

Harpacticoid copepods in Sakaerat Environmental Research Station, Nakhon Ratchasima, Thailand

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ABSTRACT

The diversity of Harpacticoida in Sakaerat Environmental Research Station (SERS) has still been overlooked. According to the sampling of copepod in SERS in September 2013 and January 2014, five harpacticoid species, including *Phyllognathopus viguieri*, *Elaphoidella bidens decorata*, *E. namnaoensis*, *Elaphoidella* sp.1, and *Elaphoidella* sp.2, were collected by a plankton net with 60 µm mesh size. The Thai *Phyllognathopus viguieri* is slightly different from the supplementary description of the species in the ornamentation of anal operculum and feature of posterolateral seta on caudal ramus of the female. *E. bidens decorata* is also different from their original descriptions. *Elaphoidella* sp.1 and *Elaphoidella* sp.2 are most morphologically similar to *E. intermedia* and *E. longipedis*, respectively, but, the lack of male specimen of *E. intermedia* and the structural difference of exopod of fifth leg of *Elaphoidella* sp.2 preclude assigning them as the mentioned species.

Keywords: mountainous area, freshwater harpacticoids, Nakhon Ratchasima

INTRODUCTION

A high diversity of flora and fauna in Sakaerat Environmental Research Station (SERS) has been recorded (for a list of species, see http://203.151.206.68/sakaerat_site/), but the diversity of freshwater Harpacticoida has still been overlooked. In Thailand, only two species of freshwater harpacticoid have so far been recorded before 2007, including *Onychocamptus mohammed* (Blanchard and Richard, 1891), and *Elaphoidella margaritae* Pesce and Apostolov, 1985 (Table 1). More recently, according to the sampling of copepod from 44 different localities of subterranean water habitats (i.e. caves) in the mountainous area, seven valid species were added to the list of the harpacticoid fauna of Thailand, with the first record of the genera *Phyllognathopus*, Mrázek, 1893, and *Epacthophanes*, Mrázek, 1893 (Boonyanusith *et al.*, 2013b; Watiroyram, 2012). In addition, three out of four newly described Cyclopoida are first record of the genera *Fierscyclops*, Karanovic, 2004, and *Bryocyclops*, Kiefer, 1927 (Boonyanusith *et al.*, 2013a, b; Watiroyram *et al.*, 2012). These indicate a high diversity of copepod in mountainous area of the country. In this occasion, as a result of sampling of copepod in SERS, Nakhon

Ratchasima province, five harpacticoid species were encountered. Diagnostic characters were figured and described hereafter.

MATERIALS AND METHODS

The sampling was conducted in September 2013 and January 2014 in the area of SERS, Nakhon Ratchasima province. Copepods were collected from various types of water-bodies with a plankton net (60 µm mesh size). They were then placed in plastic bottles and fixed in formaldehyde solution with a final concentration of 4%. In the laboratory, copepods were sorted under a stereomicroscope and stored in 70% ethanol. Specimens were subsequently transferred into a mixture of glycerol and 70% ethanol (ratio ~1:10 v/v), prepared for identification. Few specimens were dissected at the magnification of x80. Armament and ornamentation of the body were examined under a magnification of x1000. All drawings of important characters were made at the same magnification (x1000). The illustrations were finally prepared using the CorelDraw®12 graphic programme (Corel Draw, Mountain View, CA, USA). Identification follows Wells (2007) and Chappuis (1931).

RESULTS

After the two sampling expeditions in SERS were conducted, five harpacticoid species were encountered, belonging to the genera *Elaphoidella* and *Phyllognathopus* (Table 1). *Phyllognathopus viguieri* was easily recognized, bearing a characteristic inner terminal caudal seta. This characteristic is different from that of all other species of the genus (see Galassi *et al.*, 2011). The female of all *Elaphoidella* from Sakaerat have combination of following characters: a) first thoracic segment is fused to cephalosome and covered by cephalic shield, b) 3- or 2-segmented endopod of first swimming leg is armed with inner seta on second segment, c) 3-segmented exopod of P1-P4 is armed with one outer spine on second segment, d) at least 4 elements armed on distal segment of exopod of P1-P4 and 2 outer elements are spines, e) characteristic shape of genital field, f) 1-segmented exopod of antenna is armed with 4 or 3 elements, g) distinct exopod and basoendopod of P5 are armed with not more than 5 setae, h) proximal endopodal segment of P2-P4 is much shorter than distal one. However, they are very different from one another. In the next section only the diagnostic characters of the species were described and figured.

Taxonomic account

Family Phyllognathopodidae Gurney, 1932

Genus *Phyllognathopus* Mrázek, 1893

Species *Phyllognathopus viguieri* (Maupas, 1892)

Material examined. 2 adults female and 1 adult male, completely dissected and mounted on a slide in glycerol; collected on 10 September 2013 and 11 January 2014 in Tor Kad brook.

Female: habitus fusiform; 10-segmented; P1 bearing somite not fused to cephalosome. Anal operculum convex; with 4-6 acute projections of hyaline frill along distal margin (Fig. 1A). Caudal rami as in Figure 1A. Posterolateral seta (III) normal developed; strong. Inner terminal seta (V) club-shaped; swollen at base (Fig. 1A). Armature of swimming legs shown in table below. Exopod of P5 fused to baseopod; with 4 elements.

(Roman numbers = spines; Arabic numbers = setae):

| Leg | Coxa | | Exopod | | | Endopod | | |
|-----|------|-------|--------|-----|---------|---------|---------|---------|
| | Coxa | Basis | 1 | 2 | 3 | 1 | 2 | 3 |
| P1 | 0-0 | I-I | I-0 | I-0 | I-I+1-1 | 0-0 | 0-1 | 0-2-1 |
| P2 | 0-0 | I-0 | I-0 | I-0 | II-2-0 | 0-0 | 0-1 | 0-I+2-0 |
| P3 | 0-0 | I-0 | I-0 | I-0 | II-2-0 | 0-0 | 0-0 | 0-I+2-0 |
| P4 | 0-0 | 1-0 | I-0 | 0-0 | 0-3-0 | 0-0 | 0-I+2-0 | - |

Male: feature and construction of caudal ramus similar to those of the female but inner terminal caudal seta (V) normal developed. exopod of P5 clearly discernable but incorporated to basis (fig. 1C). Left and right P6 fused together, forming a single ribbon plate (Fig. 1D).

Comparison. The Thai *Phyllognathopus viguieri* is morphologically different from the supplementary description of Galassi et al. (2011) and from the description of Chang and Yoon (2007) by having acute projections of hyaline frill on distal margin of anal operculum and normal developed posterolateral seta on caudal rami of the female. According to two mentioned references, distal margin of anal operculum is smooth and posterolateral seta on caudal ramus is transformed to a large and stout spiniform element. Variation of anal operculum was observed by Chang and Yoon (2007), who found several minute projections on distal margin. We would suggest that the character has also been observed in specimens from West Thailand (see Figure 44f-g, Boonyanusith, 2013), and the projections are longer in specimens from Sakaerat than those of the western Thailand and South Korea.

Family Canthocamptidae Braddy, 1880

Genus *Elaphoidella* Chappuis, 1928

Species *Elaphoidella bidens decorata* (Daday, 1901)

Material examined. 2 adults female, completely dissected and mounted on a slide in glycerol; collected on 11 January 2014 in a weir.

Female: body 9-segmented. Abdominal segments with broad, serrate hyaline frill; indentation coarse and sharp (Figs. 1E-F). Distal margin of third abdominal segment with a continuous row of spinules on lateral and ventral surface. Fourth abdominal segment with a continuous row of spinules on lateral and ventral surface; spinules of ventral row short smaller. Anal somite without spinule ornamen-

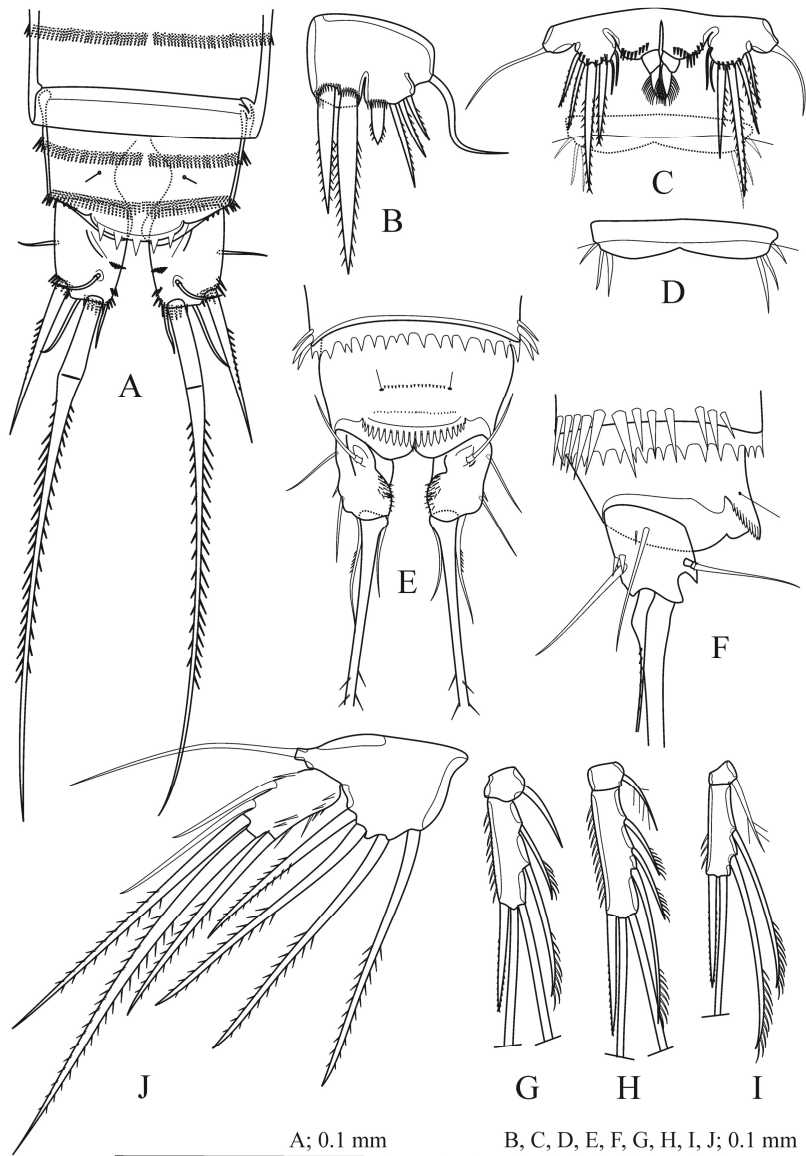


Figure 1 *Phyllognathopus viguieri*, female; A-B, male C-D. A; anal somite, dorsal, B-C; P5, D; P6, *Elaphoidella bidens decorata*, female; E; anal somite, dorsal, F; anal somite, lateral, G; endopod of P2, H; endopod of P6, I; endopod of P4, J; endopod of P5.

tation or with few minute ventral spinule near insertion of caudal rami. Anal operculum with comb-like hyaline frill on distal margin; hyaline frill characterized by about 19 oblong indentations. Caudal rami short, with dorsal keel and unguiform projection (Fig. 1F). Armature of swimming legs as showed in table below and Figure 1G-J.

(Roman numbers = spines; Arabic numbers = setae):

| Leg | Exopod | | Endopod | | | | | |
|-----|--------|-------|---------|-----|---------|-----|---------|-------|
| | Coxa | Basis | 1 | 2 | 3 | 1 | 2 | 3 |
| P1 | 0-0 | I-1 | I-0 | I-1 | I-I+1-1 | 0-1 | 0-1 | 0-2-1 |
| P2 | 0-0 | I-0 | I-0 | I-1 | II-2-1 | 0-0 | I-2-2 | - |
| P3 | 0-0 | I-0 | I-0 | I-1 | II-2-2 | 0-0 | I-2-3 | - |
| P4 | 0-0 | I-0 | I-0 | I-1 | II-2-2 | 0-0 | 0-I+1-2 | - |

Male: Not known

Comparison. Specimens from Sakaerat and Western Thailand differ from those of the description of the subspecies in the number of projections of anal operculum. In the original description and specimens from northern Thailand, *E. bidens decorata* has 10-14 spinules (i.e. hyaline projections) on distal margin of anal operculum (Wells, 2007). However, the specimens from Western Thailand have 18-38 spinules, and number of spinule of specimens from Sakaerat is in this range.

Species *Elaphoidella namnaoensis* Brancelj, Watiroyram & Sanoamuang, 2010

Material examined. 2 adults female, completely dissected and mounted on a slide in glycerol; collected on 11 January 2014 in Tham Jong Ang stream.

Female: similar to the description of Brancelj et al. (2010) (Figs. 2A-G).

Male: not known

Comparison. No remarkably variations were observed.

Species *Elaphoidella* sp.1

Material examined. 3 adults female, completely dissected and mounted on a slide in glycerol; collected on 10 September 2013 and 11 January 2014 in Tham Jong Ang stream.

Female: body 9-segmented. Abdominal segments with broad, weakly serrated hyaline frill; indentations shallow (Figs. 3A-C). Distal margin of third abdominal segment with a row of spinules on lateral and ventral surface. Fourth abdominal segment with a continuous row of spinules; spinules on ventral surface evenly reduced from lateral spinules to medial spinule (Fig. 3A). Anal somite with 2-4 spinules on lateral margin, with 1-2 ventral spinules at insertion of caudal rami.

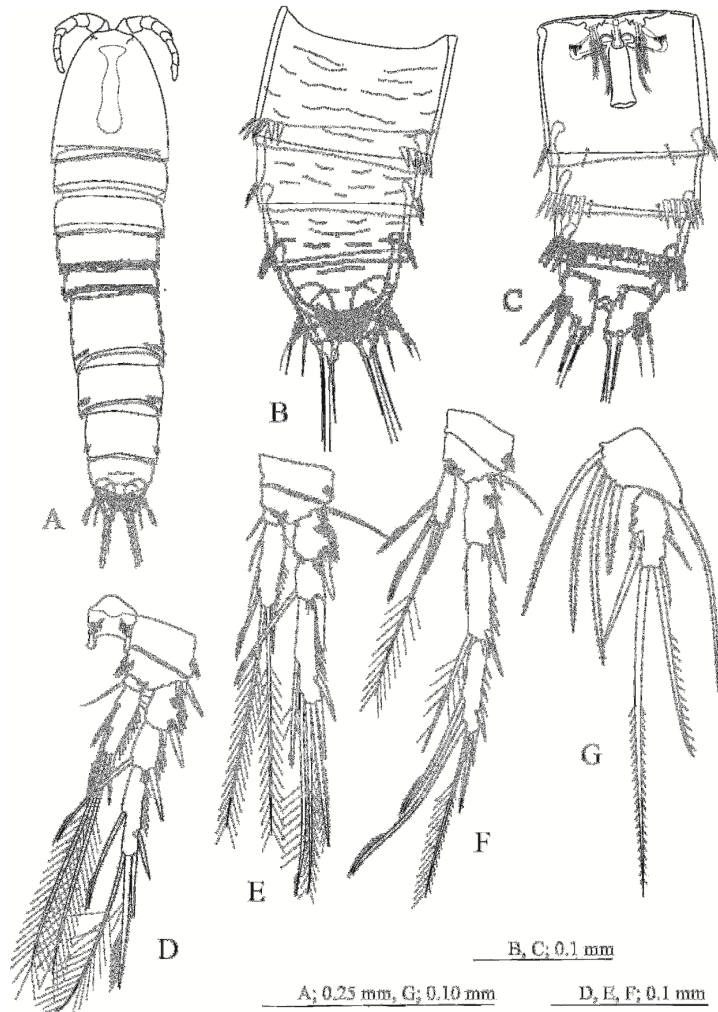


Figure 2 *Elaphoidella namnaoensis*, A-G. A; habitus, B; abdomen, dorsal, C; abdomen, ventral, D; P2, E; P3, F; P4, G; P5.

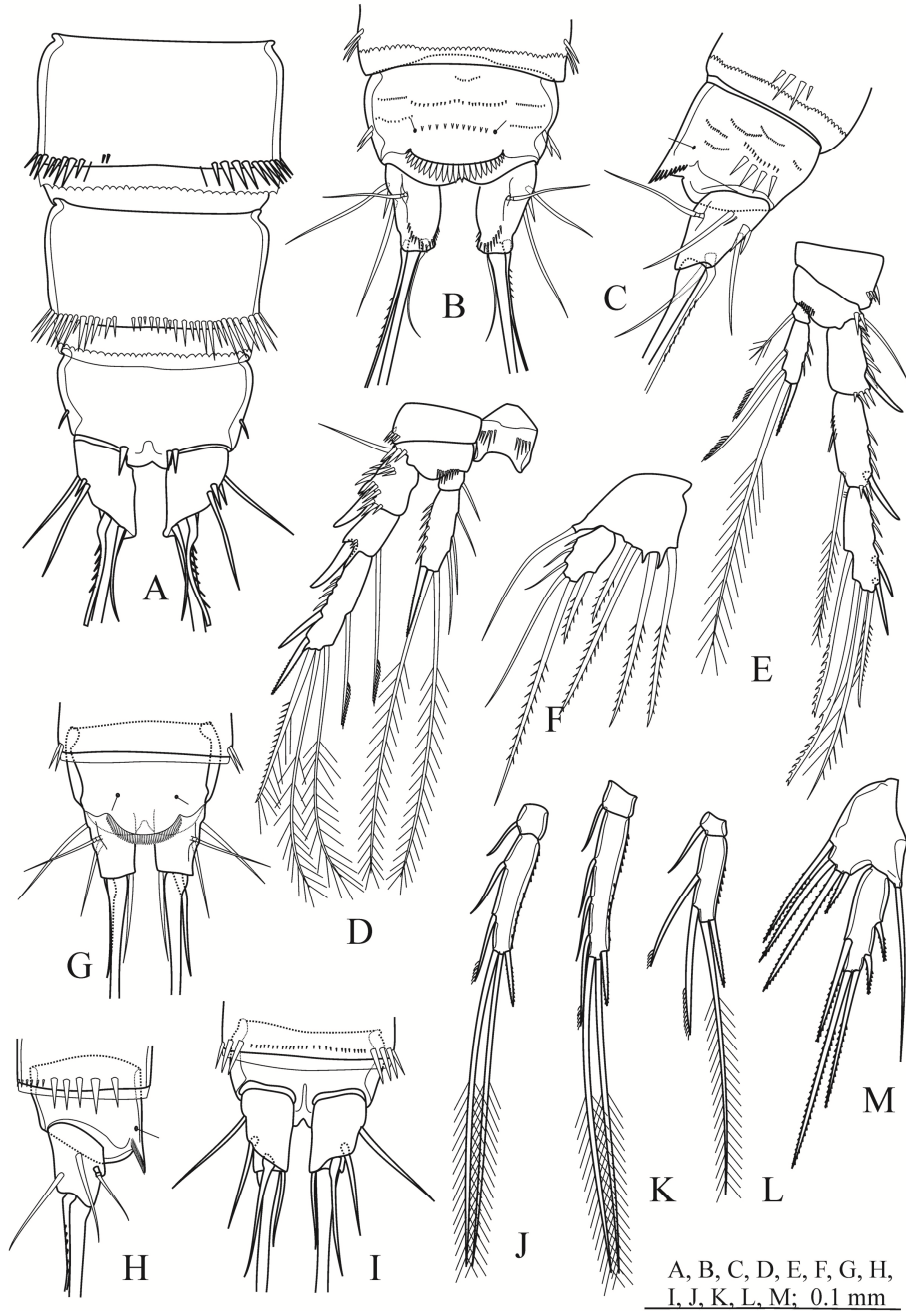


Figure 3 *Elaphoidella* sp.1, A; last three abdominal segments, ventral, B; anal somite, dorsal, C; anal somite, lateral, D; P3, E; P4, F; P5, *Elaphoidella* sp.2, G; anal somite, dorsal, H; anal somite, lateral, I; anal somite, ventral, J; endopod of P2, K; endopod of P3, L; endopod of P4, M; P5.

Anal operculum with comb-like hyaline frill on distal margin; hyaline frill characterized by 25-26 wedge-like indentations (Fig. 3B). Caudal rami with arch row of minute spinules on medial margin, with protrusion over the insertion of the terminal setae (Fig. 3B). Distal inner marginal seta on distal endopodal segment of P3 about 1.5 times as long as middle one. Armature of swimming legs as in table above (see *E. bidens decorata*).

Male: Not known

Comparison. *Elaphoidella* sp.1 is most similar to *E. intermedia* Chappuis, 1931 in having: a) serrated hyaline frill on abdominal segments, b) about 30 hyaline projections on distal margin of anal operculum, and c) seta on inner marginal seta on proximal endopodal segment of P2-P4. *Elaphoidella* sp.1 differs from *E. intermedia* by having: a) arch row of minute spinules on medial margin of caudal ramus, b) higher length ratio of distal inner terminal seta (seta III) and two other setae (seta I-II) of distal endopodal segment of P3 (1.5 vs 1), and c) thin smooth proximalmost outer marginal seta (seta I) of exopod of P5 (vs spinulose seta). *E. intermedia* was firstly described from a small spring and waterfall of Java (Chappuis, 1931), and subsequently encountered in a cave water reservoir in the mountain region in North Vietnam (Borutzky, 1967).

Species *Elaphoidella* sp.2

Material examined. 2 adults female, completely dissected and mounted on a slide in glycerol; collected on 11 January 2014 in Tor Kad brook.

Female: body 9-segmented. All abdominal segments with broad, smooth hyaline frill. Distal margin of third abdominal segment with lateral rows of spinules. Fourth abdominal segment with continuous row of spinules; spinules along ventral surface very small (Figs. 3H-I). Anal somite without spinule ornamentation. Anal operculum with comb-like hyaline frill on distal margin; hyaline frill characterized by about 50 oblong indentations (Fig. 3G). Caudal rami symmetrically conical, about 1.5 times as long as wide, without spinule ornamentation (Figs. 3G-I). Armature of swimming legs as in table above (see *E. bidens decorata*). Distal endopodal segment of P2-P4 and exopod of P5 remarkably elongate (Figs. 3J-M).

Male: not known

Comparison. Based on the key of Wells (2007), *Elaphoidella* sp.2 is most morphologically similar to *E. longipedis* Chappuis, 1931 in having: a) smooth hyaline frill on abdominal segments, and b) elongate exopodal segment of P5, but presence of two normal developed outer marginal setae (I-II) is different from short smooth setae in the description of Chappuis (1931) and Dussart (1982). Furthermore, according to Chappuis (1931), the length of distal exopodal segment of P2 and P3 is longer than that of the combination of two proximal segments. It is different from our specimens, which the length of distal exopodal segment of P2 and P3 is equal to the length of the combination. *E. longipedis* was described from Sumatra (Chappuis, 1931). It was subsequently encountered in Madagascar (Dussart, 1982).

DISCUSSION

This investigation was the first attempt to study diversity of the Harpacticoida in mountainous area of Northeast Thailand, and five harpacticoid species were encountered, belonging to the genera *Phyllognathopus* and *Elaphoidella*. These genera had previously been collected from subterranean water in other regions of Thailand (Boonyanusith *et al.*, 2013b; Brancelj *et al.*, 2013). Recently, the genus *Phyllognathopus* contains 9 species and subspecies, and *P. viguieri* is probably most widely distributed, frequently recorded from subterranean water habitats (see Galassi *et al.*, 2011). In Thailand, it was firstly recorded from the caves in karstic area of the western region (Boonyanusith, 2013; Boonyanusith *et al.*, 2013b), and might also be encountered from various types of water-body in mountainous area. However, it remains unclear for us that this species was not encountered from the caves of the northern region in the previous investigation (Watiroyram, 2012). We would suggest that more intensive sampling should be done there. *Elaphoidella* is the second largest copepod genus in the world, contains about 250 described species and subspecies (Pesce, 2014). Of this number, 17 species have been recorded in Southeast Asia, listed in Watiroyram (2012). In Thailand, *E. margaritae* is the first representative of the genus (Pesce and Apostolov, 1985). According to two collecting expeditions done in the northern and western mountain ranges of the country, several species were encountered (Table 1), and many species are expected to be new species (Watiroyram, 2012; Boonyanusith, 2013). *E. bidens decorata* was first recorded from caves of the northern region under the name of *E. intermedia*, and has subsequently been encountered from caves in the western region. Morphological comparison clearly showed the difference of caudal ramus among the two species (Boonyanusith, 2013). *E. namnaoensis* was first described from caves of the northern region, subsequently encountered in caves and surface freshwater habitats in the western region and in SERS. It is possible that this species is distributed throughout Thailand and neighboring countries. *Elaphoidella* sp.1 and *Elaphoidella* sp.2 are most morphologically similar to *E. intermedia* and *E. longipedis*, respectively. Unfortunately, due to the lack of male specimens of *Elaphoidella* sp.1 and the distinct configuration of exopod of fifth leg of *Elaphoidella* sp.2, hence we decided to retain them as unidentified *Elaphoidella* species, and wait for the adequate description and the revision of the genus.

Although samplings were intensively conducted in various surface water bodies, only two harpacticoid species have previously been recorded from lowland area (Cottarelli *et al.*, 2010; Pesca and Apostolov, 1985). The less interest on the benthic and subterranean copepods is probably a main factor of low diversity of the Harpacticoida in Thailand. Conversely, twenty different species of the Harpacticoida have been recorded from habitats located in mountainous area (Apostolov, 2007; Watiroyram, 2012; Boonyanusith *et al.*, 2013b). Moreover, low number of species in any one sampling locality is generally small relative to number of species in the region (personal observation). It might concern with a high degree of heterogeneity and ecological fragmentation of the habitat in mountainous area. To prove this assumption, the continuously sampling of copepod should be performed there.

Table 1 List of encountered harpacticoid species and valid species which have previously been recorded in Thailand. (alphabets A, B, C, D, E, F and G stand for Pesce and Apostolov (1985), Apostolov (2007), Brancelj *et al.*, (2010), Cottarelli *et al.*, (2010), Watiroyram (2012), Boonyanusith *et al.*, (2013b), and Brancelj *et al.*, 2013, respectively)

| Taxa | Distribution | This paper | References |
|--|---|---|------------|
| <i>Asiacaris dispar</i> Cottarelli, Bruno and Berera, 2010 | River bank, Pha-ngan island, Surat Thani | | D |
| <i>Atthyella vietnamica</i> Borutsky, 1967 | Cave, Phitsanulok | | E, G |
| <i>Bryocamptus cf.</i> <i>echinotus</i> | Caves, Lampang; Phetchabun | | E |
| <i>Elaphoidella</i> sp.1 | | Tham Jong Ang stream; Yi Pun pond; | |
| <i>Elaphoidella</i> sp.2 | | Tor Kad brook | |
| <i>E. bidens decorata</i> (Daday, 1901) | Caves; man-made pond; stream, Mae Hong Son; Lampang; Tak; Phetchabun; Phitsanulok; Kanchanaburi; Ratchaburi; Nakhon Ratchasima | Weir, Tham Jong Ang stream | F, G |
| <i>E. bromeliacola</i> (Chappuis, 1928) | Caves, Phetchabun; Kanchanaburi | | E, F |
| <i>E. margaritae</i> Pesce and Apostolov, 1985 | Well, Phuket | | A, G |
| <i>Epacthophanes richardi</i> Mrázek, 1894 | Caves, Chiang Mai; Lampang; Kanchanaburi; Ratchaburi | | E, F |
| <i>Onychocamptus</i> <i>muhammed</i> (Blanchard & Richard, 1891) | Cave, Phetchabun | | B, E |
| <i>Phyllognathopus viguieri</i> (Maupas, 1892) | Caves, Kanchanaburi; Ratchaburi | Tor Kad brook | F |

CONCLUSION

Previous investigations clearly showed a high diversity of copepod in Thailand. However, actual number of copepod fauna, especially Harpacticoida, in this country is underestimated. Previous investigations, as well as this study, showed a high diversity of Harpacticoida in mountainous area. So, intensively collecting sample is urgently needed there.

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REFERENCES

- Apostolov, A. (2007). Nortes sur les harpacticoides cavernicolus (Crustacea: Copepoda) de Vietnam du nord. *Historia Naturalis Bulgarica*, 18, 65-73.
- Boonyanusith, C. (2013). *Species diversity and distribution of copepods in caves in the western part of Thailand*. Doctor of Philosophy Thesis in Biology, Graduate School, Khon Kaen University.
- Boonyanusith, C., Brancelj, A. and Sanoamuang, L. (2013a). First representative of the genus *Fierscyclops* Karanovic, 2004 (Copepoda, Cyclopidae) from South East Asia. *Journal of Limnology*, 72(suppl.2), 275-289.
- Boonyanusith, C., Brancelj, A. and Sanoamuang, L. (2013b). Species diversity and distribution of cave-dwelling copepods in Kanchanaburi and Ratchaburi provinces. *The 14th Graduate Research Conference*, February 22, Khon Kaen, Thailand. [In Thai]
- Borutzky, E.V. (1967). Freshwater Copepoda Harpacticoida of north Vietnam. *Zoologicheskyy Zhurnal*, 46, 1015–1023. [In Russian]
- Brancelj, A., Watiroyram, S. and Sanoamuang, L. (2010). The first record of cave-dwelling Copepoda from Thailand and description of a new species: *Elaphoidella namnaoensis* n. sp. (Copepoda, Harpacticoida). *Crustaceana*, 83(7), 779–793.
- Brancelj, A., Boonyanusith, C., Watiroyram, S. and Sanoamuang, L. (2013). The groundwater-dwelling fauna of South East Asia. *Journal of Limnology*, 72(suppl.2), 327-344.
- Chang, C.Y. and Yoon, H.J. (2007). Freshwater harpacticoids of genera *Phyllognathopus* and *Harpacticella* from South Korea. *Korean Journal of Systematic Zoology*, 23(1), 57-68.
- Chappuis, P.A. (1931). Copepoda Harpacticoida der Deutschen Limnologischen Sunda-Expedition. *Archiv für Hydrobiologie*, 1(Suppl.8), 512–584.
- Cottarelli, V., Bruno, M.C. and Berera, R. (2010). First record of Parastenocarididae from Thailand and description of a new genus (Copepoda: Harpacticoida). *Journal of Crustacean Biology*, 30(3), 478–494.
- Dussart, B.H. (1982) Crustacés copépodes des eaux interieures. *Faune de Madagascar*, 58, 1–146.
- Galassi, D.M.P., De Laurentiis, P. and Fiasca, B. (2011). Systematics of the Phyllognathopodidae (Copepoda, Harpacticoida): re-examination of *Phyllognathopus viguieri* (Maupas, 1892) and *Parbatocamptus jochenmartensi*

- Dumont and Maas, 1988, proposal of a new genus for *Phyllognathopus bassoti* Rouch, 1972, and description of a new species of *Phyllognathopus*. *ZooKeys*, 104, 1-65.
- Pesce, G.L. (2014). *Elaphoidella* Chappuis, 1928, 27 January, <<http://www.luciopesce.net/copepods/arpa/elaph.htm>> (14 April 2014).
- Pesce, G.L. and Apostolov, A.M. (1985). *Elaphoidella margaritae* sp. n., a new phreatic harpacticoid from subterranean waters of Thailand (Crustacea, Copepoda, Canthocamptidae). *Acta Zoologica Bulgaria*, 28, 70–75.
- Watiroyam, S. (2012). *Species diversity and distribution of freshwater Copepoda in caves in Northern Thailand*. Doctor of Philosophy Thesis in Biology, Graduate School, Khon Kaen University.
- Watiroyam, S., Brancelj, A. and Sanoamuang, L. (2012). A new *Bryocyclops* Kiefer (Crustacea: Copepoda: Cyclopoida) from karstic caves in Thailand. *Raffles Bulletin of Zoology*, 60(1), 11-21.
- Wells, J.B.J. (2007). An annotated checklist and keys to the species of Copepoda Harpacticoida (Crustacea). *Zootaxa*, 1568, 1-872.