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First record of the genus *Paracarophenax* (Acari: Acarophenacidae) from China, with description of a new species

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Abstract

A new species *Paracarophenax alternatus* Xu and Zhang **sp. nov.** is described and illustrated based on phoretic females. The mites were found attached to the adult of *Monochamus alternatus* Hope (Coleoptera: Cerambycidae) collected from traps set in Minhou county, Fuzhou city, Fujian province, China. The new species is the eighth representative of the genus and also the first record of the *Paracarophenax* associated with the host family Cerambycidae. An updated the key to species of *Paracarophenax* is provided.

Key words: Taxonomy, morphology, Japanese pine sawyer, phoresy, *Monochamus alternatus*

Introduction

The family Acarophenacidae currently consists of 7 genera (six extant and one fossil) and about 37 described species worldwide (Arjomandi *et al.* 2017; Walter & Seeman 2017; Khaustov & Abramov 2018). Only one species of this family, *Acarophenax mahunkai* Steinkraus and Cross, 1993, was recorded from China (Gao & Zou 1994). Acarophenacid mites are known as egg parasitoids of various insects, including beetles (Cerambycidae, Tenebrionidae, Nitidulidae, Dermestidae, Curculionidae, Mycetophagidae and Erotylidae) and thrips (Thysanoptera) (Goldarazena *et al.* 2001; Katlav *et al.* 2015; Arjomandi *et al.* 2017; Walter & Seeman 2017; Khaustov & Abramov 2018), and considered as potential biological control agents due to its non-toxicity to people or domesticated animals (Krantz & Walter, 2009).

The genus *Paracarophenax* resembles *Aethiophenax*, but can be easily distinguished by stigmatal openings dorsal, atria membranous; one or two pairs of setae on tergite EF, setae *e* present or absent; and setae *ps* present or absent (stigmatal openings lateral, atria sclerotized; one pair of setae on tergite EF, setae *e* absent; and setae *ps* absent in *Aethiophenax*) (Walter & Seeman 2017). *Paracarophenax* comprises 7 described species: *P. dybasi* Cross, 1965, *P. bambergensis* (Krczal, 1959), *P. undosus* Mahunka, 1975, *P. paucisetosus* Mahunka and Rack, 1977, *P. scolyti* Khaustov, 1999, *P. myzognathus* Walter and Seeman, 2017 and *P. triplaxophilus* Khaustov and Abramov, 2017. In this paper, we describe and illustrate a new species associated with *Monochamus alternatus* Hope (Coleoptera: Cerambycidae). This is the second report of the family Acarophenacidae from China. An updated key to species of *Paracarophenax* is also provided.

Materials and methods

The beetle hosts *Monochamus alternatus* were captured in trap devices set up in Minhou county, Fuzhou city, Fujian province, China. The trapped beetles were examined and then the phoretic mites were transferred into 70% ethanol under a stereo microscope. All acarophenacid mites removed and cleared in lactic acid, and mounted in Hoyer's medium. Specimens were examined at 400x and 1000x magnification by using differential interference contrast of a Leica DM5000B compound microscope.

All measurements in micrometers (μm) were taken from slide-mounted specimens using a stage-calibrated ocular ruler. Measurement data are presented for holotype, followed by ranges for paratypes in parentheses. Body length was measured from the anterior margin of the idiosoma (including gnathosoma) to the posterior margin of the opisthosoma, and body width was measured as the greatest distance posterior to coxae II. Setal lengths were measured from the center of the setal base to the tip of the seta; distances between setae were measured as the distance from the center of one setal base to that of the other. Legs were measured from the basal end of trochanter to the distal end of tarsus (excluding pretarsus). Terminology follows Katlav *et al.* (2015) and Walter & Seeman (2017) who adapted from Lindquist (1986).

Family Acarophenacidae Cross, 1965
Genus *Paracarophenax* Cross, 1965
Type Species: *Paracarophenax dybasi* Cross, 1965

***Paracarophenax alternatus* Xu and Zhang sp. nov.**
(Figs. 1–5)

Diagnosis. Adult female. Each tracheal trunk with a brush-like atrium; two pairs of setae on tergite EF, two pairs of setae on tergite H; lacking setae *ag*; apodemes 1, 2 and sejugal apodeme well developed and fused, apodeme 3 not extending beyond setae *3c*, apodeme 4 well developed but separated; tegula present; trochanters 1-1-1-1, femora 3-3-2-0, genua 4-1-1-1; setae *v'* on genu II, *v''* on tibia II, *pv''* and *pl''* on tarsus II spine-like.

Type material. Holotype Female, China, Minhou county, Fuzhou city, Fujian province, 27 Aug. 2018, by Meng-Ling Cai and Feng Xia, ex. *Monochamus alternatus* Hope (Coleoptera: Cerambycidae). **Paratypes**: 56 females, same data as holotype.

Type deposition. The holotype and 9 paratypes will be deposited in the National Zoological Museum of China, Institute of Zoology, Chinese Academy of Sciences, Beijing; 37 paratypes are deposited in the Department of Plant Protection, Fujian Agriculture and Forestry University, China; 10 paratypes are deposited in the New Zealand Arthropod Collection (NZAC), Landcare Research, Auckland, New Zealand.

Description

Adult female (n=25).

Gnathosoma (Fig. 2). Rounded, fused with idiosoma. Palps fused with gnathosomal capsule, one pair of setae laterally, length 3 (3–4). Cheliceral stylets 12 (12–14) strong and curved. Pharynx enlarged and almost elliptical, length 50 (46–52), width 14 (12–15).

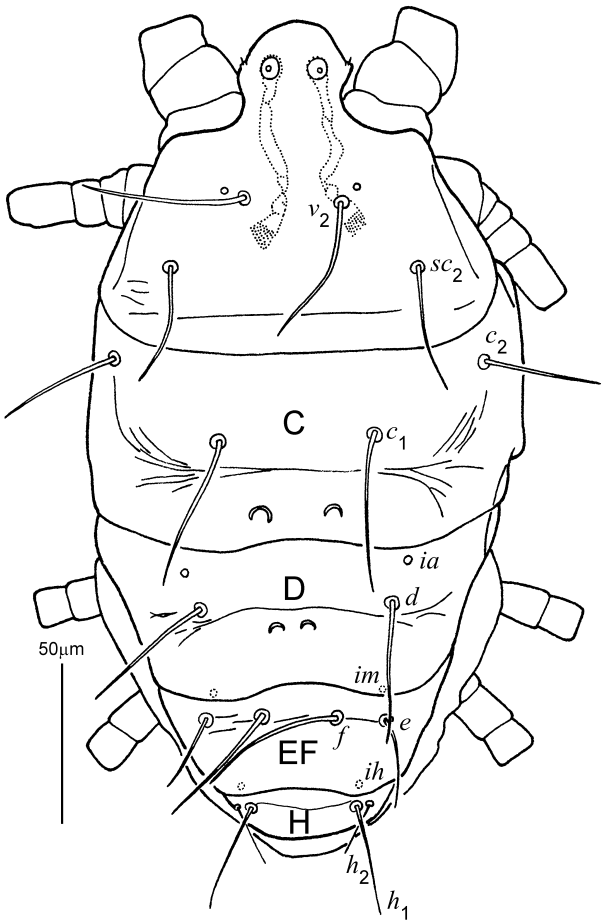

FIGURE 1. *Paracarophenax alternatus* Xu and Zhang **sp. nov.** (adult female). dorsal view of the body.

Idiosomal dorsum (Fig. 1). Ovate, length 255 (225–255), width 115 (100–115). Prodorsal shield trapezoidal, with two pairs of setae (v_2 and sc_2) thickened and blunt-ended; Lengths of setae: v_2 50 (40–50), sc_2 39 (33–40); distances between setae: v_2–v_2 30 (27–30), v_2–sc_2 30 (25–31), sc_2–sc_2 77 (72–77). Stigmata on prodorsal projection, associated with tracheal system and atria, tracheal trunks with a brush-like atrium. Cupules *ia*, *im* and *ih* situated on tergites D, EF and H, respectively. One pair of crescent-shaped ornamentation located near posterior margin of tergites C and middle of tergites D, respectively. Tergite C with two pairs of setae (c_1 and c_2); tergite D with one pair of setae *d*; tergite EF with two pairs of setae (*e* and *f*); tergite H with two pairs of setae (h_1 and h_2); all dorsal setae thickened and blunt-ended except h_2 thinner and pointed. Setae *f* about twice as long as *e*; setae v_2, c_1 and *f* subequal, setae sc_2, c_2 and *d* subequal in length, and about four-fifths as long as setae *f*; setae h_2 about two-thirds of h_1 and located very close to h_1. Setal lengths: c_1 48 (43–50), c_2 37 (30–37), *d* 37 (35–43), *e* 22 (17–26), *f* 45 (36–49), h_1 30 (20–30), h_2 17 (13–18); distances between setae: c_1–c_1 50 (45–50), c_2–c_2 115 (100–115), c_1–c_2 40 (35–40), *d*–*d* 60 (55–60), *e*–*e* 56 (47–56), *f*–*f* 22 (20–26), *e*–*f* 15 (12–17), h_1–h_1 32 (25–32), h_2–h_2 40 (33–40), h_1–h_2 5 (3–5).

Idiosomal venter (Fig. 2). Ventral plates smooth. All ventral setae thin and smooth, lengths of setae: *1a* 7 (5–7), *2a* 12 (11–15), *3a* 21 (20–28), *3c* 12 (10–15), *4a* 10 (8–12), *4b* 8 (7–10), *4c* 8 (8–10); distances between setae: *1a*–*1a* 58 (50–58), *2a*–*2a* 40 (38–42), *3a*–*3a* 42 (33–42), *4a*–*4a* 26 (23–30). All ventral apodemes well developed except for apodemes 3 (ap3) which are short and

reach the bases of setae *3c*. Apodemes 1 (ap1), apodemes 2 (ap2) and sejugal apodeme (apsej) joined with prosternal apodeme (appr); ap1 fused with appr to form a Y-shaped structure with anterior branches surrounding the base of gnathosoma. Posterior margin of posterior ventral plate with well developed tegula. Aggenital plate without setae *ag*; plate PS with one pair of setae *ps*, 6 (4–6).

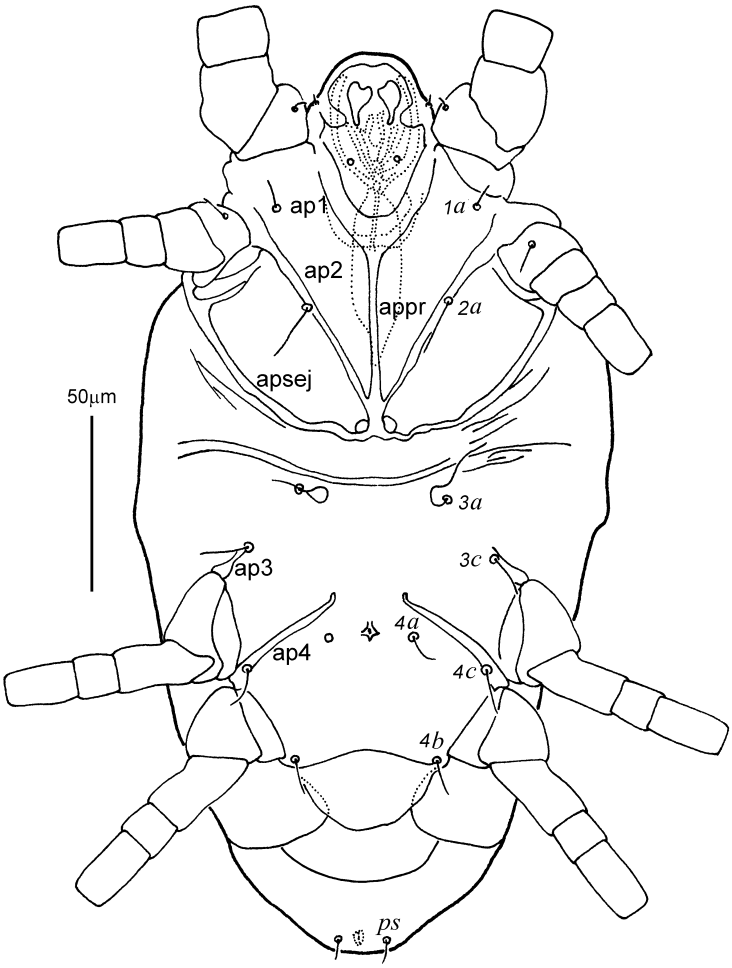

FIGURE 2. *Paracarophenax alternatus* Xu and Zhang **sp. nov.** (adult female). ventral view of the body.

Legs (Figs. 3–4). Lengths of legs I–IV: 75 (70–77), 72 (70–75), 87 (85–95), 100 (92–100). Tibiotarsus I length 39 (35–40), width 22 (20–23). Setal counts for legs I–IV (trochanter to tarsus): 1-3-4-17 +*φ*+*ω*+tarsal-claw complex, 1-3-1-4+*φ*-6+*ω*, 1-2-1-4-6, 1-0-1-4-6.

Leg I (Fig. 3A): Trochanter: seta *v'* comparatively short. Femur: setae *l'* and *v"* setiform, *d* weakly barbed and blunt-ended, 48 (45–50). Genu: setae *l'* and *l"* thickened and blunt-ended , *v'* and *v"* setiform. Tibiotarsus: 6 of 17 tibiotarsal setae are tibial (*d*, *k*, *l'*, *l"*, *v'*, *v"*) and 11 setae are tarsal (*p'*, *p''*, *pl'*, *pl''*, *pv'*, *pv"*, *s*, *tc'*, *tc"*, *ft'*, *ft''*); solenidion *φ* 10 (8–9), *ω* 8 (7–8); eupathidial setae *p'*, *p''*, *ft'*, *ft"*, *tc'* and *tc"* blunt-ended; seta *d* attenuated and whip-like, 87 (78–90); seta *pl'* 53 (48–53) about twice as long as *pl"* 27 (23–28); eupathidial seta *k*, 15 (13–15); seta *v"* whip-like, 54 (48–55), almost 3.5 times as long as *v'*, 15 (14–16); setae *l'*, *l"*, *pv'* and *pv"* smooth and setiform.

Leg II (Fig. 3B): Trochanter: seta *v'* slender and short. Femur: setae *l"*, *v"* and *d* setiform. Genu: seta *v'* spine-like, 8 (7–8). Tibia: solenidion *φ* 3 (3–5); setae *d*, *v'* and *l'* attenuated and whip-like, 70

(65–72), 50 (46–51) and 41 (38–44), respectively; seta *v"* spine-like, 8 (7–8). Tarsus: solenidion ω 4 (3–5); seta *tc"* attenuated and whip-like, 35 (30–38); setae *pl"* and *pv"* spine-like, 8 (7–8) and 10 (9–10), respectively; setae *u'* and *u"* slender and hard to discern.

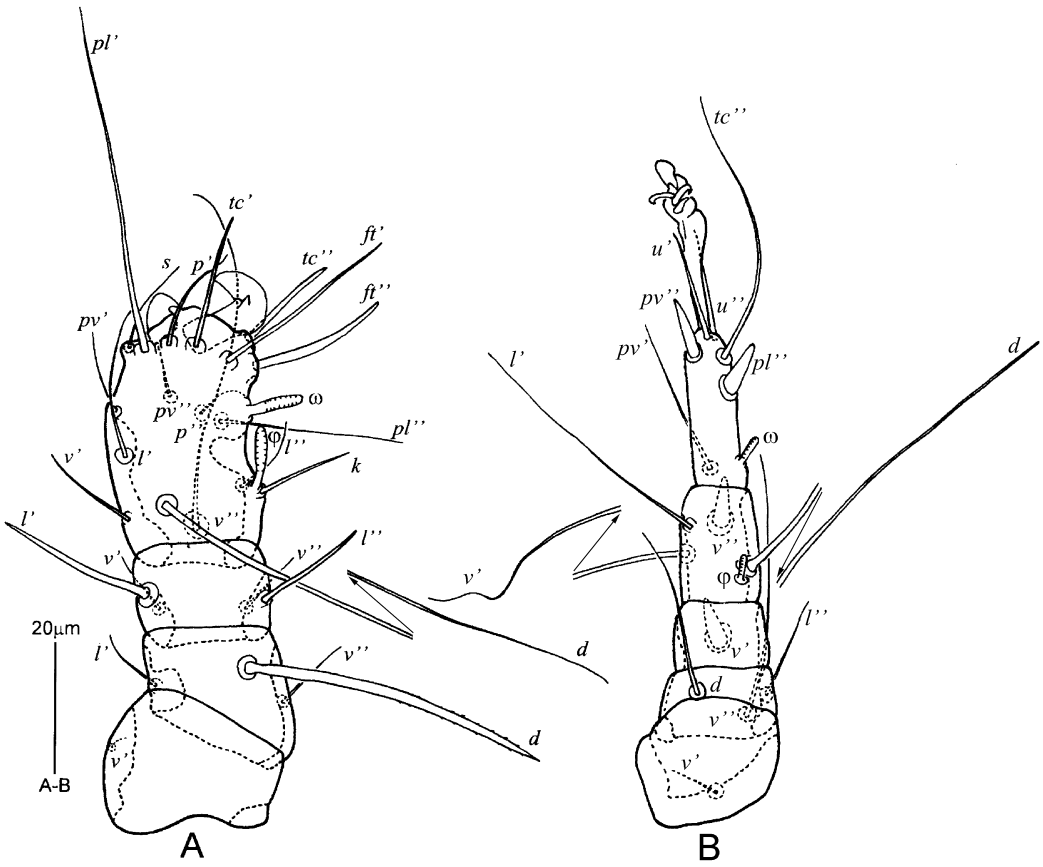

FIGURE 3. *Paracarophenax alternatus* Xu and Zhang **sp. nov.** (adult female, right side legs in dorsal view). A, leg I; B, leg II.

Leg III (Fig. 4A): Trochanter: seta *v'* slender and pointed. Femur: setae *d* and *v"* slender and pointed. Genu: setae *v'* slender and pointed. Tibia: seta *d* attenuated and whip-like, 87 (80–87); setae *v'*, *v"* and *l'* slender and pointed. Tarsus: seta *pv"* spine-like, 7 (6–7); seta *tc"* attenuated; setae *pv'* pointed and *pl''* blunt-ended; setae *u'* and *u"* as on tarsus II.

Leg IV (Fig. 4B): Trochanter: seta *v'* slender and pointed. Femur: nude. Genu: seta *v'* slender and pointed. Tibia: setae *d*, *v'* and *v"* attenuated and whip-like, 94 (83–96), 42 (39–43) and 46 (40–46) respectively; seta *l'* slender and pointed. Tarsus: seta *pv"* spine-like, 8 (7–8); seta *tc"* attenuated; setae *pv'* and *pl''* pointed; setae *u'* and *u"* as on tarsus II.

Etymology. The species name refers to the specific name of the host beetle, *Monochamus alternatus* Hope (Coleoptera: Cerambycidae) on which it was collected.

Remarks. On live specimens, the body of *Paracarophenax alternatus* Xu and Zhang **sp. nov.**, looks yellowish-brown with a shiny appearance; phoretic mites were found distributed around the coxal cavity of the adult of *Monochamus alternatus*, cramping the host setae by hook-like claws on legs I (Fig. 5). It was observed feeding on the eggs of the host beetles (Fig. 6).

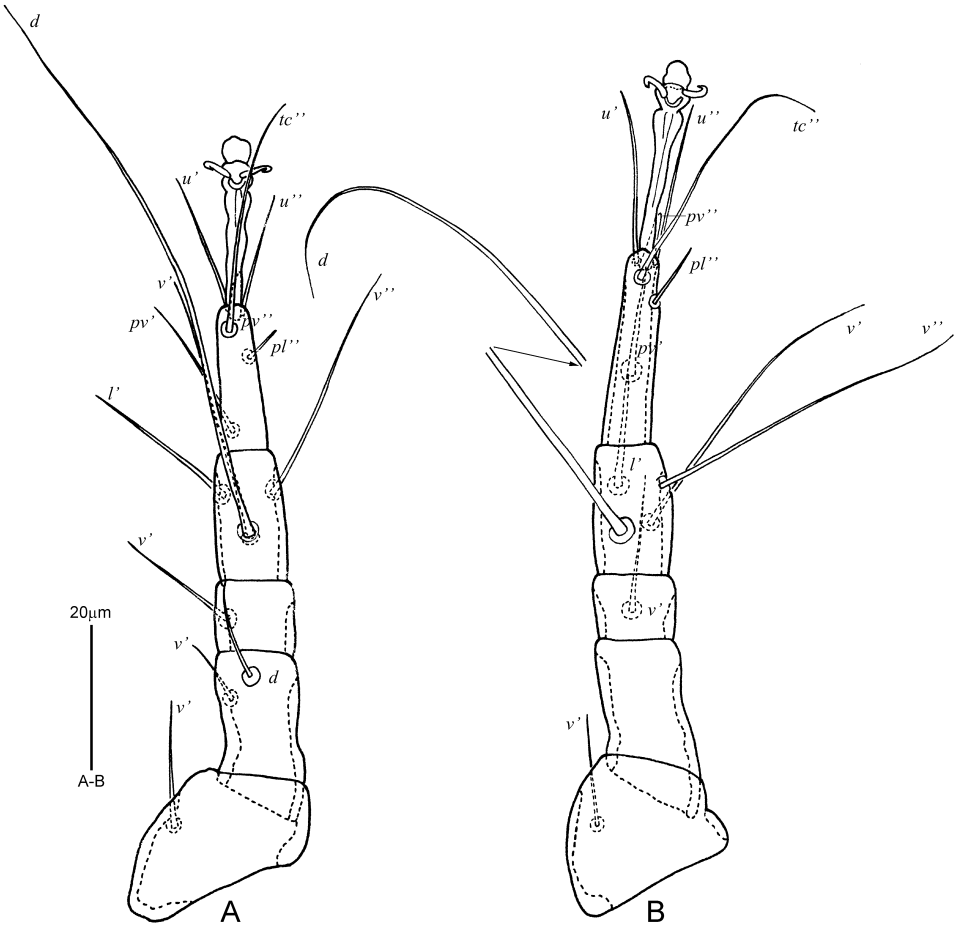

FIGURE 4. *Paracarophenax alternatus* Xu and Zhang **sp. nov.** (adult female, right side legs in dorsal view). A, leg III; B, leg IV.

Differential diagnosis: *Paracarophenax alternatus* Xu and Zhang **sp. nov.** is most similar to *P. scolyti* Khaustov, 1999 in having two pairs of setae on tergite EF; lacking setae *ag*; and trochanters I–II with a seta (*v′* present); tracheae with atrium terminating in brush-like extensions; but mainly differs in the following characters: setae *f* about twice as long as *e* (setae *e* slightly longer than *f* in *P. scolyti*); setae v_2, c_1 and *f* subequal in length, sc_2, c_2 and *d* subequal in length, and about four-fifths as long as seta *f* (setae v_2, sc_2, *d* and *e* subequal in length, c_1, c_2 and *f* subequal in length in *P. scolyti*); setae h_2 located proximate to h_1, about one fifth of the distance between setae *e* and *f* (the distance between setae h_2 and h_1 equal to the distance between setae *e* and *f* in *P. scolyti*); femora I–IV with 3, 3, 2, 0 setae (femora I–IV with 3, 3, 1, 0 setae in *P. scolyti*); setae *v'* on genu II spine-like (setae *v'* on genu II setiform in *P. scolyti*); on tibia II, setae *v'* longer than *l'* (setae *l'* about twice as long as setae *v'* in *P. scolyti*).

Key to species of *Paracarophenax* (based on Khaustov & Abramov (2017) with modifications)

1. Tergite EF with one pair of setae *f* (setae *e* absent); setae *ps* absent; trochanter II nude 2
- Tergite EF with two pairs of setae *e* and *f*; setae *ps* present; trochanter II with seta *v′* 4

2. Aggenital setae *ag* present, trochanter I with seta *v′* . . . . . *P. triplaxophilus* Khaustov and Abramov
- Aggenital setae *ag* absent, trochanter I nude 3
3. Tracheal atria bulbous, narrowing distally; sejugal apodeme fully developed; apodemes I moderately well developed . . . . . *P. paucisetosus* Mahunka and Rack
- Tracheal atria cylindrical, not narrowing distally; sejugal apodeme weakly developed medially; apodemes I weakly developed or obsolete . . . . . *P. myzognathus* Walter and Seeman
4. Opisthogaster with one pair of setae *ps*, setae *ag* absent; tegula present 5
- Opisthogaster with two pairs of setae (*ag* and *ps*); tegula absent 7
5. Setae h_2 present; tracheae with atrium terminating in brush-like extensions 6
- Setae h_2 absent; tracheae without obvious atrium extensions . . . . . *P. undosus* Mahunka
6. Setae *e* slightly longer than *f*; the distance between setae h_2 and h_1 equal to the distance between setae *e* and *f* (according to the Fig. 3 in Khaustov 1999); femur III with 1 seta; genu II with 1 setiform seta (according to the Fig. 4 in Khaustov 1999) . . . . . *P. scolyti* Khaustov
- Setae *f* about twice as long as *e*; setae h_2 located very close to h_1, and about one fifth of the distance between setae *e* and *f*; femur III with 2 setae; genu II with 1 spine-like seta. . *P. alternatus* Xu and Zhang **sp. nov.**
7. Prosternal and poststernal apodeme absent; setae h_2 as long as h_1. . . . . *P. dybasi* Cross
- Prosternal apodeme present; poststernal apodeme present as remnant; setae h_2 about twice as long as h_1 . . . . . *P. bambergensis* (Krczal)

FIGURE 5. Habitus photographs of ventral view of adult *Monochamus alternatus* with females *Paracarophenax alternatus* Xu and Zhang **sp. nov.** attached around the coxal cavity.

FIGURE 6. Photograph of *Paracarophenax alternatus* Xu and Zhang **sp. nov.** when feeding on the egg of *Monochamus alternatus*.

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