

Protura from Hainan Island, China: new species, checklist and distribution

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Abstract

More than 1500 proturan specimens from Hainan Island are systematically studied. An annotated list of all species of Protura from Hainan Island is provided and their geographical distribution is discussed. The genus *Paracondeellum* is reported from Hainan Island for the first time, and *Paracondeellum paradisum* sp. nov. is described. The type species *Paracondeellum dukouense* (Tang & Yin, 1988) is redescribed based on syntype, and the lectotype and paralectotype are designated. The characters of the genus *Paracondeellum* are redefined, and the two known species are compared in detail. The Protura fauna of Hainan Island is mainly composed of species from the Oriental region, with 91% of the species belonging to the families Berberentulidae and Eosentomidae.

Keywords

distribution, diversity, *Paracondeellum*, new species, taxonomy, type specimen

Introduction

Protura is a group of tiny soil-dwelling arthropods with more than 800 described species (Bu et al. 2012, 2017; Galli et al. 2018). The diagnosis, distribution, and key to 76 known genera and seven families of Protura worldwide were recently given by Galli et al. (2018). So far, there are 214 species belonging to 43 genera recorded in China (Bu et al. 2012, 2017; Qian et al. 2018).

Hainan Island is the second largest island of China and is located off the southernmost point of the mainland (18°10'–20°10'N, 108°37'–111°03'E; Fig. 1). The tropical forest landscape on Hainan Island is one of the hotspots for biodiversity in China, with a high floral diversity and over 6000 species of insects recorded (Huang 2002). In recent years, many rare insects, such as belonging to Zoraptera, have been found on Hainan Island (Yin et al. 2015).

There are several previous publications on the Protura from Hainan Island. The first study reported 14 species of Eosentomidae from Hainan (Yin 1986). Then, eight species of the genus *Kenyentulus* (Berberentulidae) were described (Yin 1987). Later, 24 species of Protura were recorded in Hainan Province with *Fujientomon dicestum* Yin, 1977 and *Pseudanisentomon yongxingense* Yin, 1988 included (Yin 1999, 2002). In 2004, the Protura from Jianfengling Mountain were investigated again. In 2005, *Amphientulus sinensis* Xiong, Xie & Yin, 2005 was described and seven new records and three undetermined species were newly added (Xiong 2005; Xiong et al. 2005). One of these undetermined species was subsequently described as *Anisentomon hainanense* Xiong, Bu & Yin, 2008 (Xiong et al. 2008).

In 2011 and 2017, we investigated the soil fauna of Hainan Island on several occasions and collected many proturan specimens. In the present paper, Protentomidae is recorded for the first time and one new species of genus *Paracondeillum* Yin, Xie & Zhang, 1994 is identified and described. We checked the syntypes of the type species of *Paracondeillum dukouense* (Tang & Yin, 1988), designated a lectotype and paralectotype, and redescribed it in detail. In addition, based on more than 1500 proturans collected in Hainan Island from 1984 to 2017, a checklist is presented and the distribution of Protura on Hainan Island is summarized.

Materials and methods

Most of specimens were collected between 1984 and 2004, and more recent specimens were collected during the expeditions in 2011 and 2017. All localities sampled so far are listed in Table 1 and shown in Figure 1. All specimens were extracted by means of the Tullgren funnels from soil and humus samples and preserved in 75% ethanol. They were mounted on slides using Hoyer's solution and dried in an oven at 50 °C.

Observations were made with a phase contrast microscope (Leica DM 2500). Photos were taken by a digital camera (Leica DMC 4500). Line drawings were made using a drawing tube. All specimens are deposited in the collections of Shanghai

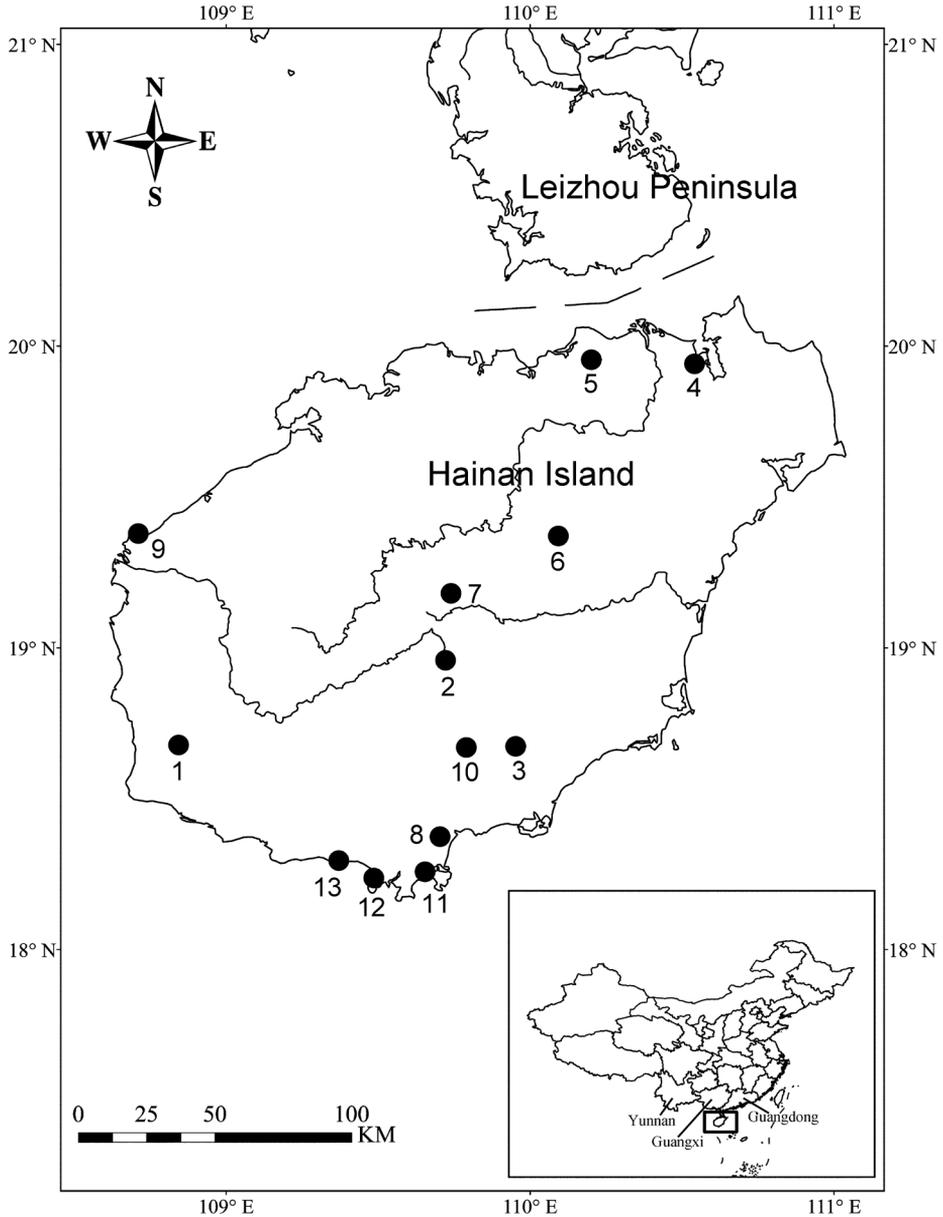


Figure 1. The sampling localities in Hainan Island. Numbers 1–13 indicate the localities listed in Tables 1, 5.

Natural History Museum (SNHM) and Shanghai Entomological Museum (SEM), Shanghai, China.

Abbreviations used in the text follow the paper by Bu and Yin (2007). Head setae and pores are named according to Rusek et al. (2012) and Shrubovych (2014). The arrangement of the taxa follows the system proposed by Yin (1999).

Table 1. The sampling localities of Protura in Hainan Island.

Number	Locality	Coordinates	Altitude (m)	Sampling years
1	Ledong County, Jianfengling National Natural Reserve	18°23'–18°52'N, 108°44'–109°02'E	120–330	1984, 1993, 2003, 2004
2	Wuzhishan City, Wuzhishan National Natural Reserve	18°49'–18°59'N, 109°32'–109°43'E	800–1200	1984, 1985, 2004, 2011
3	Wuzhishan City, Diaoluoshan National Natural Reserve	18°43'–18°58'N, 109°43'–110°03'E	500–1000	1985, 2004
4	Haikou City, Dongzhaigang National Natural Reserve	19°51'–20°01'N, 110°32'–110°37'E	20	2004
5	Haikou City, Crater National Geological Park	19°55'N, 110°12'E	223	2003
6	Tunchang County, Meiling Mountain	19°22'N, 110°04'E	150–230	2003
7	Tunchang County, Limu Mountain	19°17'N, 109°77'E	600–1000	2003
8	Baoting County, Ganshenling Provincial Natural Reserve	18°39'N, 109°66'E	500	2003
9	Changjiang County, Qizi bay	19°21'N, 108°40'E	15	2011
10	Baoting, Qixianling National Forest Park	18°42'N, 109°40'E	150	2017
11	Sanya City, Yalong Bay Tropical Paradise Forest Park	18°15'N, 109°38'E	200	2017
12	Sanya City, Luhuitou Park	18°13'N, 109°29'E	80	2017
13	Sanya City, Sanya bay	18°17'N, 109°22'E	5	2017

Results

Taxonomy

Family Protentomidae Ewing, 1936

Genus *Paracondeillum* Yin, Xie & Zhang, 1994

Diagnosis. Habitus short and robust. Pseudoculi circular without lever. Calyx of maxillary glands globular and smooth. Foretarsal sensilla of the exterior side reduced; interior sensilla *b'* absent. Abdominal appendages I–II two-segmented each with four setae, III uni-segmented with two setae. Tergites II–VII without or with few anterior setae. Sternites II–III each with three posterior setae. Sternites IV–VII each with nine posterior setae; sternite VIII with four setae in one row. Female squama genitalis short, with pointed acrostyli (Yin 1999; Galli et al. 2018).

Distribution. South China (Sichuan, Yunnan, Hainan).

Remarks. *Paracondeillum* Yin, Xie & Zhang, 1994 was originally separated from the genus *Condeillum* Tuxen, 1963. They have similar shapes of pseudocellus and maxillary gland, and the presence of setae *Pc* on sternites IV–V, but they can be easily separated by the chaetotaxy of tergite I (seta *P5* absent in *Paracondeillum* but present in *Condeillum*) and sternite VIII (four setae in *Paracondeillum* vs six setae in *Condeillum*). In addition, *Paracondeillum* can be distinguished from the genus *Neocondeillum* Tuxen & Yin, 1982 by the shape of pseudocellus (posterior lever absent in *Paracondeillum* but present in *Neocondeillum*) and the chaetotaxy of sternites IV–V (setae *Pc* present in *Paracondeillum* but absent in *Neocondeillum*).

***Paracondeellum paradisum* Bu & Yin, sp. nov.**<http://zoobank.org/A723F8F3-18BF-420F-885E-29EA34F782D7>

Figures 2–4; Tables 2, 4

Diagnosis. *Paracondeellum paradisum* sp. nov. is characterized by two pairs of *A*-setae on tergite I, one pair of *A*-setae, and eight pairs of *P*-setae on tergites II–VI, absence of *A*-setae and *P2a* seta on tergite VII, tergites IX and X with 12 and 10 setae, respectively, absence of seta *d4* on dorsal side of head, and female squama genitalis short, with conical acrostylus.

Material examined. Holotype, female (slide no. HN-SY-P2017016) (SNHM), China, Hainan, Sanya City, Yalong Bay Tropical Paradise Forest Park, soil of the tropical rain forest, 200 m elev., 18.25°N, 109.63°E, 22-III-2017, Y. Bu collector. Paratypes, 1 female (slide no. HN-SY-P2017071) (SNHM), same data as holotype.

Description. Holotype: body length 570 µm, yellow-brown, foretarsus darker (Fig. 4A).

Head. Elliptic, length 80 µm, width 50 µm (Fig. 2A). Head setae short, rostrum slightly protruded. Setae *d6* and *sd6* present, *d4* and *sd4* absent, *d6* and *d7* length 6 µm and 7 µm respectively. Pores *cp* and *fp* present. Pseudoculus oval, without lever, length 8 µm, width 6.5 µm. PR = 10 (Fig. 2B). Canal of maxillary gland short, with globular calyx and short sausage-like posterior dilation. CF = 10 (Figs 2C, 4B). Labial palpus well developed, with four setae and apical tuft, without basal sensillum (Fig. 2D). Maxillary palpus with two subequal seta-like sensilla (Fig. 2E).

Foretarsus. Length 31 µm, claw length 9 µm, TR = 3.4; empodium length 2 µm, EU = 0.22. Dorsal sensilla *t-1* and *t-2* slender and long, BS = 0.63; *t-3* short and spatulate, not reaching base of claw (Fig. 2G). Exterior side with only sensilla *a*, *b* and *f* present; *a* spatulate, *b* and *f* short (Fig. 2F). Interior sensilla *a'* and *c'* short sward-like, *b'* absent. Relative length of sensilla: $t-2 > t-1 > c' > t3 > a > a' > (b = f)$ (Fig. 2F, G). Length of middle tarsus 15 µm; claw length 10 µm. Length of hind tarsus 17 µm; claw length 12 µm.

Thorax. Thoracic chaetotaxy given in Table 2. Setae 1 and 2 on pronotum subequal in length, 6 µm and 7 µm respectively (Fig. 2H); mesonotum with seven pairs of posterior setae, *P5a* minute; metanotum with six pairs of posterior setae, *P5a* absent; setae *P1*, *P1a*, *P2* on mesonotum 6 µm, 1 µm, 7 µm, respectively; *P1a* on meso- and metanotum short, pin-shaped (Fig. 2H). Prosternum without seta *A2*. All setae on thoracic sternites of normal shape. Pores on thorax not observed.

Abdomen. Abdominal chaetotaxy given in Table 2. Tergite I with two pairs of anterior setae (*A1*, *A5*) and six pairs of posterior setae, *A5* short, sensillum-shaped (Fig. 2I). Tergites II–VI with one pair of anterior (*A1*) and eight pairs of posterior setae, *P2a* present and *P3a* absent (Figs 2J, 3A, 4E, F). Tergite VII without anterior setae and with eight posterior setae, *P2a* absent and *P3a* present (Figs 3B, C, 4E, F). Accessory setae *P1a* on tergites I–V short pin-shaped (4 µm), on tergites VI–VII normal (5 µm). Accessory setae *P2a* and *P4a* always pin-shaped, 2 µm in length. *P3a* on tergite VII

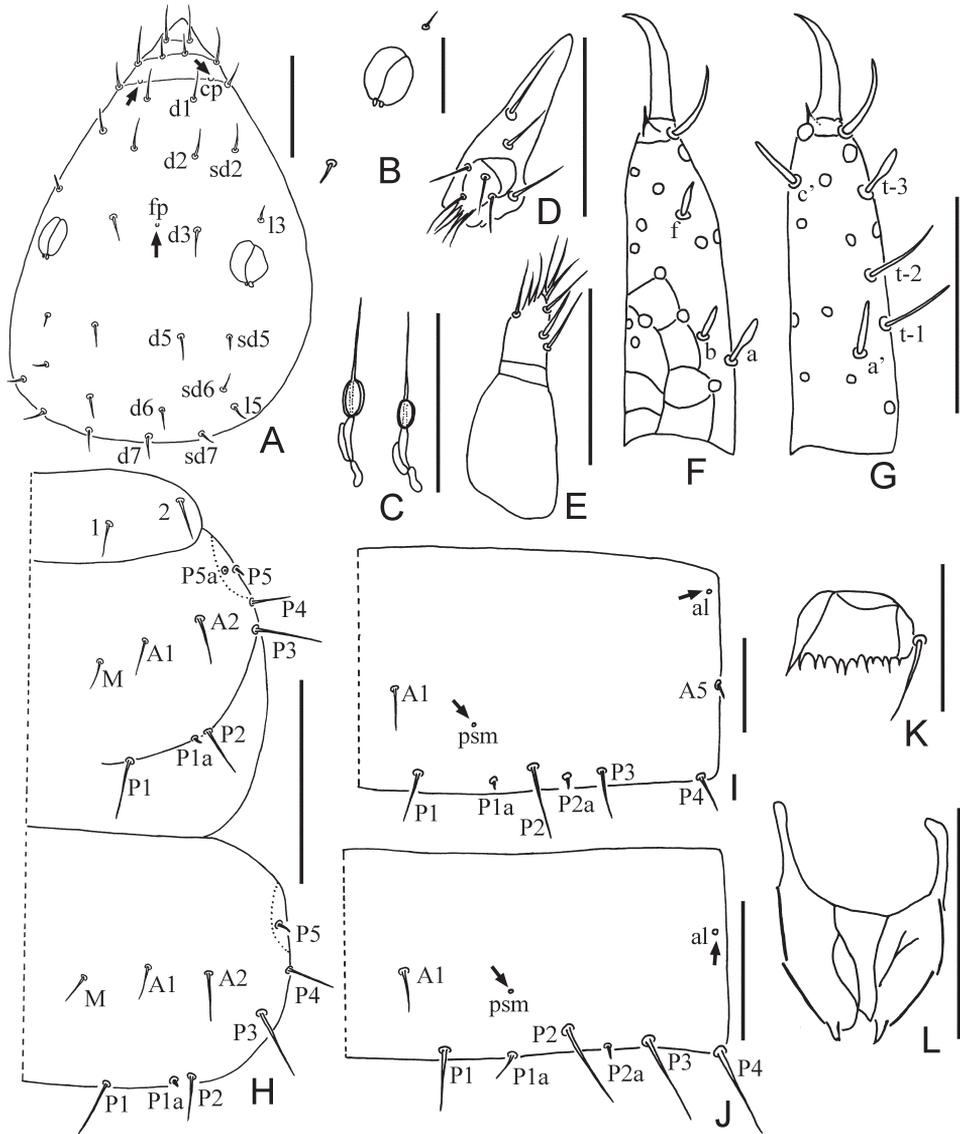


Figure 2. *Paracondeellum paradisum* sp. nov., holotype **A** head, dorsal view (*cp* = clypeal pore, *fp* = frontal pore) **B** pseudoculus **C** canal of maxillary gland **D** labial palpus **E** maxillary palpus **F** foretarsus, exterior view **G** foretarsus, interior view **H** dorsal thorax, right side **I** tergite I, right side (*al* = anterolateral pore, *psm* = posterosubmedial pore) **J** tergite VI, right side **K** comb **L** female quama genitalis. Arrows indicate pores. Scale bars: 10 µm (**B**, **K**); 20 µm (**A**, **C**–**J**, **L**).

of normal shape and 5 µm long (Fig. 4E, F). Tergite VIII with two pairs of anterior setae (*A1*, *A3*) (Fig. 4C). Posterior central seta *Pc* present on sternites IV–VII, sensillum shaped, 4–5 µm long (Figs 3A, C, 4F). *P1a* on sternites IV–VI short, pin-shaped (Fig. 3A), on sternite VII setiform (Fig. 3C).

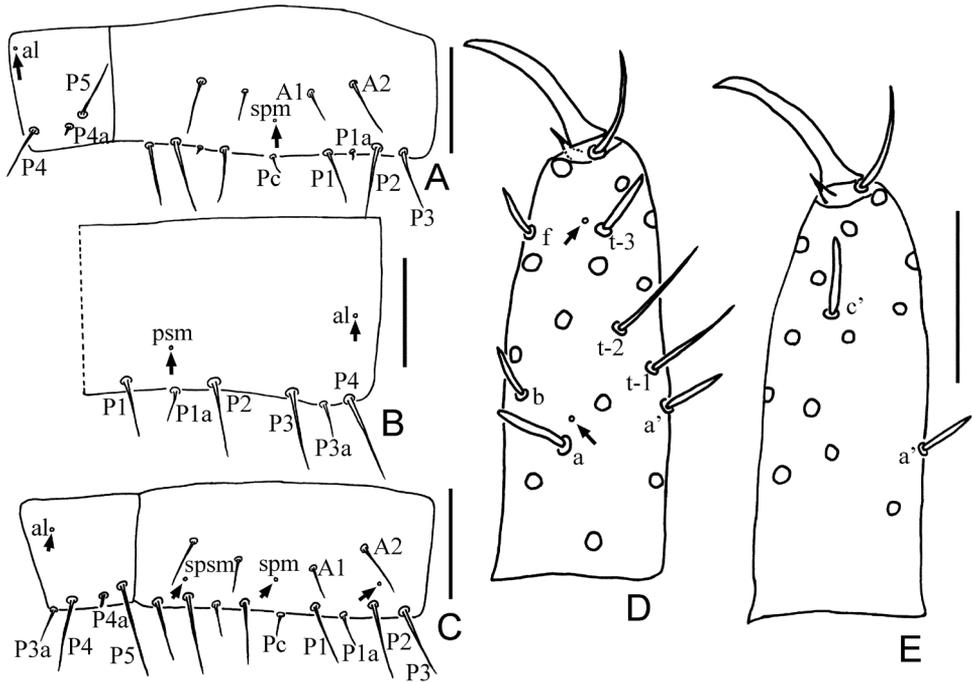


Figure 3. **A–C** *Paracondeellum paradisum* sp. nov., holotype **A** sternite VI (spm = sternal posteromedial pore) **B** tergite VII, right side **C** sternite VII (spsm = sternal posterosubmedial pore). **D–E** *Paracondeellum dukouense* (Tang & Yin, 1988) holotype **D** foretarsus, exterior view **E** foretarsus, interior view. Arrows indicate pores. Scale bars: 20 μ m.

Tergites I–VII with pores *psm* and *al* (Fig. 2I, J), VIII with pores *psm* only, IX–XI without pores, XII single median pore. Sternites I–VI each with single posteromedial pore *spm* (Figs 3A, 4F), VII with three posteromedial pores (Figs 3C, 4F), VIII with single posteromedial pore (Fig. 4D), IX–XI without pores, XII with one pair of anterolateral *sal* pores.

Abdominal appendages typical of the genus. Subapical setae and apical setae on appendage III 11 μ m and 5 μ m long respectively. Striate band on abdominal segment VIII reduced to a single serrate line (Fig. 4D). Comb on abdomen VIII rectangular, with 10 teeth, 10 μ m wide (Fig. 2K). Female squama genitalis short, with conical acrostylus (Fig. 2L).

Etymology. Latin “paradisum”, after “Paradise Forest Park” where type specimens were collected.

Distribution. China (Hainan)

Remarks. The genus *Paracondeellum* Yin, Xie & Zhang, 1994 is endemic to China and was previously known by a single species, *P. dukouense*, from Sichuan and Yunnan provinces. *Paracondeellum paradisum* sp. nov. differs from *P. dukouense* in the shape of foretarsal sensilla, pseudoculus, and female squama genitalis, and in the body chaetotaxy. A comparison of the morphology of these two species is given in Table 4.

Table 2. Adult chaetotaxy of *Paracondeellum paradisum* sp. nov.

	Segment	Dorsal		Ventral	
		Formula	Setae	Formula	Setae
Th.	I	4	1, 2	(2+2)/6	AI, M PI, 2, 3
	II	6/14	A2, 4, M	(4+2)/4	AI, 2, M
			PI, 1a, 2, 3, 4, 5, 5a		PI, 2
	III	6/12	A2, 4, M	(6+2)/4	AI, 2, 3, M
			PI, 1a, 2, 3, 4, 5		PI, 2
	Abd.	I	4/12	AI, 5	4/2
PI, 1a, 2, 2a, 3, 4				PI	
II–III		2/16	AI	4/3	AI, 2
			PI, 1a, 2, 2a, 3, 4, 4a, 5		Pc, 2
IV–VI		2/16	AI	4/9	AI, 2
			PI, 1a, 2, 2a, 3, 4, 4a, 5		Pc, 1, 1a, 2, 3
VII		0/16		4/9	AI, 2
			PI, 1a, 2, 3, 3a, 4, 4a, 5		Pc, 1, 1a, 2, 3
VIII		4/14	AI, 3	4	
			PI, 1a, 2, 2a, 3, 3a, 4		I, 2
IX		12	1, 1a, 2, 2a, 3, 4	4	I, 2
X		10	1, 2, 2a, 3, 4	4	I, 2
XI	6		6	I, 2, 3	
XII	9		6		

***Paracondeellum dukouense* (Tang & Yin, 1988)**

Figures 3, 5; Tables 3, 4

Diagnosis. *Paracondeellum dukouense* (Tang & Yin, 1988) is characterized by the one pair of *A*-setae on tergite I, absence of *A*-setae and *PIa* seta on tergites II–VI, absence of *A*-setae and nine pairs of *P*-setae (*P2a* present) on tergite VII, tergites IX and X with 14 and 12 setae respectively, absence of seta *d4* on head, and female squama genitalis with pointed acrostylus.

Material examined. Lectotype, female (slide no. 1), paralectotype, female (slide no. 2) (SEM), China, Sichuan, Dukou City (currently, Panzhihua City), Jinjiang County, soil under grass, 1155 m elev., 26.55N, 101.85E, 26-IX-1985, B.W. Tang and G.T. Jin collectors. We designated as the lectotype the female on slide no. 1 and the other female on slide no. 2 as the paralectotype.

Redescription. Body length of holotype 880 µm and paratype 720 µm; yellow-brown, with foretarsus darker (Fig. 5A).

Head. Elliptic, length 93–100 µm, width 70 µm. Dorsal setae longer than subdorsal and lateral ones, rostrum slightly protruded (Fig. 5C). Setae *d6* and *sd6* present, *sd6* sensillum-shaped; *d4* and *sd4* absent; *d6* and *d7* 11 µm and 6 µm long, respectively (Fig. 5C). Pores *cp* and *fp* present. Pseudoculus round, without lever, length 13 µm, width 11 µm. PR = 7.2–7.7 (Fig. 5C). Canal of maxillary gland short, with globular calyx and sausage-like posterior dilation. CF = 13.3–14.3 (Fig. 5B). Labial palpus well developed, with four setae and apical tuft, without basal sensillum. Maxillary palpus with two subequal sensilla.

Foretarsus. Length 46–50 µm, claw length 15–17 µm, TR=2.9–3.1; empodium length 4–5 µm, EU=0.24–0.33. Dorsal sensilla *t-1* and *t-2* slender and long, BS=0.66;

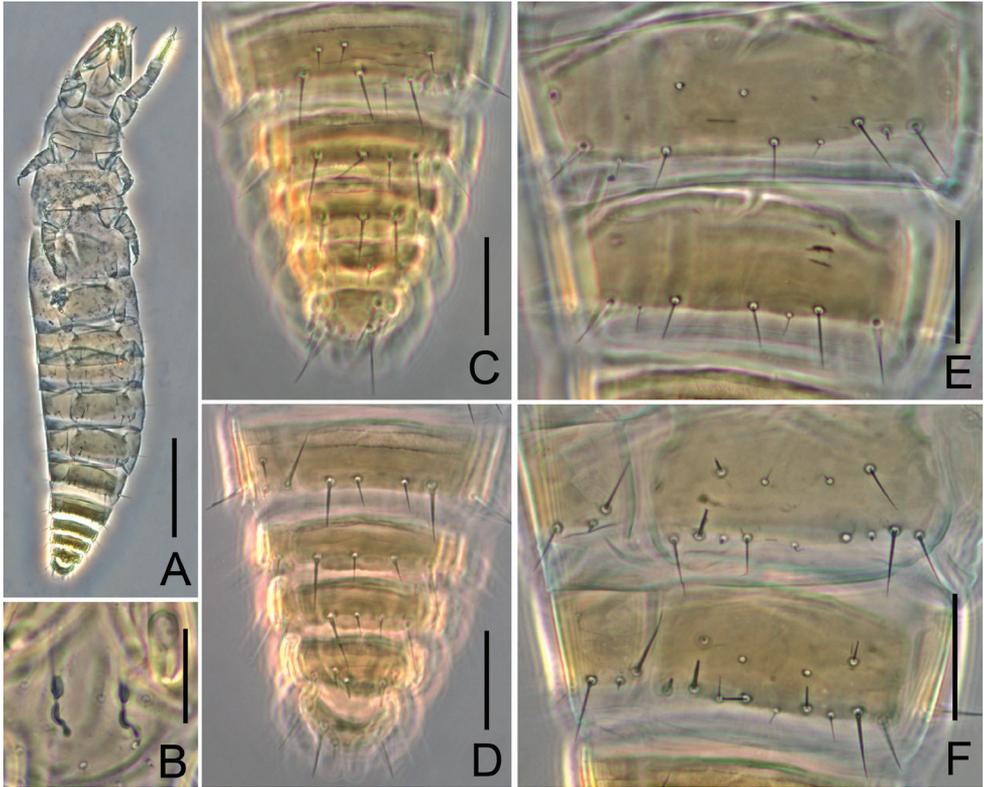


Figure 4. *Paracondeellum paradisum* sp. nov., holotype **A** habitus **B** canal of maxillary gland **C** tergites VIII–XII **D** sternites VIII–XII **E** tergites V–VII **F** sternites VI–VII. Scale bars: 100 µm (**A**); 20 µm (**B–F**).

t-3 short sward-like, nearly reaching base of claw (Fig. 3D). Exterior slide with only sensilla *a*, *b* and *f* present; *a* spatulate, *b* and *f* short sward-like (Fig. 3D). Interior sensilla *a'* and *c'* short sward-like, *b'* absent (Fig. 3E). Relative length of sensilla: $t-2 > t-1 > c' > a > t3 > a' > (b = f)$ (Fig. 3D, E). Length of middle tarsus 20 µm; claw length 12 µm. Length of hind tarsus 23 µm; claw length 15 µm.

Thorax. Thoracic chaetotaxy given in Table 3. Setae *I* and *2* on pronotum subequal in length, 10 µm long; mesonotum with seven pairs of posterior setae, *P5a* minute; metanotum with six pairs of posterior setae, *P5a* absent; setae *P1*, *P1a*, *P2* on mesonotum 10 µm, 1.5 µm, 14 µm respectively; *P1a* on meso- and metanotum short, pin-shaped. Prosternum with anterior seta *A2* (Fig. 5D), meso- and metasternum each with four posterior setae (Fig. 5E), metasternum with six anterior setae. All setae on sterna normal. Pores on thorax not detectable.

Abdomen. Abdominal chaetotaxy given in Table 3. Tergite I with one pair of anterior setae (*A5*) and six pairs of posterior setae, *A5* short, sensillum-shaped. Tergites II–VI without anterior setae and seven pairs of posterior setae, *P2a* present, *P1a* and *P3a* absent (Fig. 5F). Tergite VII without anterior setae and with nine pairs of posterior setae, both *P2a* and *P3a* present (Fig. 5G). Accessory setae *P2a* and *P4a* on tergites II–VII short, sensillum-shaped, 4 µm in length, *P1a* and *P3a* on tergites VII normal,



Figure 5. *Paracondecellum dukouense* (Tang & Yin, 1988), holotype **A** habitus **B** canal of maxillary gland **C** head, dorsal view **D** prosternum **E** mesosternum **F** tergite VI **G** tergites VII–VIII **H** sternite VI **I** sternite VII **J** sternite V **K** tergites VIII–XII **L** sternites VIII–XII. Arrows indicate pores. Scale bars: 20 µm.

9–10 µm in length (Fig. 5F, G). Tergite VIII with three pairs of anterior setae (*A1*, *A3*, *A5*) and seven pairs of posterior setae, *P3a* short (5 µm) (Fig. 5G, K, L). Posterior central seta *Pc* present on sternites IV–VII slender, 8–9 µm long (Fig. 5H–J). *P1a* on sternites IV–VI short pin-shaped, 2 µm long (Fig. 5H, J), on sternite VII as normal seta, 9 µm long (Fig. 5I). Sternites IX and X with short *P3a* seta (Fig. 5L), which had been omitted in original description.

Tergites I–VII with pores *psm* and *al*, VIII with pores *psm* only, IX–XI without pores, XII with single median pore. Pores on sternites I–VI not observed due to the opacity of the old specimens (Fig. 5H, J); three posteromedial pores observed on sternite VII (Fig. 5I), VIII with posteromedial pore (Fig. 5L), IX–XI without pores, XII with one pair of *sal* pore.

Abdominal appendages typical of the genus. Subapical setae and apical setae on appendage III 12–13 µm and 6–8 µm long, respectively. Striate band on abdominal segment VIII reduced to a single serrate line (Fig. 5G, K, L). Comb on abdomen VIII

Table 3. Adult chaetotaxy of *Paracondeellum dukouense* (Tang & Yin, 1988).

Segment		Dorsal		Ventral	
		Formula	Setae	Formula	Setae
Th.	I	4	1, 2	(4+2)/6	A1, 2, M
			P1, 2, 3		
	II	6/14	A2, 4, M	(4+2)/4	A1, 2, M
			P1, 1a, 2, 3, 4, 5, 5a		P1, 2
	III	6/12	A2, 4, M	(6+2)/4	A1, 2, 3, M
			P1, 1a, 2, 3, 4, 5		P1, 2
Abd.	I	2/12	A5	4/2	A1, 2
			P1, 1a, 2, 2a, 3, 4		P1
	II–III	0/14		4/3	A1, 2
			P1, 2, 2a, 3, 4, 4a, 5		Pc, 2
	IV–VI	0/14		4/9	A1, 2
			P1, 2, 2a, 3, 4, 4a, 5		Pc, 1, 1a, 2, 3
	VII	0/18		4/9	A1, 2
			P1, 1a, 2, 2a, 3, 3a, 4, 4a, 5		Pc, 1, 1a, 2, 3
	VIII	6/14	A1, 3, 5		
			P1, 1a, 2, 2a, 3, 3a, 4	4	1, 2
	IX	14	1, 1a, 2, 2a, 3, 3a, 4	4	1, 2
	X	12	1, 2, 2a, 3, 3a, 4	4	1, 2
XI	6		6	1, 2, 3	
XII	9		6		

Table 4. Comparison between *Paracondeellum paradisum* sp. nov. and *P. dukouense* (Tang & Yin, 1988).

	<i>Paracondeellum paradisum</i> sp. nov.	<i>P. dukouense</i>
body length (µm)	570	720–880
pseudoculus (µm)	8	13
foretarsus (µm)	31	46–50
sensilla <i>b</i> and <i>f</i>	short, rod-like	longer, sward-like
sensillum <i>t-3</i>	short and spatulate	longer, sward-like
<i>A</i> -setae on tergite I	4 (<i>A1</i> , <i>A5</i>)	2 (<i>A5</i>)
<i>A</i> -setae on tergites II–VI	2 (<i>A1</i>)	0
<i>P</i> -setae on tergites II–VI	16 (<i>P1a</i> present)	14 (<i>P1a</i> absent)
<i>P</i> -setae on tergite VII	16 (<i>P2a</i> absent)	18 (<i>P2a</i> present)
<i>A</i> -setae on tergite VIII	4 (<i>A1</i> , <i>A3</i>)	6 (<i>A1</i> , <i>A3</i> , <i>A5</i>)
setae on tergite IX	12 (<i>P3a</i> absent)	14 (<i>P3a</i> present)
setae on tergite X	10 (<i>P3a</i> absent)	12 (<i>P3a</i> present)
<i>A</i> -setae on prosternum	2 (<i>A2</i> absent)	4 (<i>A2</i> present)

rectangular, with 10 teeth, 12–13 µm wide (Fig. 5K). Female squama genitalis short, with pointed acrostylus.

Etymology. Named for Dukou City (now Panzhihua City, Sichuan Province) where type specimens were collected.

Distribution. China (Sichuan, Yunnan).

Remarks. *Paracondeellum dukouense* was originally described based on two syntypes (Tang and Yin 1988). In the original description (Tang and Yin 1988) and in the monograph of Yin (1999), most important characters such as foretarsal sensilla, pseudoculus, maxillary gland, as well as body chaetotaxy were briefly described and illustrated. After careful study of type specimens under a modern phase contrast microscope with higher resolution, we find that sensillum *c*' is present on the foretarsus and

that some of the setae on the body were previously ignored due to the lower resolution of the microscope used. We correct here these mistakes in the original description and supplement the description of head chaetotaxy, the porotaxy, and the shapes of setae on the body. Table 4 compares *P. dukouense* with the new species.

List of species from Hainan Island
Family Protentomidae Ewing, 1936

Paracondeellum paradisum sp. nov.

Description. The description is given above.

Family Berberentulidae Yin, 1983

Baculentulus tienmushanensis (Yin, 1963)

Material examined. 1 male, 1 mj, locality 3, 19-I-1985, coll. G. T. Jin & Z. Y. Liu. 4 females, 1 mj, locality 5, 26-II-2003; 1 female, locality 1, 14-I-2004; 10 females, 6 mj, locality 2, 27-I-2004, coll. Y. Xiong. 1 mj, locality 11, 22-III-2017, coll. Y. Bu.

Distribution. Widely distributed in China (Hainan, Zhejiang, Shanghai, Jiangxi, Anhui, Hubei, Sichuan, Chongqing, Guizhou, Yunnan, Ningxia, Gansu, Shaanxi, Henan, Hebei, Liaoning, Neimenggu).

Kenyentulus cilicicalyci Yin, 1987

Material examined. 5 females, locality 1, 27-XI-1984, coll. G. T. Jin & Z. Y. Liu. 1 female, VI-1993; 1 female, IV-1994, locality 1, coll. C. H. Liao. 9 females, 2 males, locality 5, 26-II-2003; 1 female, locality 6, 2-III-2003; 1 female, locality 5, 15-VI-2003; 6 females, 1 male, locality 1, 6-X-2003; 9 females, 2 males, 13 mj, locality 1, 14-I-2004; 7 females, 3 males, locality 1, 15-I-2004; 1 female, locality 1, 14-IV-2004; 2 females, 5 males, 1 mj, locality 1, 15-VII-2004, coll. Y. Xiong. 2 females, 1 male, 2 mj, locality 9, 20-III-2011, coll. Y. Bu & C. W. Huang. 14 females, 10 male, 1 mj, locality 11, 22-III-2017; 3 males, locality 12, 17-X-2017, coll. Y. Bu.

Distribution. Widely distributed in China (Hainan, Zhejiang, Hunan, Sichuan, Chongqing, Guizhou, Yunnan, Shaanxi).

Kenyentulus dolichadeni Yin, 1987

Material examined. 3 females, locality 2, 14-XI-1984, coll. G. T. Jin & Z. Y. Liu.

Distribution. China (Hainan, Zhejiang, Guangxi, Guizhou, Hubei, Sichuan, Jiangxi).

***Kenyentulus hainanensis* Yin, 1987**

Material examined. 4 females, 1 male, locality 1, 30-XI-1984; 2 females, 2 males, locality 2, 14-XI-1984; 1 male, 2 mj, locality 3, 19-I-1985, coll. G. T. Jin & Z. Y. Liu.

Distribution. China (Hainan, Guangdong).

***Kenyentulus henanensis* Yin, 1983**

Material examined. 2 female, 1 male, locality 2, 19-XI-1984, coll. G. T. Jin & Z. Y. Liu.

Distribution. Widely distributed in China (Hainan, Zhejiang, Jiangxi, Henan, Hubei, Guizhou, Yunnan, Ningxia).

***Kenyentulus japonicus* (Imadate, 1961)**

Material examined. 2 females, locality 2, 14-XI-1984; 5 females, 5 males, locality 1, 25-XI-1984, coll. G. T. Jin & Z. Y. Liu.

Distribution. Widely distributed in China (Hainan, Zhejiang, Jiangsu, Shanghai, Jiangxi, Anhui, Hunan, Sichuan, Guizhou, Yunnan, Shaanxi); Japan.

***Kenyentulus jianfengensis* Yin, 1987**

Material examined. 4 females, locality 1, 1-XII-1984, coll. G. T. Jin & Z. Y. Liu. 2 females, 1 male, 1 mj, locality 1, 6-X-2003; 7 females, 5 males, 2 mj, locality 1, 15-I-2004; 1 mj, locality 3, 27-I-2004; 3 females, 1 males, 1 mj, locality 1, 14-IV-2004; 7 females, 9 males, locality 1, 15-VII-2004, coll. Y. Xiong.

Distribution. China (Hainan, Guizhou).

***Kenyentulus jinghongensis* Yin, 1983**

Material examined. 3 females, locality 1, 25-XI-1984, coll. G. T. Jin & Z. Y. Liu.

Distribution. China (Hainan, Yunnan, Guizhou).

***Kenyentulus minys* Yin, 1983**

Material examined. 2 females, 2 males, locality 1, 19-XI-1984, coll. G. T. Jin & Z. Y. Liu.

Distribution. China (Hainan, Yunnan, Guangxi, Jiangxi)

***Amphientulus sinensis* Xiong, Xie & Yin, 2005**

Material examined. 1 female, locality 1, 17-XII-2002; 1 female, locality 2; 8 females, 4 males, 1 mj, locality 3, 27-I-2004, coll. Y. Xiong.

Distribution. China (Hainan, Guangdong).

Family Sinentomidae Yin, 1965***Sinentomon erythranum* Yin, 1965**

Material examined. 1 female, 1 male, 1 mj, locality 5, 26-II-2003; 1 mj, locality 1, 6-X-2003; 7 females, locality 1, 15-VII-2004, coll. Y. Xiong. 1 female, 1 LI, locality 13, 16-X-2017; 1 LI, locality 12, 17-X-2017, coll. Y. Bu.

Distribution. Widely distributed in South China (Hainan, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Guangxi, Guangdong, Hunan, Guizhou, Yunnan).

Family Fujientomidae Yin, 1996***Fujientomon dicestum* Yin, 1977**

Material examined. 1 female, locality 5, 26-II-2003, coll. Y. Xiong.

Distribution. China (Hainan, Shanghai, Jiangsu, Zhejiang, Anhui, Ningxia).

Family Eosentomidae Berlese, 1909***Eosentomon actitum* Zhang, 1983**

Material examined. 8 females, 6 males, 2 mj, locality 1, XII-1984; 24 females, 24 males, 27 mj, locality 3, 23-I-1985, coll. G. T. Jin & Z. Y. Liu. 2 females, 3 males, locality 8, 22-II-2003, coll. Y. Xiong. 2 females, 3 mj, locality 11, 22-III-2017, coll. Y. Bu.

Distribution. China (Hainan, Guangdong, Sichuan).

***Eosentomon hainanense* Yin, 1986**

Material examined. 40 females, 33 males, 2 mj, locality 1, 25-XI-1984, coll. G. T. Jin & Z. Y. Liu. 2 females, VI-1993, locality 1, coll. C. H. Liao. 1 female, 5 males, locality 8, 22-II-2003; 4 females, 1 male, locality 6, 2-III-2003; 1 female, 3 males, 4 mj,

locality 5, 15-VI-2003; 19 female, 15 males, 8 mj, locality 1, 7-X-2003; 33 females, 31 males, 15 mj, locality 1, 14-I-2004; 1 male, locality 3, 960 m elev., 27-I-2004; 8 females, 8 males, 1 mj, locality 1, 15-VII-2004, coll. Y. Xiong.

Distribution. China (Hainan, Yunnan).

***Eosentomon iban* Imadate, 1965**

Material examined. 2 females, 2 males, locality 1, 27-XI-1984, coll. G. T. Jin & Z. Y. Liu.

Distribution. China (Hainan); Malaysia, Brunei.

***Eosentomon jinhongense* Yin, 1982**

Material examined. 2 females, 1 male, locality 2, 14-XI-1984, coll. G. T. Jin & Z. Y. Liu.

Distribution. China (Hainan, Yunnan).

***Eosentomon margarops* Yin & Zhang, 1982**

Material examined. 1 female, 2 males, 1 mj, locality 5, 26-II-2003; 1 female, 1 male, 2 mj, locality 5, 15-VI-2003; 1 female, 2 males, locality 1, 6-X-2003; 6 females, 3 males, 1 mj, locality 1, 15-I-2004; 2 females, 1 male, 1 mj, locality 2, 820 m elev., 27-I-2004; 3 females, 2 males, 2 mj, locality 3, 1000 m elev., 27-I-2004; 2 females, 1 male, locality 1, 14-IV-2004; 2 females, locality 1, 15-VII-2004, coll. Y. Xiong. 1 female, locality 10, 23-III-2017, coll. Y. Bu.

Distribution. China (Hainan, Guangdong, Sichuan).

***Eosentomon novemchaetum* Yin, 1965**

Material examined. 1 female, locality 11, 22-III-2017, coll. Y. Bu.

Distribution. China (Hainan, Shanghai, Jiangsu, Anhui, Jiangxi, Liaoning, Shaanxi)

***Eosentomon orientale* Yin, 1965**

Material examined. 1 female, locality 1, 25-XI-1984, coll. G. T. Jin & Z. Y. Liu.

Distribution. Widely distributed in China (Hainan, Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Guangxi, Guangdong, Sichuan, Chongqing, Guizhou, Ningxia, Shaanxi, Liaoning).

***Eosentomon sakura* Imadate & Yosii, 1959**

Material examined. 5 females, 3 males, locality 1, 25-XI-1984, coll. G. T. Jin & Z. Y. Liu. 13 females, 7 males, 9 mj, locality 8, 22-II-2003; 1 female, 1 mj, locality 5, 20-I-2003; 8 females, 13 males, 7 mj, locality 5, 26-II-2003; 1 female, 1 male, locality 6, 2-III-2003; 2 females, 5 males, 2 mj, locality 5, 15-VI-2003; 2 females, 1 mj, locality 1, 6-X-2003; 3 females, 1 male, 2 mj, locality 7, 13-VII-2003; 5 females, 2 males, 2 mj, locality 1, 15-I-2004; 46 females, 45 males, 29 mj, locality 4, 23-I-2004; 12 females, 20 males, 10 mj, locality 2, 820 m elev., 27-I-2004; 5 females, 5 males, 2 mj, locality 1, 500 m elev., 27-I-2004, coll. Y. Xiong. 1 male, locality 2, 20-III-2011, coll. Y. Bu & C. W. Huang. 8 females, 7 males, 3 mj, locality 11, 22-III-2017, coll. Y. Bu.

Distribution. Widely distributed in China (Hainan, Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Guangxi, Guangdong, Yunnan, Sichuan, Fujian, Guizhou, Taiwan, Hong Kong, Shaanxi).

***Eosentomon shanum* (Zhang, 1984)**

Material examined. 2 females, 1 male, locality 4, 23-I-2004; 1 female, 2 males, locality 1, 14-IV-2004; 5 females, 1 mj, locality 1, 15-VII-2004, coll. Y. Xiong.

Distribution. China (Hainan, Guangxi, Hunan, Jiangxi).

***Eosentomon spanum* Yin, 1986**

Material examined. 1 female, 1 male, locality 1, 27-XI-1984, coll. G. T. Jin & Z. Y. Liu.

Distribution. China (Hainan).

***Eosentomon tropicum* Yin, 1986**

Material examined. 5 females, locality 1, 25-XI-1984, coll. G. T. Jin & Z. Y. Liu. 1 female, VII-1993, locality 1, coll. C. H. Liao. 1 female, 3 males, 3 mj, locality 8, 22-II-2003; 4 females, 3 males, 4 mj, locality 1, 6-X-2003; 2 mj, locality 1, 15-I-2004; 3 females, 1 male, locality 1, 15-VII-2004, coll. Y. Xiong. 2 females, locality 11, 22-III-2017, coll. Y. Bu.

Distribution. China (Hainan).

***Eosentomon xishaense* Yin, 1988**

Material examined. 2 females, locality 1, 27-XI-1984, coll. G. T. Jin & Z. Y. Liu. 1 mj, VI-1993, locality 1, coll. C. H. Liao. 1 female, locality 5, 20-I-2003; 3 mj, locality

1, 14-IV-2004; 4 females, 2 males, locality 1, 15-VII-2004, coll. Y. Xiong. 1 female, locality 9, 20-III-2011, coll. Y. Bu & C. W. Huang. 2 females, 1 male, 1 mj, locality 11, 22-III-2017; 1 male, locality 10, 23-III-2017, coll. Y. Bu.

Distribution. China (Hainan, Xisha Islands, Yongxing Island).

***Eosentomon yanshanense* Yin & Zhang, 1982**

Material examined. 2 females, locality 1, 25-XI-1984, coll. G. T. Jin & Z. Y. Liu. 2 females, 4 males, 7 mj, locality 6, 2-III-2003; 9 females, 3 males, 10 mj, locality 4, 23-I-2004; 2 females, 2 males, locality 1, 14-IV-2004; 2 females, 1 mj, locality 1, 15-VII-2004, coll. Y. Xiong.

Distribution. China (Hainan, Guangxi, Guangdong, Fujian, Jiangxi, Hunan, Hubei, Yunnan).

***Eosentomon zhanjiangense* Zhang, 1983**

Material examined. 2 females, locality 1, 19-I-1985, coll. G. T. Jin & Z. Y. Liu. 1 females, 2 males, locality 1, 14-IV-2004, coll. Y. Xiong.

Distribution. China (Hainan, Guangdong).

***Anisentomon hainanense* Xiong, Bu & Yin, 2008**

Material examined. 1 female, 1 male, locality 1, 6-X-2003, coll. Y. Xiong.

Distribution. China (Hainan).

***Anisentomon quadrisetum* Zhang & Yin, 1981**

Material examined. 1 female, 1 male, locality 1, 7-X-2003, 14 females; 7 males, locality 1, 14-I-2004, coll. Y. Xiong. 1 male, 1 mj, locality 11, 22-III-2017, coll. Y. Bu.

Distribution. China (Hainan, Guangxi, Guangdong).

***Neanisentomon yuenicum* Zhang & Yin, 1984**

Material examined. 1 female, locality 1, 14-IV-2004, coll. Y. Xiong. 1 female, 1 male, locality 10, 23-III-2017, coll. Y. Bu.

Distribution. China (Hainan, Guangdong).

***Paranisentomon tuxeni* (Imadate & Yosii, 1959)**

Material examined. 6 females, 1 mj, locality 3, 1000 m elev., 27-I-2004, coll. Y. Xiong.

Distribution. China (Hainan, Hubei, Hunan, Jiangxi, Anhui, Guizhou, Shaanxi).

***Pseudanisentomon paurophthalmum* Zhang & Yin, 1984**

Material examined. 1 female, 1 mj, locality 11, 22-III-2017, coll. Y. Bu.

Distribution. China (Hainan, Guangxi).

***Pseudanisentomon molykos* Zhang & Yin, 1984**

Material examined. 5 females, 2 males, 1 mj, locality 1, 6-X-2003; 1 female, locality 1, 14-IV-2004, coll. Y. Xiong.

Distribution. China (Hainan, Guangdong, Guangxi, Yunnan).

***Pseudanisentomon sininotiale* Zhang & Yin, 1984**

Material examined. 2 females, locality 1, 27-XI-1984, coll. G. T. Jin & Z. Y. Liu. 2 females, 4 males, locality 4, 23-I-2004; 1 male, locality 3, 600 m elev., 27-I-2004, coll. Y. Xiong.

Distribution. China (Hainan, Guangxi, Hunan).

Discussion. The 34 species of Protura recorded from Hainan Island belong to 11 genera and five families (Protentomidae, Berberentulidae, Sinentomidae, Fujientomidae and Eosentomidae) (Table 5). Most species (91%) belong to Eosentomidae (21 species) and Berberentulidae (10 species), while the other three families are represented by one species each. Both Berberentulidae and Eosentomidae are widely distributed in China and have high species richness. In contrast, Sinentomidae, Protentomidae, and Fujientomidae each has fewer species occurring in China. Undoubtedly, proturans found in Hainan Island are mainly related to the fauna of Oriental Region and are distinctly different from those from Russian Far East and Siberia (Bu et al. 2014; Shrubovych 2014), which are dominated by the family Acerentomidae.

By comparing the species distribution, we found that the Protura fauna of Hainan Island is closely related to those of neighboring mainland regions (Yin 1999; Szeptycki 2007), and there are 13, 10, and 11 species shared with Guangdong, Guangxi, and Yunnan provinces, respectively (Fig. 1; Table 5), which is consistent with the geological history of Hainan Island (Wang 1991; Zhang and Fang 2012). Until the Quaternary period (2.5 million years ago), Hainan Island was still connected with Leizhou Peninsula of Guangdong Province. In the Middle Pleistocene, fault depression led to the separation of Hainan Island from the mainland. With sea level fluctuations, Hainan Island was connected to or separated from the mainland for several times. Since the

Table 5. The list of proturan species from Hainan Island and their distribution in Hainan Island and three neighboring mainland provinces.

Classification	Species	Hainan	Guangdong	Guangxi	Yunnan
Acerentomata Yin, 1996					
Protentomidae Ewing, 1936					
<i>Paracondeellum</i> Yin, Xie & Zhang, 1994	<i>P. paradisum</i> sp. n.*	11**			
Berberentulidae Yin, 1983					
<i>Baculentulus</i> Tuxen, 1977	<i>B. tienmushanensis</i> (Yin, 1963)	2, 3, 5, 11			+
<i>Kenyentulus</i> Tuxen, 1981	<i>K. ciliciocalyci</i> Yin, 1987	1, 5, 6, 9, 11, 12			+
	<i>K. dolichadeni</i> Yin, 1987	2			
	<i>K. hainanensis</i> Yin, 1987	1, 3	+		
	<i>K. henanensis</i> Yin, 1983	2			+
	<i>K. japonicus</i> (Imadate, 1961)	2			+
	<i>K. jianfengensis</i> Yin, 1987	1, 2			
	<i>K. jinghongensis</i> Yin, 1983	1			+
	<i>K. minys</i> Yin, 1983	1		+	+
<i>Amphientulus</i> Tuxen, 1981	<i>A. sinensis</i> Xiong, Xie & Yin, 2005	1, 3	+		
Sinentomata Yin, 1996					
Sinentomidae Yin, 1965					
<i>Sinentomon</i> Yin, 1965	<i>S. erythranum</i> Yin, 1965	1, 5, 12, 13	+	+	+
Fujientomidae Yin, 1996					
<i>Fujientomon</i> Yin, 1977	<i>F. dicesum</i> Yin, 1977	5			
Eosentomata Yin, 1996					
Eosentomidae Berlese, 1909					
<i>Eosentomon</i> Berlese, 1909	<i>E. actitum</i> Zhang, 1983	1, 3, 8, 11	+		
	<i>E. hainanense</i> Yin, 1986*	1, 3, 5, 6, 8	+		+
	<i>E. iban</i> Imadate, 1965	1			
	<i>E. jinhongense</i> Yin, 1982	2			+
	<i>E. margarops</i> Yin & Zhang, 1982	1, 2, 3, 5, 10	+		
	<i>E. novemchaetum</i> Yin, 1965	11			
	<i>E. orientale</i> Yin, 1965	1	+		+
	<i>E. sakura</i> Imadate & Yosii, 1959	1, 2, 4–8, 11	+	+	+
	<i>E. shanum</i> (Zhang, 1984)	1, 4		+	
	<i>E. spanum</i> Yin, 1986*	1			
	<i>E. tropicum</i> Yin, 1986*	1, 8, 11			
	<i>E. xishaense</i> Yin, 1988	1, 5, 9–11			
	<i>E. yanshanense</i> Yin & Zhang, 1982	1, 4, 6	+	+	+
	<i>E. zhanjiangense</i> Zhang, 1983	1	+		
<i>Anisentomon</i> Yin, 1977	<i>A. hainanense</i> Xiong, Bu & Yin, 2008*	1			
	<i>A. quadrisetum</i> Zhang & Yin, 1981	1, 11	+	+	
<i>Neanisentomon</i> Zhang & Yin, 1984	<i>N. yuenicum</i> Zhang & Yin, 1984	1, 10	+		
<i>Paranisentomon</i> Zhang & Yin, 1984	<i>P. tuxeni</i> (Imadate & Yosii, 1959)	3			
<i>Pseudanisentomon</i> Zhang & Yin, 1984	<i>P. paurophthalmon</i> Zhang & Yin, 1984	11		+	
	<i>P. molykos</i> Zhang & Yin, 1984	1	+	+	
	<i>P. sinintiale</i> Zhang & Yin, 1984	1, 4		+	

* Species known only from Hainan Island so far.

** Numbers indicate the localities given in Table 1.

end of the Quaternary period, due to the drastically rise of sea level, Hainan Island has been separated from the mainland without interruption.

Among the mainland regions neighboring Hainan Island, the Protura fauna of Yunnan Province has been systematically studied (Zhang et al. 1996; Yin et al. 2000), and nearly 80 species were reported from that province, with the Berberentulidae and Eosentomidae having fairly high diversity (Zhang et al. 1996; Yin et al. 2000). In this

study, we found the diversity of Protura fauna from Hainan Island is very similar to that from Yunnan Province. The only difference is the presence of family Hesperentomidae in Yunnan, which is absent in Hainan Island.

Sampling localities in Hainan Island are still sparse, and additional collection of proturans should be made in the future, so as to reveal the true diversity and provide a better understanding of the biogeography of Protura on the Hainan Island.

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