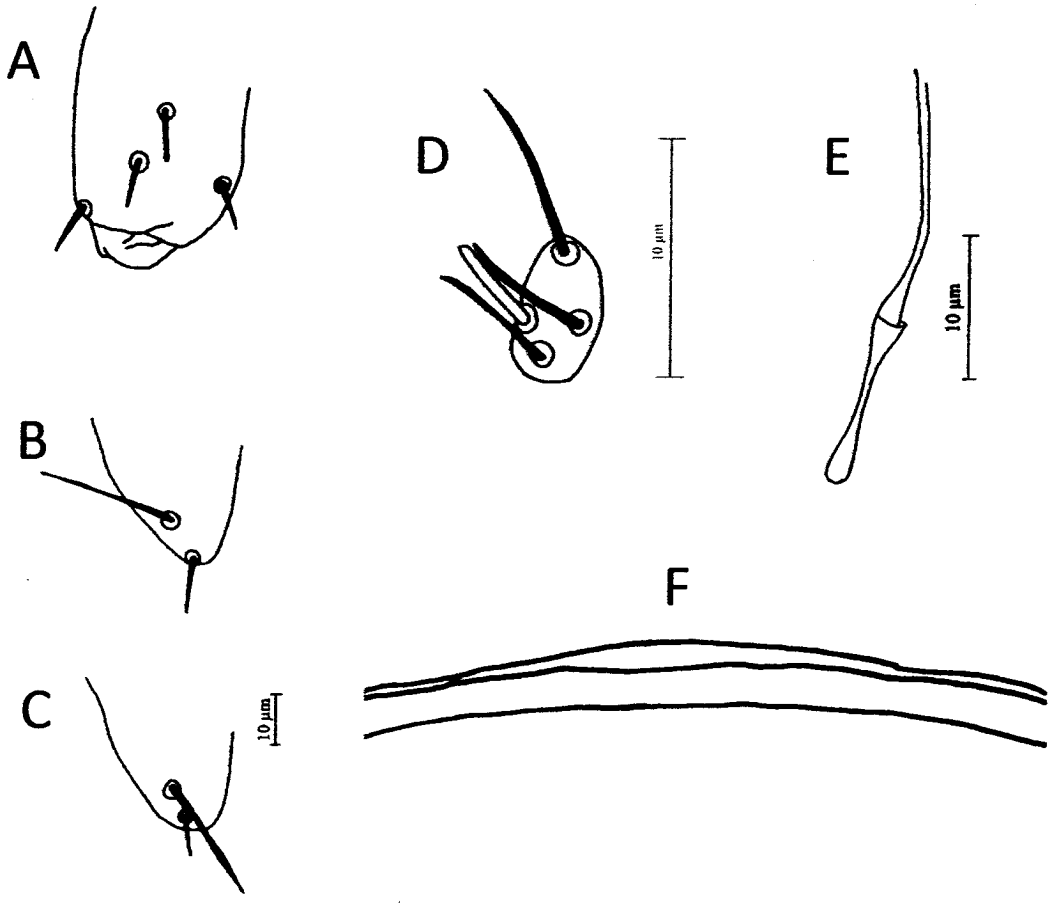


Figure 27 Structures of genus *Baculentulus*.

A, abdominal appendage I; B, abdominal appendage II; C, abdominal appendage III; D, labial palpus; E, canal of maxillary gland; F, striate band.

***Baculentulus* sp.**

(Fig. 28)

Diagnosis. Interior sensillum *b'* absent.

Description. Body length 790–893 μm.

Head (Fig. 28A) Oval, length 84–88 μm, width 71–77 μm. Additional setae absent. Rostrum not protruded. Pseudoculus (Fig. 28B) almost circular, length 6–6.5 μm, width 6.4–7 μm, PR = 13.3–14.7. Canal of maxillary gland (Fig. 28C) simple.

Thorax (Table 7) Mesonotum and metanotum with three pairs of anterior setae (A2, 4, M), with eight pairs of posterior setae (P1, 1a, 2, 2a, 3, 4, 5, 5a).

Foretarsal (Fig. 28D and E) length 64–71 μm, claw length 21–22 μm, TR = 3–3.2; Empodium length 3.9–5 μm, EU = 0.18–0.23, S-shaped setae length 24–27 μm. Dorsal sensilla *t*-1 baculiform, BS = 0.42–0.45; *t*-2 normal and long; *t*-3 small and spatulate. Exterior sensilla *a* long, its apex reaching the base of *γ3*; *b* long, reaching the base of *g*; *c* long, its apex reaching the base of *f*; *d* long, its apex reaching the base of δ5; *e* and *f* long, its apex reaching tarsus; *g* relatively short, its apex reaching the base to α7. Interior sensilla *a'* broad and long, distally contracted, its apex surpassing the base of *γ3*; *b'* absent; *c'* long, its apex surpassing tarsus. Middle tarsal length 29–32 μm, claw length 13–15 μm. Hind tarsal length 33–36 μm, claw length 13–16 μm.

Abdomen (Table 7) Urotergite I with two pairs of anterior setae (A1, 2), seven pairs of posterior setae. Urotergites II–VI with three pairs of anterior setae (A1, 2, 5). Urotergite VII with two pairs of anterior setae (A4, 5). Urotergites II–VII with eight pairs of posterior setae.

Striate band on abdominal segment VIII reduced; comb VIII (Fig. 28F) consisting of about nine posterior teeth of irregular size.

Genitals Male: (Fig. 28G) basistylus with short setae. Female: (Fig. 28H) with pointed acrostyli.

Specimens examined. 1 ♂, 3 ♀, evergreen hill forest, 1650 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. –

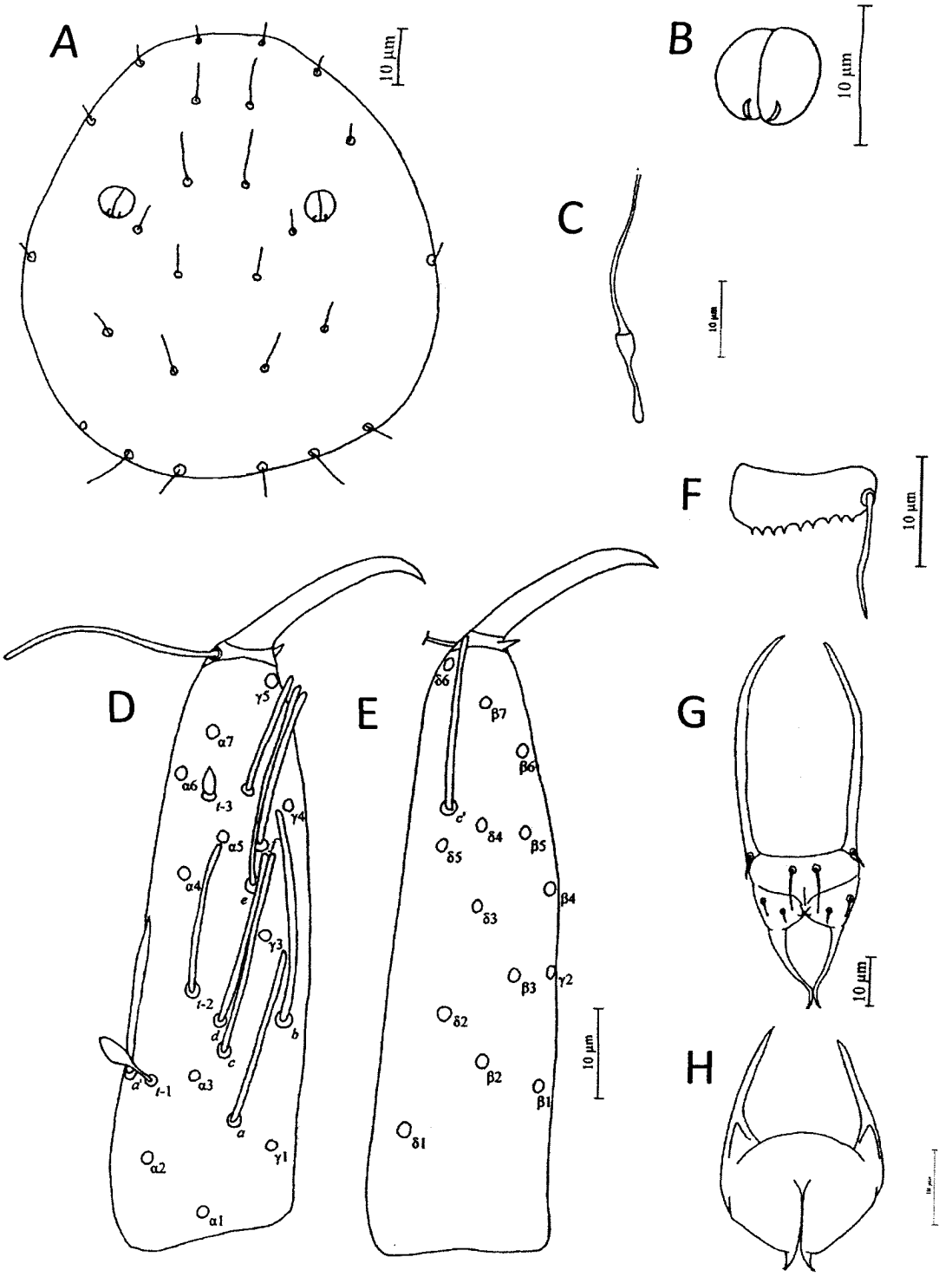


Figure 28 Structures of *Baculentulus* sp.

A, dorsal view of head; B, pseudoculus; C, canal of maxillary gland; D, anterior view of foretarsus; E, posterior view of foretarsus; F, comb on abdominal VIII; G, male squama genitalis; H, female squama genitalis.

Table 7 Chaetotaxy of *Baculentulus* sp.

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	4	1,2	$\frac{4-4}{6}$	A1,2,M1,2
				P1,2,3
Thorax II	$\frac{4-2}{16}$	A2,4,M	$\frac{7-2}{4}$	Ac,2,3,4,M
		P1,1a,2,2a,3,4,5,5a		P1,2
Thorax III	$\frac{4-2}{16}$	A2,4,M	$\frac{7-2}{4}$	Ac,2,3,4,M
		P1,1a,2,2a,3,4,5,5a		P1,2
Abdomen I	$\frac{4}{14}$	A1,2	$\frac{3}{2}$	Ac,2
		P1,1a,2,2a,3,4a,5		P1
Abdomen II-III	$\frac{6}{16}$	A1,2,5	$\frac{3}{5}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		Pc,2,3
Abdomen IV	$\frac{6}{16}$	A1,2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen V	$\frac{6}{16}$	A1,2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen VI	$\frac{6}{16}$	A1,2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen VII	$\frac{4}{16}$	A4,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen VIII	$\frac{6-7}{8}$	A1,3,5,Mc,2,3,5	$\frac{4}{0}$	A1,2
		P2,3,4,5		
Abdomen IX	14	1,1a,2,2a,3,4,5	4	1,2
Abdomen X	12	1,2,2a,3,4,5	4	1,2
Abdomen XI	6	1,2,3	6	1,2,3
Abdomen XII	9	Ac,1,2,3,4	6	1,2,3

Genus *Kenyentulus* Tuxen, 1981

Diagnosis: The abdominal appendage I (Fig. 29A) with 4 setae and terminal vesicle, and the abdominal appendages II and III (Fig. 29B and C) with 2 setae, without terminal vesicle, a long sub apical one. Labial palps (Fig. 29D) reduced with 3 setae. Canal of maxillary gland (Fig. 29E) with 2 or 3 dilatations proximal to calyx. Sensilla *t*-1 on foretarsus baculiform, *t*-3 knob–shaped, *b'* present. Striate band (Fig. 29F) reduced. Urosternite VIII without posterior setae.

Type–species: *Kenyentulus kenyanus* (Condé, 1948).

Distribution: Seychelles, India, Nepal, China, Thailand, Singapore, Malaya, Java, Borneo, Taiwan, Korea, and Japan

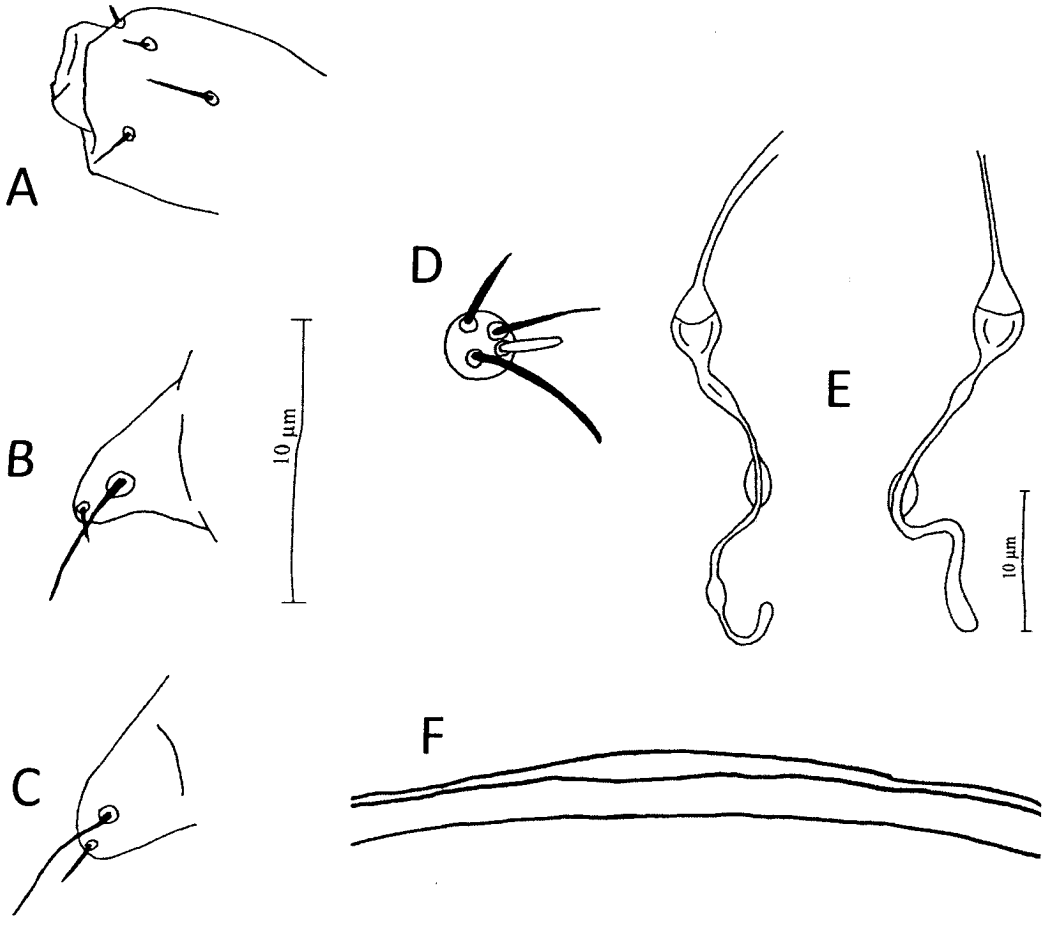


Figure 29 Structures of genus *Kenyentulus*.

A, abdominal appendage I; B, abdominal appendage II; C, abdominal appendage III; D, labial palpus; E, canal of maxillary gland; F, striate band.

***Kenyentulus* sp. 1**

(Fig. 30)

Diagnosis. Canal of maxillary gland with two additions on the proximal part. Urotergite I-IV with three pairs of anterior setae (A1, 2, 5).

Description. Body length 680–840 μm.

Head (Fig. 30A) Oval, length 79–86 μm, width 69–78 μm. Additional setae absent. Rostrum not protruded. Pseudoculus (Fig. 30B), length 6–6.7 μm, width 6.2–7 μm, PR = 11.8–13.3. Canal of maxillary gland (Fig. 30C) relatively long with two additions on the proximal part.

Thorax (Table 8) Mesonotum and metanotum with three pairs of anterior setae (A2, 4, M), with eight pairs of posterior setae (P1, 1a, 2, 2a, 3, 4, 5, 5a).

Foretarsal (Fig. 30D and E) length 50–54 μm, claw length 16–18 μm, TR= 2.9–3.2; empodium length 3.0–3.8 μm, EU = 0.18–0.25, S–shaped setae length 19–22 μm. Dorsal sensilla *t*-1 claviform, BS = 0.42–0.48; *t*-2 normal and long; *t*-3 small and spatulate. Exterior sensilla *a* long, its apex surpassing the base of *γ3*; *b* slim and short, surpassing the base of *γ2*; *c* and *d* long, its apex surpassing the base of *f*; *e* normal, its apex surpassing the base of *g*, *f* long, its apex reaching the base of γ5; *g* relatively short, its apex reaching the base to γ5. Interior sensilla *a'* long, its apex reaching the base of *b'*; *b'* long, its apex reaching the base of *c'*; *c'* long, its apex surpassing tarsus. Middle tarsal length 22–24 μm, claw length 11–13 μm. Hind tarsal length 24–27 μm, claw length 12–15 μm.

Abdomen (Table 8) Urotergite I-IV with three pairs of anterior setae (A1, 2, 5). Urotergite V–VI with two pairs of anterior setae (A2, 5). Urotergite VII with three pairs of anterior setae (A2, 4, 5).

Striate band on abdominal segment VIII reduced; comb VIII (Fig. 30F) consisting of about eight small size.

Genitals Male: unknown. Female: (Fig. 30H) with sharply pointed acrostyli.

Specimens examined. 11 ♀, bamboo stands, 700 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. –

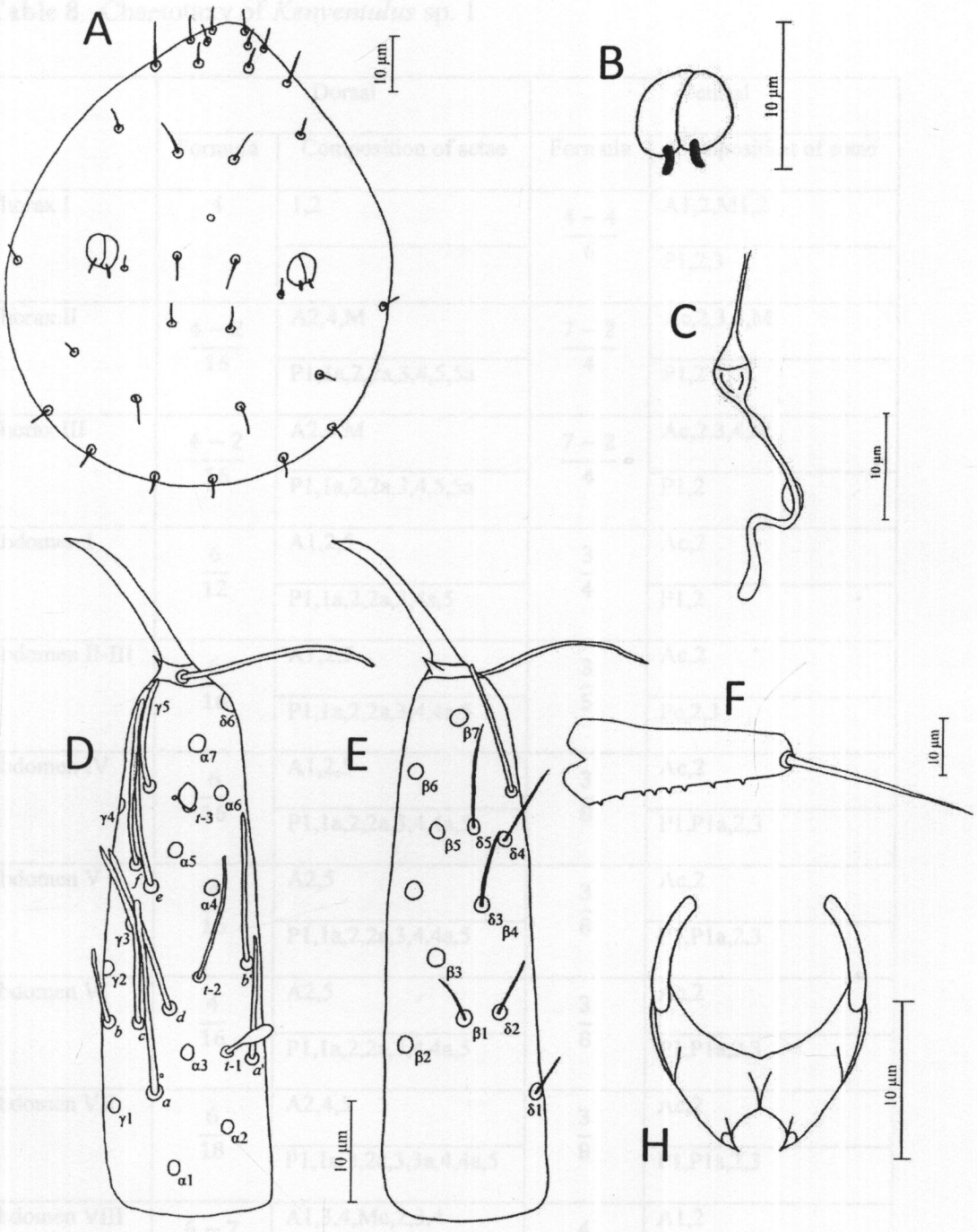


Figure 30 Structures of *Kenyentulus* sp. 1.

A, dorsal view of head; B, pseudoculus; C, canal of maxillary gland; D, anterior view of foretarsus; E, posterior view of foretarsus; F, comb on abdominal VIII; H, female squama genitalis.

Table 8 Chaetotaxy of *Kenyentulus* sp. 1

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	4	1,2	$\frac{4-4}{6}$	A1,2,M1,2
				P1,2,3
Thorax II	$\frac{4-2}{16}$	A2,4,M	$\frac{7-2}{4}$	Ac,2,3,4,M
		P1,1a,2,2a,3,4,5,5a		P1,2
Thorax III	$\frac{4-2}{16}$	A2,4,M	$\frac{7-2}{4}$	Ac,2,3,4,M
		P1,1a,2,2a,3,4,5,5a		P1,2
Abdomen I	$\frac{6}{12}$	A1,2,5	$\frac{3}{4}$	Ac,2
		P1,1a,2,2a,3,4a,5		P1,2
Abdomen II-III	$\frac{6}{16}$	A1,2,5	$\frac{3}{5}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		Pc,2,3
Abdomen IV	$\frac{6}{16}$	A1,2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen V	$\frac{4}{16}$	A2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen VI	$\frac{4}{16}$	A2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen VII	$\frac{6}{18}$	A2,4,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,3a,4,4a,5		P1,P1a,2,3
Abdomen VIII	$\frac{6-7}{8}$	A1,3,4,Mc,2,3,4	$\frac{4}{0}$	A1,2
		P2,3,4,5		
Abdomen IX	14	1,1a,2,2a,3,4,5	4	1,2
Abdomen X	12	1,2,2a,3,4,5	4	1,2
Abdomen XI	6	1,2,3	6	1,2,3
Abdomen XII	9	Ac,1,2,3,4	6	1,2,3

***Kenyentulus* sp. 2**

(Fig. 31)

Diagnosis. Canal of maxillary gland with two additions on the proximal part. Urotergite IV-VI with two pairs of anterior setae (A2, 5).

Description. Body length 745–810 μm.

Head (Fig. 31A) Oval, length 64–80 μm, width 52–74 μm. Rostrum not protruded. Pseudoculus (Fig. 31B), length 4.5–6.5 μm, width 4.5–7 μm, PR = 12–14.2. Canal of maxillary gland (Fig. 31C) relatively long with two additions on the proximal part.

Thorax (Table 9) Mesonotum and metanotum with three pairs of anterior setae (A2, 4, M), with eight pairs of posterior setae (P1, 1a, 2, 2a, 3, 4, 5, 5a).

Foretarsal (Fig. 31D and E) length 51–54.5 μm, claw length 16.5–17 μm, TR = 3–3.2; empodium length 3 μm, EU = 0.18, S-shaped setae length 21–22 μm. Dorsal sensilla *t*-1 claviform, BS = 0.44–0.46; *t*-2 normal and long; *t*-3 small and spatulate. Exterior sensilla *a* long, its apex reaching the base of *e*; *b* slim and short, surpassing the base of *γ2*; *c* and *d* long, its apex reaching the base of *f*, *d* longer than *c*; *e* and *f* long, its apex reaching the base of *γ5*; *g* relatively short, its apex reaching the base to *γ5*. Interior sensilla *a'* long, its apex reaching the base of *b'*; *b'* long, its apex not reaching the base of *c'*; *c'* long, its apex surpassing tarsus. Middle tarsal length 19–23 μm, claw length 10–13 μm. Hind tarsal length 19–25 μm, claw length 11–15 μm.

Abdomen (Table 9) Urotergite I–III with three pairs of anterior setae (A1, 2, 5). Urotergite IV–VI with two pairs of anterior setae (A2, 5). Urotergite VII with three pairs of anterior setae (A2, 4, 5).

Striate band on abdominal segment VIII reduced; comb VIII (Fig. 31F) consisting of about ten small size.

Genitals Male: unknown. Female: (Fig. 31H) with sharply pointed acrostyli.

Specimens examined. 4 ♀, bamboo stands, 700 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. –

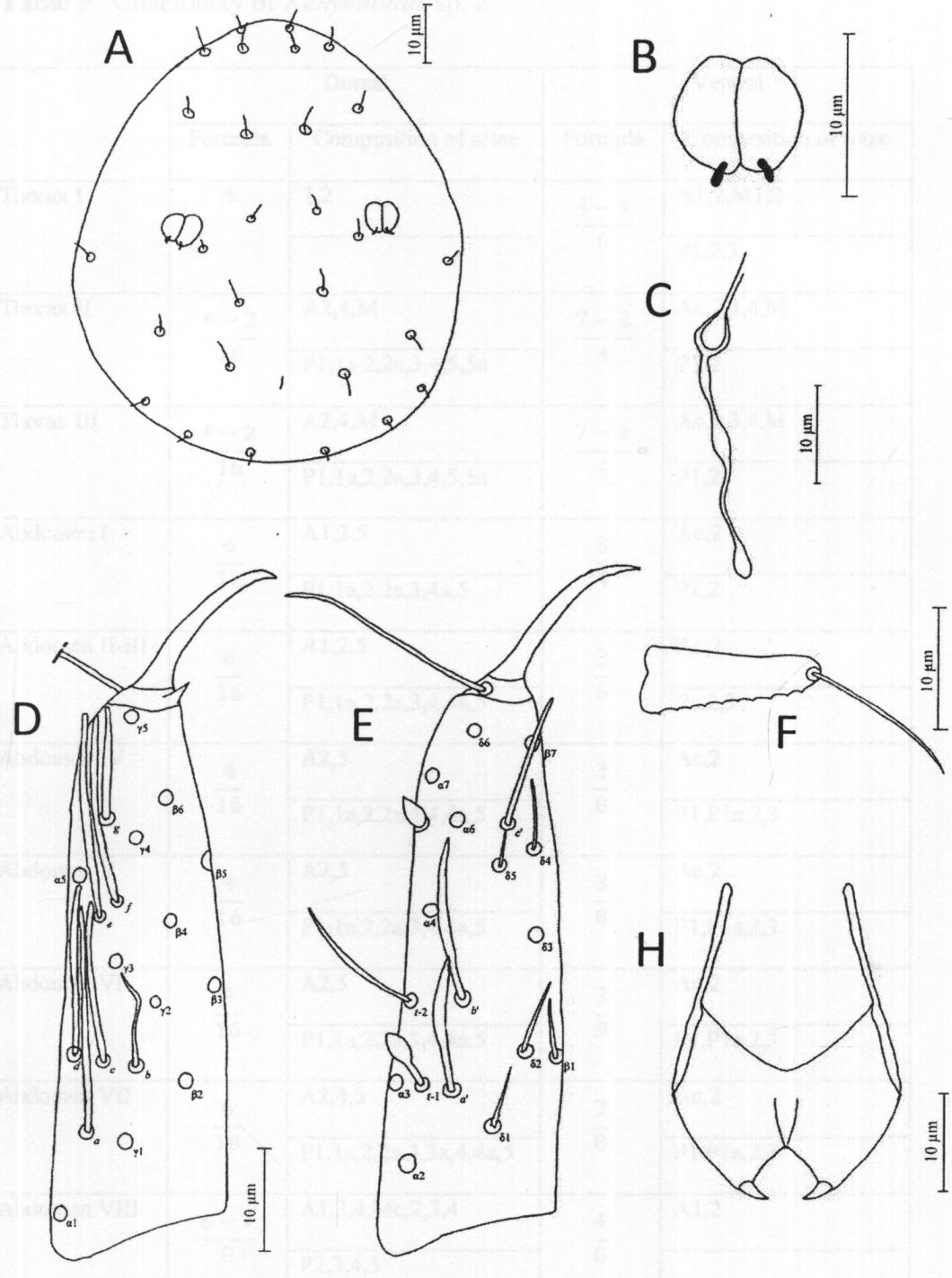


Figure 31 Structures of *Kenyentulus* sp. 2.

A, dorsal view of head; B, pseudoculus; C, canal of maxillary gland; D, exterior view of foretarsus; E, interior view of foretarsus; F, comb on abdominal VIII; H, female squama genitalis.

Table 9 Chaetotaxy of *Kenyentulus* sp. 2

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	4	1,2	$\frac{4-4}{6}$	A1,2,M1,2
				P1,2,3
Thorax II	$\frac{4-2}{16}$	A2,4,M	$\frac{7-2}{4}$	Ac,2,3,4,M
		P1,1a,2,2a,3,4,5,5a		P1,2
Thorax III	$\frac{4-2}{16}$	A2,4,M	$\frac{7-2}{4}$	Ac,2,3,4,M
		P1,1a,2,2a,3,4,5,5a		P1,2
Abdomen I	$\frac{6}{12}$	A1,2,5	$\frac{3}{4}$	Ac,2
		P1,1a,2,2a,3,4a,5		P1,2
Abdomen II-III	$\frac{6}{16}$	A1,2,5	$\frac{3}{5}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		Pc,2,3
Abdomen IV	$\frac{4}{16}$	A2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen V	$\frac{4}{16}$	A2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen VI	$\frac{4}{16}$	A2,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,4,4a,5		P1,P1a,2,3
Abdomen VII	$\frac{6}{18}$	A2,4,5	$\frac{3}{8}$	Ac,2
		P1,1a,2,2a,3,3a,4,4a,5		P1,P1a,2,3
Abdomen VIII	$\frac{6-7}{8}$	A1,3,4,Mc,2,3,4	$\frac{4}{0}$	A1,2
		P2,3,4,5		
Abdomen IX	14	1,1a,2,2a,3,4,5	4	1,2
Abdomen X	12	1,2,2a,3,4,5	4	1,2
Abdomen XI	6	1,2,3	6	1,2,3
Abdomen XII	9	Ac,1,2,3,4	6	1,2,3

Genus *Eosentomon* Berlese, 1908

Diagnosis: Eosentomids with 5 setae and terminal vesicle on the abdominal appendages I–III (Fig. 32A-C). Mesonotum and metanotum (Fig. 32D) with spiracles. Mandibles rather broad and stout, ending usually in 3 teethes, and striate in its distal part. Sensilla *e* and *g* on foretarsus spatulate.

Type–species: *Eosentomon transitorium Berlese, 1908*

Distribution: World wide

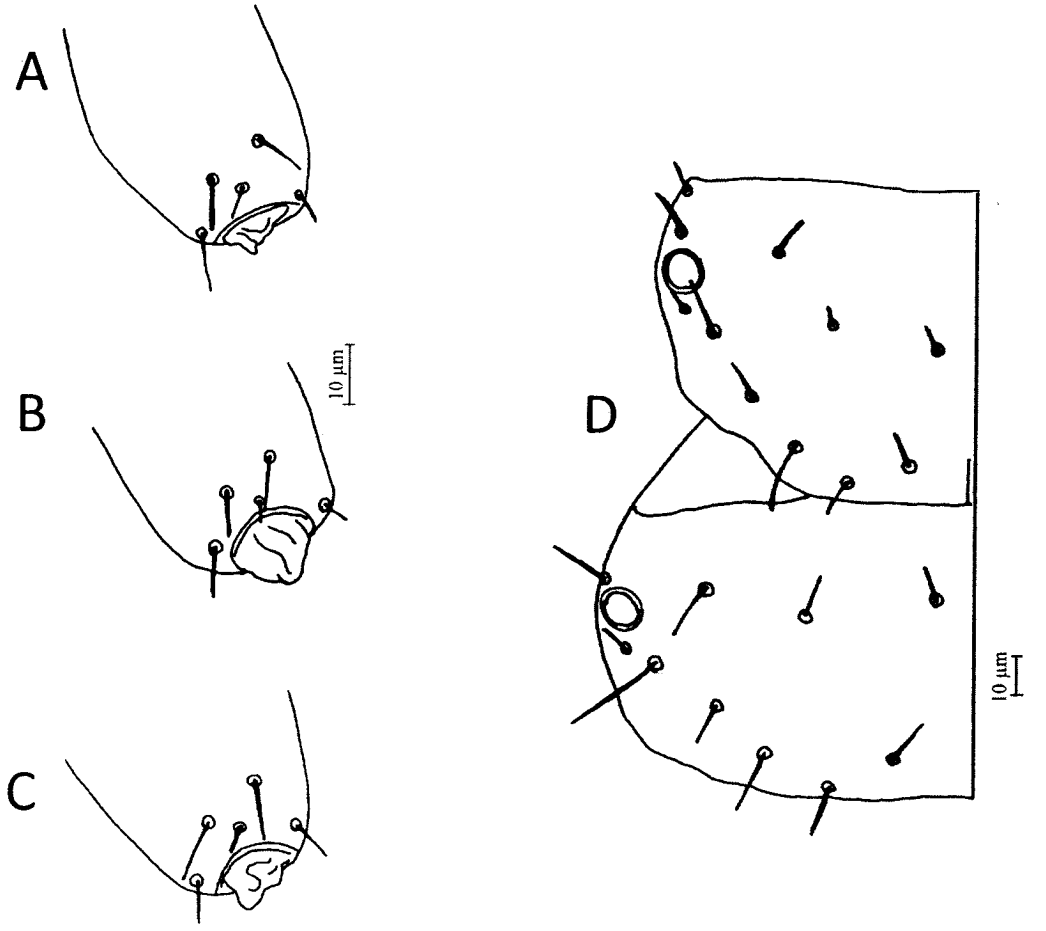


Figure 32 Structures of genus *Eosentomon*.

A, abdominal appendage I; B, abdominal appendage II; C, abdominal appendage III; D, spiracles on mesonotum and metanotum.

Eosentomon **sp. 1**

(Fig. 33)

Diagnosis. Urotergites V–VII with two pairs of anterior setae (A4, 5).

Description. Body length 880–950 μm.

Head (Fig. 33A) Oval, length 128–135 μm, width 117–122 μm. Posterior sensilla, anterior additional setae, posterior additional setae, anterior sensilla, medium 4 setae present; subposterior setae 2.2 times longer than posterior setae; sensilla posterior to pseudoculus rudimentary. Pseudoculus (Fig. 33B) ovoid with one central depression and line, length 14 μm, width 11 μm, PR = 0.96.

Thorax (Table 10) On mesonotum and metanotum, P1a situated posterior to the row of P1 and P2, seta-like; P2a on the same row as P2 and P3, seta-like. Metanotum with P5a, but P5a′ indistinct. Tracheal camerae (Fig. 33C) slender.

Foretarsal (Fig. 33D and E) length 94–96 μm, claw length 22–23 μm, TR = 4.1–4.2; Empodium length 21–22 μm, EU = 0.91–0.96, S-shaped seta length 23–25 μm. Dorsal sensilla *t*-1 about halfway between α3 and α3′, BS = 1.1–1.2; *t*-2 filiform, relatively long, its apex reaching base of α5; *t*-3 normal. Exterior sensilla *a* of medium size; *b* and *c* linear; *d* broad, distally contracted, and relatively long, its apex reaching base of α7; *e* and *g* spatulate; *f* 1 filiform, its apex surpassing base of γ5; *f* 2 short. Interior sensilla *a′* short, its apex slightly reaching the base α3′; *b*′1 broad; *b*′2 filiform, its apex reaching base of α6; *c′* normal, its apex reaching base of δ6. Middle tarsal length 48–50 μm, claw length 13–15 μm. Hind tarsal length 60–63 μm, claw length 16–18 μm.

Abdomen (Table 10) On Urotergites II–IV with five pairs of anterior setae. Urotergites V–VII with two pairs (A4, 5). Urotergites X–XI with eight setae. Urotergite I with five pairs of posterior setae (P1, 1a, 2, 3, 3a), P3a small leaf-shaped. Urotergite II–III, P1a situated posterior to the row of P1 and P2, hair-like; P2a situated posterior to the row of P3 and P4, hair–like. Urotergites I–VI with P1a and P2a and urotergite VII with P2a situated posterior to the row of P1 and 2, hair-like; on urotergite VII P1a situated on posterior row to row of P1 and P2, near to P2, sensillum-like and short; on urotergite VIII, P1a′ without basal dilatation; P2a′ linear. Urosternite VIII with seven setae.

Genitals Male: (Fig. 33F) acroperiphallus with short setae. Female: (Fig. 33G) semicircular caput processus combined with a rather developed caput processus, a small median sclerotization of stylus in the rounded part of caput.

Specimens examined. 2 ♂, 2 ♀, summit evergreen forest, 2450 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. –

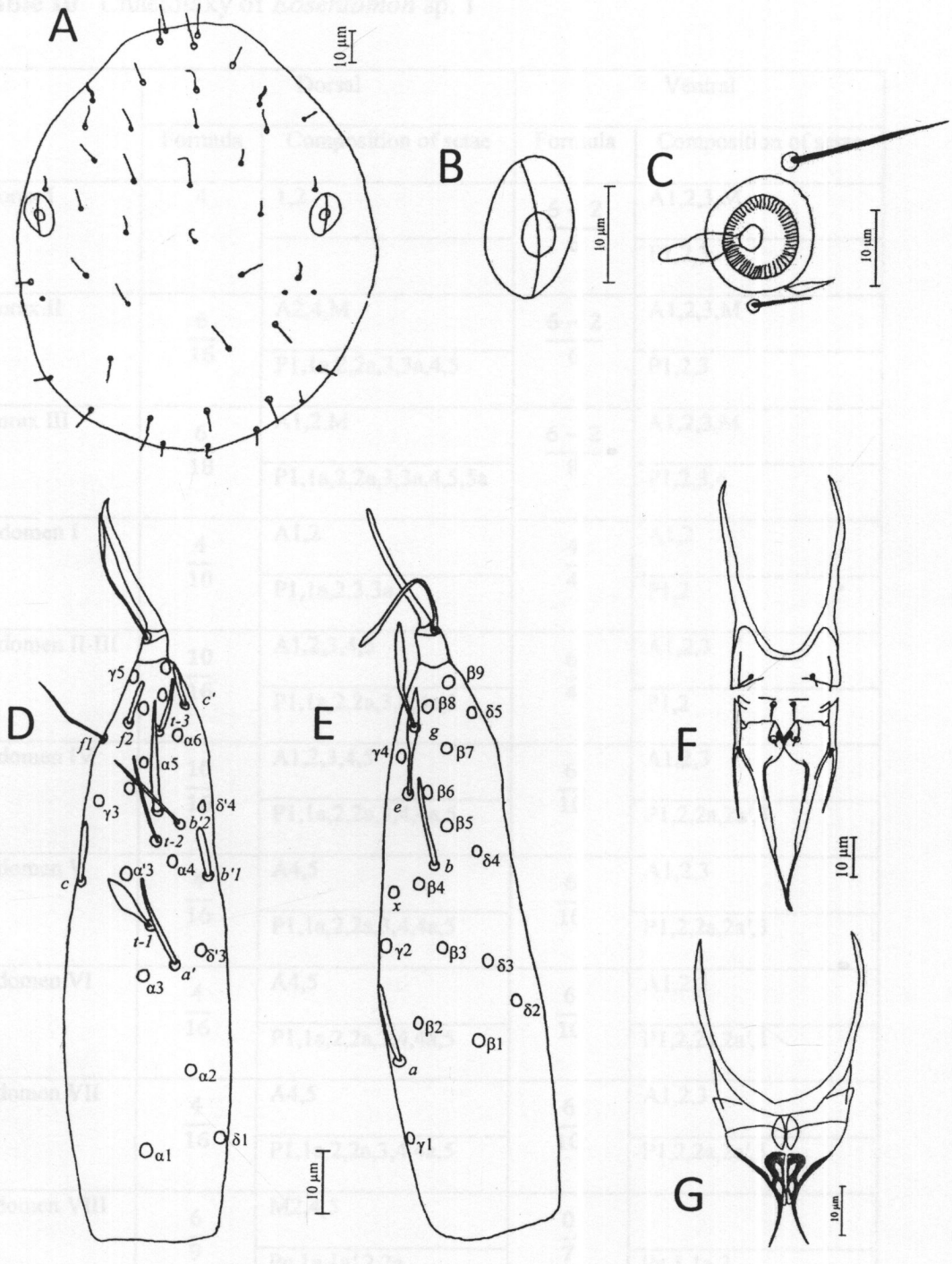


Figure 33 Structures of *Eosentomon* sp. 1.

A, dorsal view of head; B, pseudoculus; C, tracheal camerae; D, anterior view of foretarsus; E, posterior view of foretarsus; F, male squama genitalis; G, female squama genitalis.

Table 10 Chaetotaxy of *Eosentomon* sp. 1

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	4	1,2	$\frac{6-2}{6}$	A1,2,3,M
				P1,2,3
Thorax II	$\frac{6}{16}$	A2,4,M	$\frac{6-2}{6}$	A1,2,3,M
		P1,1a,2,2a,3,3a,4,5		P1,2,3
Thorax III	$\frac{6}{18}$	A1,2,M	$\frac{6-2}{8}$	A1,2,3,M
		P1,1a,2,2a,3,3a,4,5,5a		P1,2,3,4
Abdomen I	$\frac{4}{10}$	A1,2	$\frac{4}{4}$	A1,2
		P1,1a,2,3,3a		P1,2
Abdomen II-III	$\frac{10}{16}$	A1,2,3,4,5	$\frac{6}{4}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2
Abdomen IV	$\frac{10}{16}$	A1,2,3,4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen V	$\frac{4}{16}$	A4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VI	$\frac{4}{16}$	A4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VII	$\frac{4}{16}$	A4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VIII	$\frac{6}{9}$	M2,4,5	$\frac{0}{7}$	
		Pc,1a,1a',2,2a		Pc,1,1a,2
Abdomen IX	8	1,2,3,4	4	1,2
Abdomen X	8	1,2,3,4	4	1,2
Abdomen XI	8	1,2,3,4	8	1,2,3,4
Abdomen XII	9	Ac,1,2,3,4	12	1,2,3,4,5,6

Eosentomon **sp. 2**

(Fig. 34)

Diagnosis. Urotergites V–VI with two pairs of anterior setae (A4, 5). Urotergite VII with a pairs of anterior setae (A5).

Description. Body length 1300–1375 μm.

Head (Fig. 34A) Oval, length 150–157 μm, width 120–125 μm. Anterior additional setae absent; posterior additional setae, posterior sensilla, anterior sensilla, medium 4 setae present; subposterior setae 2.6 times longer than posterior setae; sensilla posterior to pseudoculus rudimentary. Pseudoculus (Fig. 34B) ovoid with one central line, length 14 μm, width 9 μm, PR= 0.96.

Thorax (Table 11) On mesonotum and metanotum, P1a situated posterior to the row of P1 and P2, seta-like; P2a on the same row as P2 and P3, seta-like. Metanotum with P5a and P5a′ distinct. Tracheal camerae (Fig. 34C) slender.

Foretarsal (Fig. 34D and E) length 110–112 μm, claw length 23 μm, TR = 4.8–4.9; empodium length 24–25 μm, EU = 1.04–1.09, S-shaped setae length 25–26 μm. Dorsal sensilla *t*-1 about halfway between α3 and α3′, BS = 1.1–1.2; *t*-2 filiform, relatively long, its apex reaching base of γ3; *t*-3 broad, distally contracted, and relatively long, its apex surpassing tarsus. Exterior sensilla *a* of medium size; *b* and *c* linear; *d* broad, distally contracted, and relatively long, its apex surpassing base of *t*-3; *e* and *g* spatulate; *f* 1 filiform, its apex reaching base of γ5; *f* 2 short. Interior sensilla *a′* short, its apex slightly reaching the base *t*-2; *b′*1 absent; *b′*2 seta–form, its apex reaching base of α5; *c′* absent. Middle tarsal length 56–58 μm, claw length 15–17 μm. Hind tarsal length 70–74 μm, claw length 17–19 μm.

Abdomen (Table 11) On Urotergites II–IV with five pairs of anterior setae. Urotergites V–VI with two pairs (A4, 5). Urotergite VII with a pairs (A5). Urotergite I with five pairs of posterior setae (P1, 1a, 2, 3, 3a), P3a small leaf-shaped. Urotergite II–III, P1a situated posterior to the row of P1 and P2, hair–like; P2a situated posterior to the row of P3 and P4, hair-like. Urotergites X–XI with four pairs of setae. P1a and P2a on urotergites I–V and P2a on urotergites VI–VII situated posterior to the row of P1 and 2, hair-like; on urotergites VI–VII P1a situated on posterior row to row of P1 and P2, near to P2, sensillum-like and short. On urosternite I P1 situated posterior to the row of P1 and 2, hair-like, slightly shorter than P1 in length; P3 and P4 minute, club-shaped, 3 μm in length.

Genitals Male: unknown. Female: (Fig. 34G) caput processus roundly bent against the middle line like crane head, with oblique appendices, filum processus relatively long, proximolateral sclerotization well developed.

Specimens examined. 3 ♀, summit evergreen cloud forest, 2450 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. –

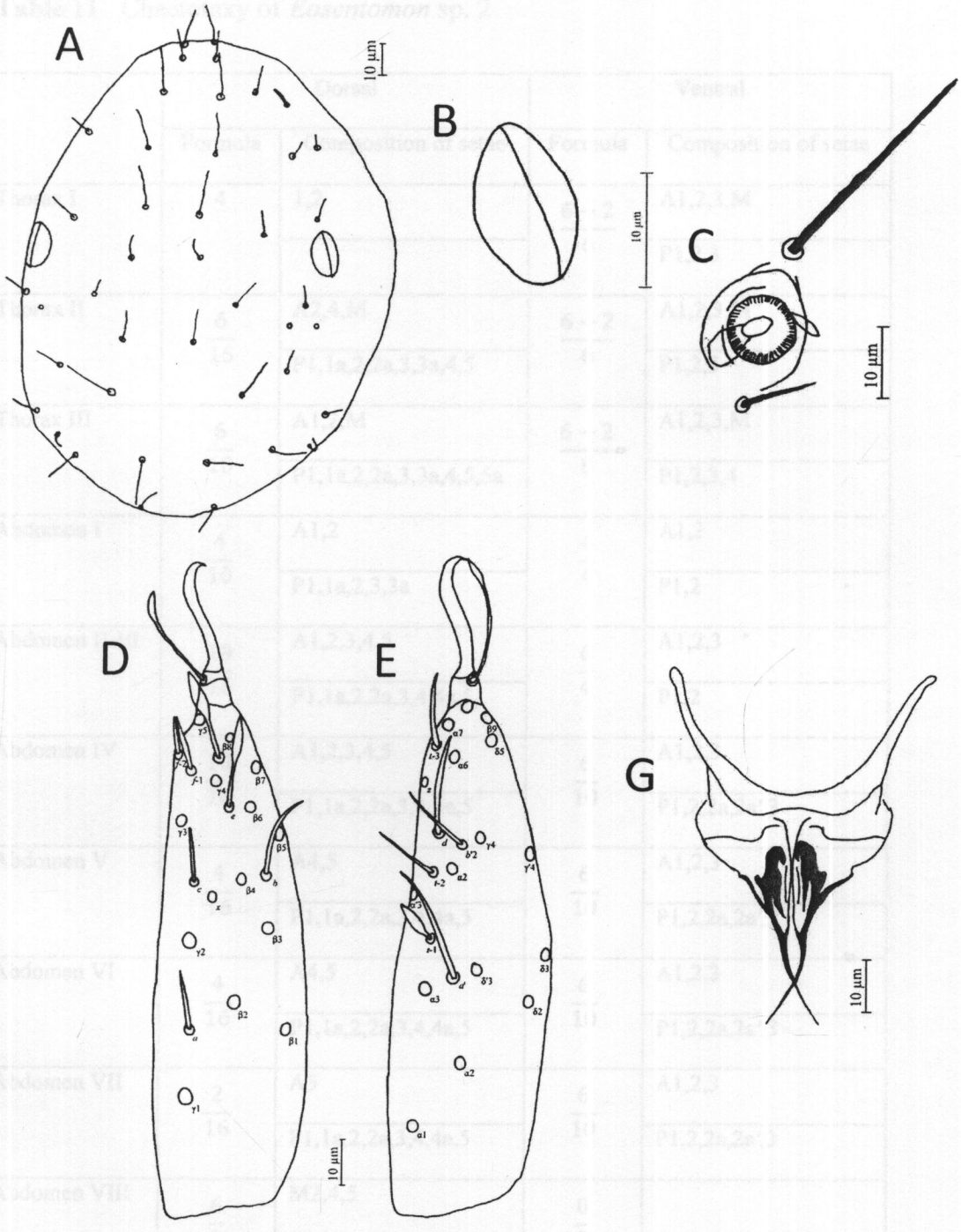


Figure 34 Structures of *Eosentomon* sp. 2.

A, dorsal view of head; B, pseudoculus; C, tracheal camerae; D, posterior view of foretarsus; E, anterior view of foretarsus; G, female squama genitalis.

Table 11 Chaetotaxy of *Eosentomon* sp. 2

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	4	1,2	$\frac{6-2}{6}$	A1,2,3,M
				P1,2,3
Thorax II	$\frac{6}{16}$	A2,4,M	$\frac{6-2}{6}$	A1,2,3,M
		P1,1a,2,2a,3,3a,4,5		P1,2,3
Thorax III	$\frac{6}{18}$	A1,2,M	$\frac{6-2}{8}$	A1,2,3,M
		P1,1a,2,2a,3,3a,4,5,5a		P1,2,3,4
Abdomen I	$\frac{4}{10}$	A1,2	$\frac{4}{4}$	A1,2
		P1,1a,2,3,3a		P1,2
Abdomen II-III	$\frac{10}{16}$	A1,2,3,4,5	$\frac{6}{4}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2
Abdomen IV	$\frac{10}{16}$	A1,2,3,4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen V	$\frac{4}{16}$	A4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VI	$\frac{4}{16}$	A4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VII	$\frac{2}{16}$	A5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VIII	$\frac{6}{9}$	M2,4,5	$\frac{0}{7}$	
		Pc,1a,1a',2,2a		Pc,1,1a,2
Abdomen IX	8	1,2,3,4	4	1,2
Abdomen X	8	1,2,3,4	4	1,2
Abdomen XI	8	1,2,3,4	8	1,2,3,4
Abdomen XII	9	Ac,1,2,3,4	12	1,2,3,4,5,6

Eosentomon **sp. 3**

(Fig. 35)

Diagnosis. Urotergites V–VI with three pairs of anterior setae (A1, 4, 5). Urotergite VII with two pairs of anterior setae (A4, 5).

Description. Body length 930–980 μm.

Head (Fig. 35A) Oval, length 128–135 μm, width 117–122 μm. Posterior sensilla, anterior additional setae, posterior additional setae, anterior sensilla, medium 4 setae present; subposterior setae 2.8 times longer than posterior setae; sensilla posterior to pseudoculus rudimentary. Pseudoculus (Fig. 35B) ovoid with one central depression and line, length 12 μm, width 10 μm, PR= 11.25.

Thorax (Table 12) On mesonotum and metanotum, P1a situated posterior to the row of P1 and P2, seta-like; P2a on the same row as P2 and P3, seta-like. Metanotum with P5a, but P5a′ indistinct. Tracheal camerae (Fig. 35C) slender.

Foretarsal (Fig. 35D and E) length 91–93 μm, claw length 19 μm, TR = 4.8–4.9; empodium length 20–21 μm, EU = 1.05–1.10, S-shaped seta length 19–25 μm. Dorsal sensilla *t*-1 about halfway between α3 and α3′, BS = 1.1–1.2; *t*-2 thin, relatively long, its apex surpass the base of γ3; *t*-3 normal. Exterior sensilla *a* of medium size; *b* and *c* linear; *d* broad, distally contracted, and relatively long, its apex surpassing the base of α7; *e* and *g* spatulate; *f* 1 filiform, its apex reaching the base of γ5; *f* 2 short. Interior sensilla *a′* short, its apex reaching the base α3′; *b*′1 broad; *b*′2 filiform, its apex reaching base of *c*′; *c′* normal, its apex reaching base of δ6. Middle tarsal length 40–43 μm, claw length 11–12 μm. Hind tarsal length 51–53 μm, claw length 13–15 μm.

Abdomen (Table 12) Urotergites II–IV with five pairs of anterior setae. Urotergites V–VI with three pairs (A1, 4, 5). Urotergite VII with two pairs (A4, 5). Urotergite I with five pairs of posterior setae (P1, 1a, 2, 3, 3a), P3a small leaf–shaped. Urotergite II–III, P1a situated posterior to the row of P1 and P2, hair-like; P2a situated posterior to the row of P3 and P4, hair-like. Urotergites IX–XI with eight setae. P1a and P2a on urotergites I–VI and P2a on urotergite VII situated posterior to the row of P1 and 2, hair-like; on urotergite VII P1a situated on posterior row to row of P1 and P2, about halfway between P1 and 2, sensillum-like and short; on urotergite VIII, P1a′ without basal dilatation; P2a′ linear.

Genitals Male: (Fig. 35F) basiperiphallus with short seta, acroperiphallus with short seta. Female: (Fig. 35G) caput processus swan's head–shaped; median sclerotization present; filum processus relatively long.

Specimens examined. 1 ♀, bamboo stands, 700 m altitude; 2 ♂, summit evergreen forest, 2450 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. –

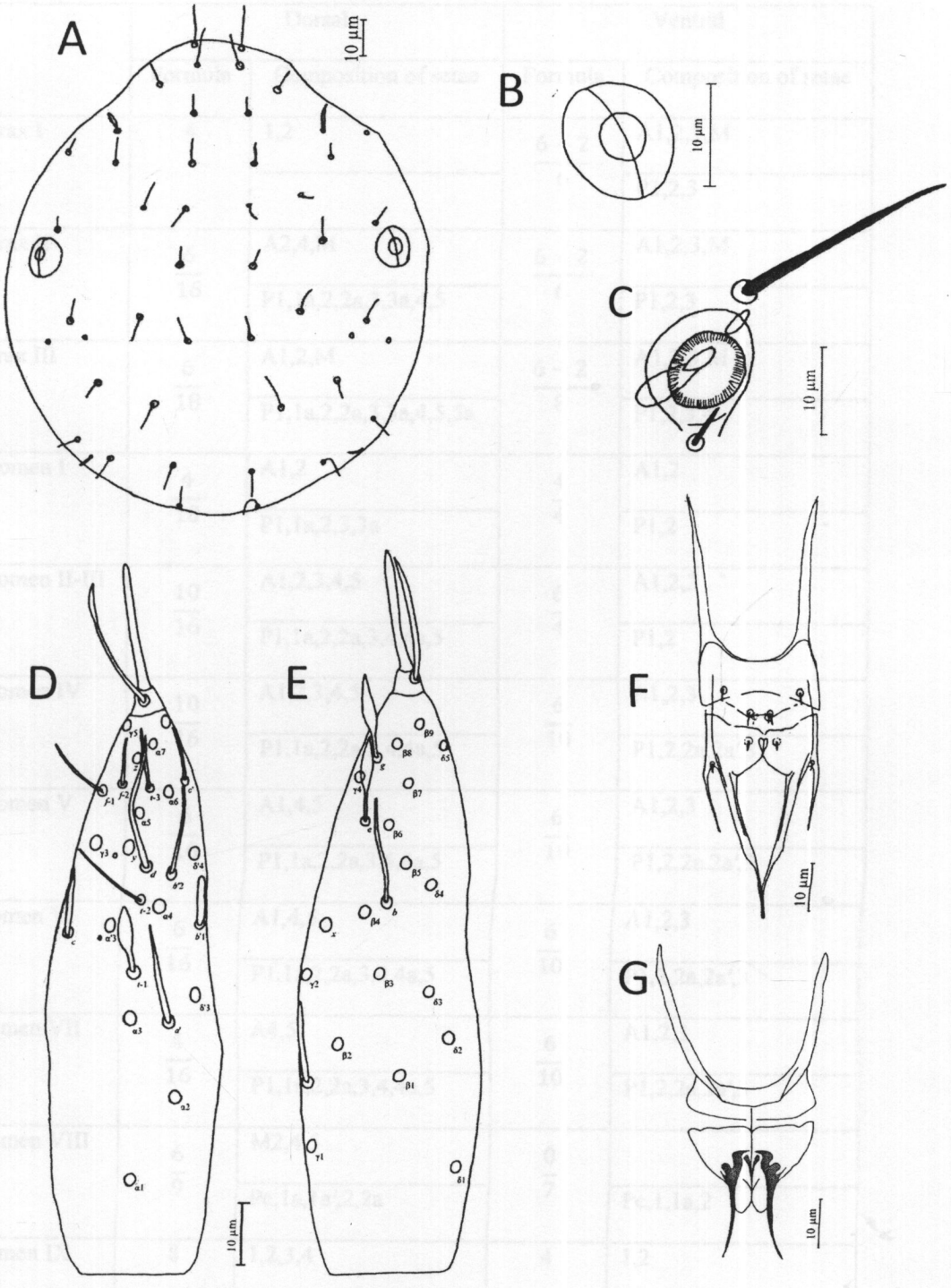


Figure 35 Structures of *Eosentomon* sp. 3.

A, dorsal view of head; B, pseudoculus; C, tracheal camerae; D, anterior view of foretarsus; E, posterior view of foretarsus; F, male squama genitalis; G, female squama genitalis.

Table 12 Chaetotaxy of *Eosentomon* sp. 3

	Dorsal		Ventral	
	Formula	Composition of setae	Formula	Composition of setae
Thorax I	4	1,2	$\frac{6-2}{6}$	A1,2,3,M
				P1,2,3
Thorax II	$\frac{6}{16}$	A2,4,M	$\frac{6-2}{6}$	A1,2,3,M
		P1,1a,2,2a,3,3a,4,5		P1,2,3
Thorax III	$\frac{6}{18}$	A1,2,M	$\frac{6-2}{8}$	A1,2,3,M
		P1,1a,2,2a,3,3a,4,5,5a		P1,2,3,4
Abdomen I	$\frac{4}{10}$	A1,2	$\frac{4}{4}$	A1,2
		P1,1a,2,3,3a		P1,2
Abdomen II-III	$\frac{10}{16}$	A1,2,3,4,5	$\frac{6}{4}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2
Abdomen IV	$\frac{10}{16}$	A1,2,3,4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen V	$\frac{6}{16}$	A1,4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VI	$\frac{6}{16}$	A1,4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VII	$\frac{4}{16}$	A4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VIII	$\frac{6}{9}$	M2,4,5	$\frac{0}{7}$	
		Pc,1a,1a',2,2a		Pc,1,1a,2
Abdomen IX	8	1,2,3,4	4	1,2
Abdomen X	8	1,2,3,4	4	1,2
Abdomen XI	8	1,2,3,4	8	1,2,3,4
Abdomen XII	9	Ac,1,2,3,4	12	1,2,3,4,5,6

Eosentomon **sp. 4**

(Fig. 36)

Diagnosis. Urotergites V with three pairs of anterior setae (A1, 4, 5). Urotergite VI–VII with two pairs of anterior setae (A4, 5).

Description. Body length 920–1200 μm.

Head (Fig. 36A) Oval, length 116–132 μm, width 87–113 μm. Posterior sensilla, anterior additional setae, posterior additional setae, anterior sensilla, medium 4 setae present; subposterior setae 1.9 times longer than posterior setae; sensilla posterior to pseudoculus rudimentary. Pseudoculus (Fig. 36B) ovoid, length 12 μm, width 11 μm, PR= 10.42.

Thorax (Table 13) On mesonotum and metanotum, P1a situated posterior to the row of P1 and P2, seta-like; P2a on the same row as P2 and P3, seta-like. Metanotum with P5a, but P5a′ indistinct. Tracheal camerae (Fig. 36C) slender.

Foretarsal (Fig. 36D and E) length 87–91 μm, claw length 18–21 μm, TR = 4.2–4.8; empodium length 19–23 μm, EU = 1.0–1.1, S–shaped setae length 19–22 μm. Dorsal sensilla *t*-1 about halfway between α3 and α3′, BS = 1.1–1.2; *t*-2 filiform, relatively long, its apex surpass the base of α5; *t*-3 normal. Exterior sensilla *a* of medium size; *b* and *c* linear; *d* broad, distally contracted, and relatively long, its apex reaching the base of *z*; *e* and *g* spatulate; *f* 1 filiform, its apex surpassing the base of γ5; *f* 2 short. Interior sensilla *a′* short, its apex reaching the base α3′; *b′*1 broad; *b′*2 filiform, its apex reaching base of α6; *c′* normal. Middle tarsal length 43–45 μm, claw length 10–13 μm. Hind tarsal length 53–56 μm, claw length 13–16 μm.

Abdomen (Table 13) On urotergites II–IV with five pairs of anterior setae. Urotergite V with three pairs of anterior setae (A1, 4, 5). Urotergites VI–VII with two pairs of anterior setae (A4, 5). Urotergite I with five pairs of posterior setae (P1, 1a, 2, 3, 3a), P3a small sensilla-like. Urotergite II–III, P1a situated posterior to the row of P1 and P2, hair-like; P2a situated posterior to the row of P3 and P4, hair-like. Urotergites X–XI with four pairs of setae. P1a and P2a on urotergites I–VI and P2a on urotergite VII situated posterior to the row of P1 and 2, hair-like. On urotergite VII P1a situated on posterior row to row of P1 and P2, near to P2, sensillum-like and short. On urosternite I P1situated posterior to the row of P1 and 2, hair-like, slightly shorter than P1 in length; P3 minute, club-shaped, 3 μm in length.

Genitals Male: (Fig. 36F) with short basiperiphallus setae. Female: (Fig. 36G) S-shaped sclerotization distinct on the processus sternalis; median sclerotization present; filum processus relatively short.

Specimens examined. 1 ♂, bamboo stands, 700 m altitude; 5 ♂, 5 ♀, summit evergreen forest, 2450 m altitude, Doi Inthanon National Park, Chiang Mai province, 30-I-2007.

Remark. –

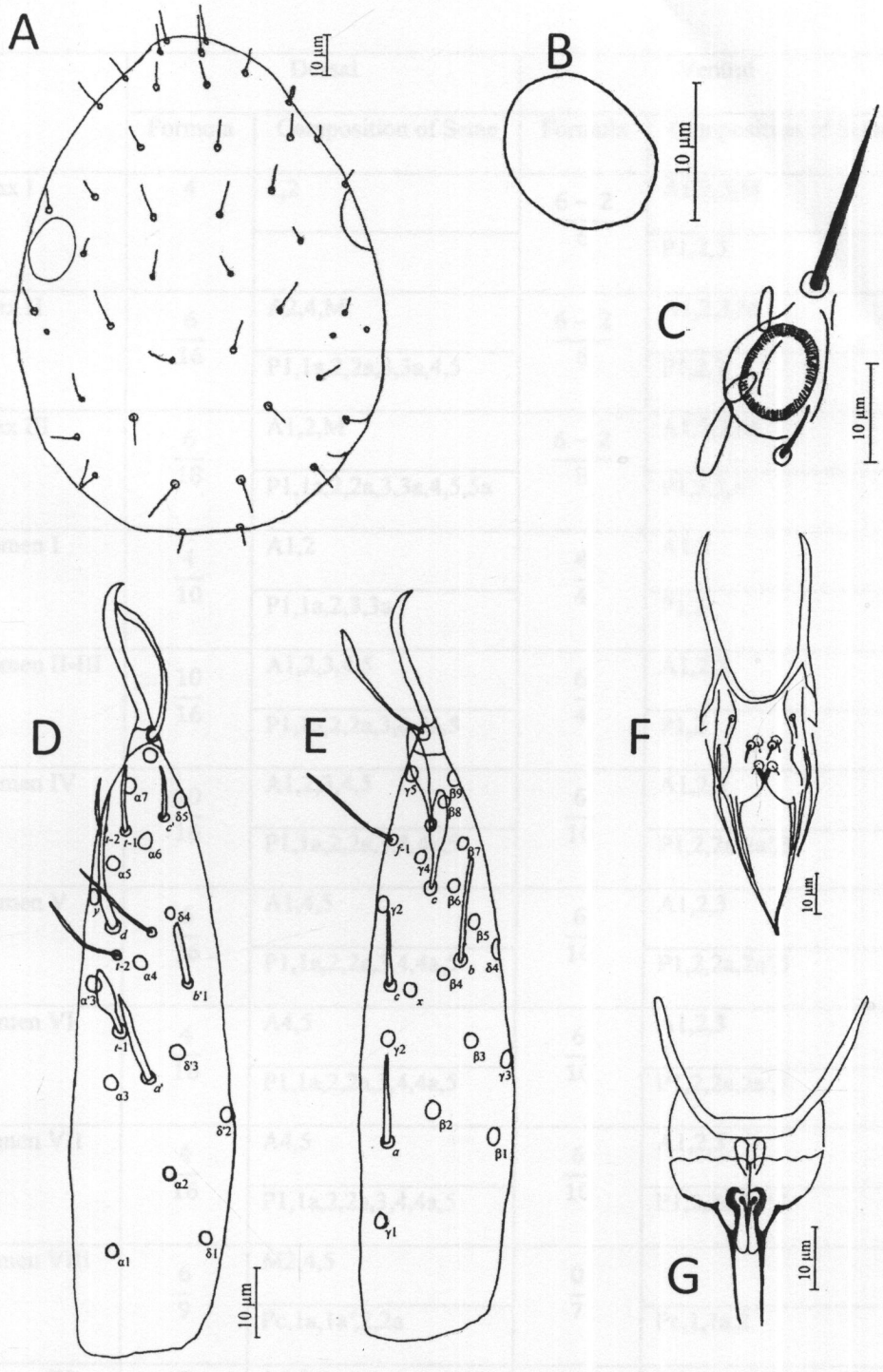


Figure 36 Structures of *Eosentomon* sp. 4.

A, dorsal view of head; B, pseudoculus; C, tracheal camerae; D, anterior view of foretarsus; E, posterior view of foretarsus; F, male squama genitalis; G, female squama genitalis.

Table 13 Chaetotaxy of *Eosentomon* sp. 4

	Dorsal		Ventral	
	Formula	Composition of Setae	Formula	Composition of Setae
Thorax I	4	1,2	$\frac{6-2}{6}$	A1,2,3,M
				P1,2,3
Thorax II	$\frac{6}{16}$	A2,4,M	$\frac{6-2}{6}$	A1,2,3,M
		P1,1a,2,2a,3,3a,4,5		P1,2,3
Thorax III	$\frac{6}{18}$	A1,2,M	$\frac{6-2}{8}$	A1,2,3,M
		P1,1a,2,2a,3,3a,4,5,5a		P1,2,3,4
Abdomen I	$\frac{4}{10}$	A1,2	$\frac{4}{4}$	A1,2
		P1,1a,2,3,3a		P1,2
Abdomen II-III	$\frac{10}{16}$	A1,2,3,4,5	$\frac{6}{4}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2
Abdomen IV	$\frac{10}{16}$	A1,2,3,4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen V	$\frac{6}{16}$	A1,4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VI	$\frac{4}{16}$	A4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VII	$\frac{4}{16}$	A4,5	$\frac{6}{10}$	A1,2,3
		P1,1a,2,2a,3,4,4a,5		P1,2,2a,2a',3
Abdomen VIII	$\frac{6}{9}$	M2,4,5	$\frac{0}{7}$	
		Pc,1a,1a',2,2a		Pc,1,1a,2
Abdomen IX	8	1,2,3,4	4	1,2
Abdomen X	8	1,2,3,4	4	1,2
Abdomen XI	8	1,2,3,4	8	1,2,3,4
Abdomen XII	9	Ac,1,2,3,4	12	1,2,3,4,5,6

CHAPTER 5
DISCUSSION

5.1 Taxonomy

This study revealed 11 species, 2 subspecies, 6 genera, and 3 families of proturans from 5 study sites within an altitudinal gradient of 700 meters to 2450 meters in the Doi Inthanon National Park, Chiang Mai province, Thailand. These proturan species were found belonging to the genera *Condeellum* Tuxen (2 spp.), *Australentulus* Tuxen (1 sp.), *Silvestridia* Bonet (1 sp.), *Baculentulus* Tuxen, 1977 (1 sp.), *Kenyentulus* Tuxen (2 spp.), and *Eosentomon* Berlese (4 spp.).

The 11 species consisted of 3 described species (*Condeellum regale* Condé, *C. ishiianum ishiianum* Imadaté, *Silvestridia keijiana* (Imadaté)), including one subspecies *C. ishiianum setosum* Imadaté newly recorded for Thailand, and 8 undescribed species (*Australentulus* sp., *Baculentulus* sp., *Kenyentulus* sp. 1, *Kenyentulus* sp. 2, *Eosentomon* sp. 1, *Eosentomon* sp. 2, *Eosentomon* sp. 3, and *Eosentomon* sp. 4).

For the genus *Condeellum*, 2 species and 2 subspecies *Condeellum regale* (Condé), *C. ishiianum ishiianum* Imadaté, and *C. ishiianum setosum* Imadaté were found newly recorded in Thailand.

Condeellum regale (Condé) and *C. ishiianum ishiianum* Imadaté, were found on Doi Suthep-Pui, Chiang Mai province then again in the Doi Inthanon National Park, Chiang Mai province, near Doi Suthep-pui. The descriptions of these species are no different from the original descriptions (Imadaté, 1965; Likhitrikarn, 2004).

Condeellum ishiianum setosum Imadaté, A newly recorded subspecies, is similar to *C. ishiianum ishiianum* (Condé), except for the presence of anterior setae (A1) on urotergite VII and the presence of 1a on urosternite IX (Imadaté, 1991). This species had previously been found in Borneo but is new to Thailand.

Australentulus sp. was found in genus *Australentulus*. The body length is much greater when compared to the body length of all other proturan species in this study. It was similar to *Australentulus prachedee* Imadaté which has been found in Thailand but distinct in the absence of anterior setae (A4) on urotergite V and the length of sensillum *c* (Imadaté, 1965, 1989).

One species *Silvestridia keijiana* (Imadaté) was found in genus *Silvestridia*. It is similar to the original description which had been previous known from Thailand (Imadaté, 1965).

The first time Imadaté (1965) published a description of *Bereberentulus* spp. was before Tuxen (1976) announced the new genus *Baculentulus*. All species in genus *Bereberentulus* which were found at that time, were changed to genus *Baculentulus*. Most characteristics of genus *Baculentulus* were similar to genus *Bereberentulus* but can be differentiated based on the sensillum *t*-1 of *Bereberentulus* is claviform and in *Baculentulus* it is baculiform. This species, *Baculentulus* sp., is similar to *Baculentulus umesaoi* (Imadaté, 1965) but it is distinct in chaetotaxy of urotergites IX-X and the length of foretarsal sensilla *a*, *c*, *d*, and *e*.

In *Kenyentulus*, two species *Kenyentulus* sp. 1 and sp. 2. were found. *Kenyentulus* sp. 1 was similar to *Kenyentulus malaysiensis* (Imadaté, 1965) on the foretarsal sensillum *b'* at the same level with *t*-2 and urotergite V-VI, with two pairs of anterior setae (A2, 5) but it is distinct in the length of foretarsal sensilla *a*, *e*, *f*.

Kenyentulus sp. 2 was similar to *Kenyentulus* sp. 1 but *Kenyentulus* sp. 2 was distinct in urotergite IV possessing two pairs of anterior setae (A2, 5) while *Kenyentulus* sp. 1 had urotergite IV with three pairs of anterior setae (A1, 2, 5).

The last genus found was *Eosentomon*. This is a large genus with more than 280 described species (Szeptycki, 2003). It was difficult to find the descriptions and complicated to check the descriptions because proturan is a poorly known group like many groups of Acarina, Myriapoda, etc. and there are few specialists who study proturan (Szeptycki, 2002). However, four species could be distinguished from the specimens collected. They were unlike the species previously known from Thailand (Imadaté, 1965; Likhitrikarn, 2004).

In 1965, Imadaté reported 25 species, 7 genera, and 3 families of proturans found throughout Thailand (Imadaté and Kira, 1964). Later, Likhitrikarn (2004) conducted a survey in the Doi Suthep-Pui National Park, Chiang Mai province, Northern Thailand and found 11 species in 4 genera and 3 families. Three of the species were found to be new and are pending publication. Finally, this study found 11 species, 2 subspecies, 6 genera, and 3 families, one newly recorded in Thailand, and 8 undescribed species.

Until now, a total of 25 proturan species and 2 subspecies were known to occur in Thailand. These are low numbers of proturan species when compared with the described species, in 71 genera worldwide (Szeptycki, 2002). Europe has 166 species in 17 genera (Imadaté, 1989; Szeptycki, 2002). Austria is known to possess 32 species in 10 genera, and 3 families (Department of the Environment and Heritage, 2006; Tuxen, 1964). In Japan 68 species, 25 genera, and 4 families have been found (Imadaté, 1974; Nakamura, 2003). China has 156 species, 34 genera, and 10 families. In this study, 8 undescribed species were found. It is highly probable that these will be new species due to the lack of previous studies on proturan in Thailand and other Southeast Asia countries. Studies in these areas are always likely to discover new taxa. For example, Szeptycki and Imadaté (1987) conducted a study in Korea and found 11 species in 6 genera, 10 of them were new species and one new recording. Nakamura's (1997) studied in Taiwan found 10 species in 4 genera, 5 of which were new species. If we collect more specimens in Thailand, it is likely we will discover new species and possibly new genera as well. Therefore, the studies of proturan in Thailand should be continued and expanded.

5.2 Checklist of proturans in Thailand

Suborder **Acerentomoidea** Condé, 1951

Family **Protentomidae**, Ewing, 1936

Genus ***Condeellum*** Tuxen, 1963

Condeellum regale (Condé, 1958)

Condeellum ishiianum ishiianum Imadaté, 1965

Condeellum ishiianum setosum Imadaté, 1991

Family **Acerentomidae** Silvestri, 1907

Genus ***Australentulus*** Tuxen, 1967

Australentulus prachedee (Imadaté, 1965)

Genus ***Silvestridia*** Bonet, 1942

Silvestridia keijiana (Imadaté, 1965)

Genus ***Baculentulus*** Tuxen, 1977

Baculentulus morikawai (Imadaté & Yosii, 1956)

Baculentulus duongkeoi (Imadaté, 1965)

Baculentulus bervinguis (Condé, 1961)

Baculentulus umesaoi (Imadaté, 1965)

Baculentulus matsuokai (Imadaté, 1965)

Baculentulus lanna (Imadaté, 1965)

Baculentulus ogawai (Imadaté, 1965)

Baculentulus oginoi (Imadaté, 1965)

Genus ***Gracilentulus*** Tuxen, 1963

Gracilentulus sachikoae Imadaté, 1965

Genus ***Kenyentulus*** Tuxen, 1981

Kenyentulus ohyamai (Imadaté, 1965)

Suborder **Eosentomoidea** Condé, 1951

Family **Eosentomidae** Berlese, 1909

Genus ***Eosentomon*** Berlese, 1909

Eosentomon kloomi Imadaté, 1965

Eosentomon paktai Imadaté, 1965

Eosentomon thamnooni Imadaté, 1965

Eosentomon imbutum Imadaté, 1965

Eosentomon yanaka Imadaté, 1965

Eosentomon sawasdi Imadaté, 1965

Eosentomon sayani Imadaté, 1965

Eosentomon pairathi Imadaté, 1965

Eosentomon hyatti Condé, 1958

Eosentomon torbongsi Imadaté, 1965

Eosentomon udorni Imadaté, 1965

5.3 Distribution

Table 14 shows the relationship between distribution of species found in Doi Inthanon National Park, Chiang Mai province.

Table 14 Altitudinal occurrences of proturan species found in the Doi Inthanon National Park, Chiang Mai province.

	Altitude				
	700 m	1000 m	1650 m	2100 m	2450 m
Condeellum regale	√				
C. ishiianum ishiianum	√		√		
C. ishiianum setosum	√		√	√	
Australentulus sp.				√	
Silvestridia keijiana			√		
Baculentulus sp.			√		
Kenyentulus sp. 1	√				
Kenyentulus sp. 2	√				
Eosentomon sp. 1					√
Eosentomon sp. 2					√
Eosentomon sp. 3	√				√
Eosentomon sp. 4	√				√

Condeellum regale, is represented by only a single specimen found in bamboo stands at an elevation of 700 meters.

Condeellum ishiianum ishiianum and *C. ishiianum setosum* were found in bamboo stands and an evergreen hill forest at 1650 meters elevation. These two species are very similar and difficult to identify.

Australentulus sp. was represented only in evergreen hill forests at 2100 meters.

Silvestridia keijiana and *Baculentulus* sp., were found only in evergreen hill forests at 1650 meters elevation. These species were dominant at this altitudinal site.

Kenyentulus spp. were found only in bamboo stands at 700 meters.

Eosentomon sp. 1 and sp. 2 are high altitude species that occurred only in evergreen hill forests at 2450 meters elevation.

Eosentomon sp. 4 occured in evergreen hill forests at 2450 meters elevation, and was dominant at the higher elevations.

Table 14 shows that the highest number of proturan species were found at altitudes above 700 meters elevation to the summit; at altitudes around 1000 meters, proturans were not found at altitudes around 2100 meters, lower numbers of proturan species were found, and at altitudes of 2450 meters, only *Eosentomon* spp. were found.

The main objective of this study was to study the taxonomy of proturan in Thailand. The finding of this research can be a basic guide for new researchers who wish to study proturan in Thailand and as an example of species description and keys because no study of this type presently exists.

5.4 Future research of proturan in Thailand

Despite many new discoveries, the number of known species remains insufficient. Even in the best known areas, for example Japan or Poland, new taxa are still being discovered. The 66 species recorded from Poland comprise about 60–70% of the species expected in this country. Probably only 10 % of the world fauna is known (Szeptycki, 2002). Therefore, the study of proturan should continue so that new proturan species can be described before the possible extinction of undiscovered species, due to environmental degradation and/or larger scale environmental changes, *i.e.*, global warming.

Normally, proturan studies will survey the forest soil but Christian and Szeptycki (2004) found proturans 42 species in urban Vienna. Moreover, it was a surprise when Lussenhop (1973) found proturans near a Chicago Expressway Margin. Therefore, you can collect specimens of proturan outside of forest so a study can be done in agricultural, urban and a variety of non-traditional environments.

Proturans are a soil micro-arthropods. Studies about soil micro-arthropods can be indicators of the environment health because they are very small creatures in the soil and sensitive to changes in the environment (Barratt *et al.*, 2006; Broza and Izhaki, 1997; Teodorescu and Cogãlniceanu, 2005; Convey *et al*, 2003; Salmon *et al.*, 2006; Jing, 2005; Broza, 1997; Migliorinia, 2004; Paoletti, 1991; Strojan, 1978). In conclusion, there remains much to be discovered.

CHAPTER 6
CONCLUSION

Soil samples were collected on 30 January 2007 along an altitudinal gradient in Doi Inthanon National Park, Chiang Mai province, Thailand. Five different forest types were chosen at 500 meters intervals: dry deciduous dipterocarp forest; mixed deciduous forest; lower evergreen forest; upper evergreen forest; and cloud forest, respectively. At each site, 10 soil samples were collected using a 15 × 15 centimeters quadrate to a depth of 5 centimeters. The soil samples were then transferred to Berlese funnels for 72 hours in order to extract the arthropod fauna. The proturan specimens were separated and permanent slides were made for each sample.

After specimen preparation and identification, it was determined that eleven species and two subspecies of proturans were collected. These 11 species and 2 subspecies consist of 3 described species (*Condeellum regale* (Condé), *C. ishiianum ishiianum* Imadaté, *Silvestridia keijiana* (Imadaté)), one newly recorded subspecies for Thailand (*C. ishiianum setosum* Imadaté), and 8 undescribed species (*Australentulus* sp., *Baculentulus* sp., *Kenyentulus* sp. 1, *Kenyentulus* sp. 2, *Eosentomon* sp. 1, *Eosentomon* sp. 2, *Eosentomon* sp. 3, and *Eosentomon* sp. 4). The 8 undescribed species have high probabilities of being new species.

Previously, there have been few studies of proturan taxonomy in Thailand. Therefore, the main objective of this study was to make a basic guide, including life history aspects of general biology and more importantly, taxonomic keys for future researchers who wish to study proturans in Thailand. The morphology and diagnostic characters of proturans are reviewed in some detail. In addition, pictorial keys to genera and species of adult proturans were constructed to aid in identification. This study begins a necessary taxonomic base for any studies of proturan in the future.

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APPENDIX

APPENDIX

Procedures for mounting techniques

1. Place specimens into vials with 3% formalin for 3 minutes.
2. Place specimens in vials of distilled water (room temperature).
3. Drain off the distilled water and replace with distilled water twice.
4. Place specimens in vials of lactophenol cotton blue for *ca.* 30 minutes to 5 hours or over night (to ensure that full clearing has occurred).
5. Place specimens in vials of 50% EtOH for about 10 minutes. Specimens were then transferred to 70% EtOH for 10 minutes. Repeat with 80% EtOH, 95% EtOH, 99% EtOH. and 100% EtOH.
6. Place specimens into vials with 1:1 solution of 100% EtOH and Xylene for 10 minutes.
7. Place specimen into vials with 1:2 solution of 100% EtOH and Xylene for 10 minutes.
8. Place specimen into vials with Xylene for 10 minutes.
9. Place one drop of "Permount" in the middle of a microscope slide.
10. Place specimens into "Permount" and apply a cover slip.

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