THE FIRST RECORD OF CAVE-DWELLING COPEPODA FROM THAILAND AND DESCRIPTION OF A NEW SPECIES: *ELAPHOIDELLA NAMNAOENSIS* N. SP. (COPEPODA, HARPACTICOIDA)

BY

ANTON BRANCELJ[1,3]), SANTI WATIROYRAM[2,4]) and LA-ORSRI SANOAMUANG[2,5])

[1]) National Institute of Biology, Večna pot 111, SI-1000 Ljubljana, Slovenia

[2]) Applied Taxonomic Research Center, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand

ABSTRACT

During a brief collecting expedition in Nam Nao National Park, Phetchabun province (northern Thailand) in November 2007, various water bodies connected with subterranean water were sampled. In five caves, eight samples were collected from pools and six species of Copepoda were collected. For the first time, a stygobiotic (= cave-dwelling) species of Copepoda was discovered in Thailand. It belongs to the order Harpacticoida and was recognized as a new species, *Elaphoidella namnaoensis* n. sp. Specimens were only collected from pools filled by percolating water. This indicates a specific ecology of the new species, linked to the unsaturated zone of karstic aquifers, where the hydrology is determined exclusively by rainfall.

A detailed description of the new species is presented here, supplemented with some information on its ecology and morphological adaptations. These adaptations are compared to those found in other *Elaphoidella* species from the unsaturated zone of karstic aquifers in Europe.

RÉSUMÉ

Au cours d'une brève mission de récolte au Parc National de Nam Nao, province de Phetchabun (nord de la Thaïlande) en novembre 2007, des collections d'eau variées en relation avec les eaux souterraines ont été échantillonnées. Dans cinq grottes, huit échantillons ont été récoltés dans des bassins et six espèces de copépodes ont été obtenues. Pour la première fois, une espèce stygobie (vivant dans les grottes) de copépodes a été découverte en Thaïlande. Elle appartient à l'ordre des Harpacticoida et a été reconnue comme une espèce nouvelle: *Elaphoidella namnaoensis* n. sp. Les spécimens ont été recueillis seulement dans les bassins remplis d'eau de percolation. Ceci indique une écologie particulière pour cette nouvelle espèce, liée à la zone insaturée de l'aquifère karstique, où l'hydrologie est déterminée exclusivement par les précipitations.

[3]) Corresponding author; e-mail: anton.brancelj@nib.si

[4]) e-mail: santikku@hotmail.com

[5]) e-mail: la-orsri@kku.ac.th

Also available online: www.brill.nl/cr

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Une description détaillée de la nouvelle espèce est présentée ici, complétée par des informations sur son écologie et ses adaptations morphologiques. Ces adaptations sont comparées à celles rencontrées chez d'autres *Elaphoidella* de la zone insaturée des aquifères karstiques d'Europe.

INTRODUCTION

Most freshwater cave-dwelling species (= stygobionts) of Copepoda are known from Europe, from both saturated and unsaturated zones of karstic aquifers. In the last decade, preliminary sampling campaigns revealed that a cave-dwelling copepod fauna is also present elsewhere (South America: A. Brancelj, pers. obs.; North America: A. Brancelj, pers. obs.; Pipan et al., 2006; Asia: this paper).

About 250 species and subspecies of the genus *Elaphoidella* (Copepoda, Harpacticoida) are known from different habitats world-wide (for a complete list, see Wells, 2007; and also: http://invertebrates.si.edu/copepod/species/species_Result.cfm; http://www.geocities.com/~mediaq/elaph.html). *Elaphoidella* spp. inhabit habitats from epigean to hypogean water bodies, from standing to running waters and semi-terrestrial habitats (Galassi, 2001; Reid, 2001; Mori & Brancelj, 2008). In caves they are common in unsaturated as well as in saturated zones. The unsaturated zone of karstic aquifers (epikarst included) in particular appears to be a groundwater habitat harbouring unique species, frequently endemic to one site only (Brancelj & Culver, 2005; Brancelj, 2006, 2009).

The unsaturated zone is a portion of the karstic aquifer, where "rainfall infiltrates through the soil into the underlying bedrock, where it moves vertically through the pore spaces in the rock, displacing the air that occupied the pores" (White, 2005). The epikarst is "the shallow, superficial part of karst areas in which climate, tree roots, and karst processes fracture and enlarge rock joints and cracks" (Bakalowicz, 2005). The saturated zone is a portion of karstic aquifer, where all pore spaces are water filled. The interface between unsaturated and saturated zones is called the water table (White, 2005).

From the tropical part of America (i.e., Cuba) there are, so far, records of 16 species of *Elaphoidella* from subterranean habitats, including the hyporheic environment (sampled by means of the Karaman-Chappuis method) and stagnant pools in cave galleries (sampled by hand nets). Fifteen of these were, by the time of their discovery, new to science, and were described by Petkovski (1973, 1980, 1982).

In tropical Asia, one of the few specialists on Copepoda before World War II was P. A. Chappuis, who described several species of *Elaphoidella* from Java, most of them from epigean habitats (Chappuis, 1928). Three years later, he described several additional species from Java, including the first subterranean *Elaphoidella* (*Elaphoidella intermedia* Chappuis, 1931) from a small spring and waterfall near

the village of Sarangan ("Mitteljava" = Middle Java) (Chappuis, 1931). After 1945, research expeditions aimed at copepod faunistic surveys in south-east Asia, including the genus *Elaphoidella*, were sporadic. The only known description of a new subterranean species in Asia dates back to 1967, when Borutzky (1967) described a new species, *E. vietnamica*, from a cave water reservoir in the mountain region Chin ne (Khoa Bin) in North Vietnam. In the same sample, he also found one adult female of *E. intermedia*. Twenty years later, in 1985, Pesce & Apostolov (1985) described a new species, *E. margaritae*, from subterranean waters of Thailand. It was collected from wells (i.e., porous aquifers) in Thailand, and is similar in ecology to cave-dwelling stygobitic species (i.e., inhabitants of karstic aquifers).

In 2007 a new sampling campaign to collect cave-dwelling animals in Thailand was started within the framework of the Thailand Research Fund special programme for the Royal Golden Jubilee Ph.D. Program. The first results of this research are presented here, and a new stygobiotic *Elaphoidella* species from a Thai cave is described.

MATERIAL AND METHODS

Location and sampling methods

During an expedition to Nam Nao National Park, Phetchabun province (northern Thailand) in November 2007, five caves were sampled in the unsaturated zone, where pools filled with water dripping from the ceiling formed the focus of our interest. Three types of water bodies were discerned. In a permanently dark section, pools on clay deposits in horizontal galleries were separated from pools on calcareous sinter (= flow-stone). At the entrance, in a semi-illuminated part of two caves, water was sampled from the "Buddha's pot", i.e., a bowl collecting dripping water and positioned near the Buddha statue at the entrance to a cave. Water from those small water-bodies (volume of up to 5 l) was collected and filtered by means of special sampling equipment (Brancelj & Culver, 2005).

Samples from individual pools were stored in plastic bottles immediately after sampling, and formaldehyde was added to a final concentration of about 4%. Animals were sorted under a stereomicroscope and stored in 70% alcohol. Before dissection, specimens were placed in a mixture of glycerol and 70% alcohol (ratio $\sim$1 : 10 v/v), which was replaced within one hour by pure glycerol. They were dissected at 100$\times$ magnification under an Olympus SZH-2 stereomicroscope. All appendages and body ornamentation were examined under a magnification of 1000$\times$. All drawings, except for the female habitus, were made at the same magnification (1000$\times$), with a drawing tube mounted on an Olympus compound

microscope (BHS 40). The final version of the drawings was made using the CorelDRAW® 12 graphic program. For permanent slides, all body parts were put in a drop of glycerol on a microscope slide, covered by a cover glass, and sealed with nail polish.

The following abbreviations are used throughout the text and figures: Endp, endopod; Exp, exopod; Exp/Endp-1, proximal segment; Exp/Endp-2, middle segment; Exp/Endp-3, distal segment; P1-P5, thoracic appendages. The nomenclature and descriptive terminology follow Huys & Boxshall (1991).

Type locality

Tham Yai Nam Nao cave is positioned in the Nam Nao National Park, about 200 km northwest of Khon Kaen (Thailand). It is about 10 km long, with horizontal galleries only. The entrance is under a high cliff, at an elevation of 684 m a.s.l. The coordinates of the entrance are: 16°63′19.0″N 101°51′57.9″E. In the entrance hall there is a Buddha statue and near it a small pot (volume of about 2 l) collecting water dripping from the ceiling. The pot is in a semi-illuminated place. Beyond the entrance is about 800 m long horizontal gallery, accessible without any special equipment except a battery lamp. At some places in the inner part of the cave there are pools, filled occasionally by a swollen river and partly by dripping water. The largest pool, filled mainly by dripping water, is about 100 m from the entrance where the ceiling of the gallery is only 1.5 m high. That pool is actually the type locality of *Elaphoidella namnaoensis* n. sp. During our visit (2 November 2007) the pool was 5 cm deep, 1 m wide, and 2 m long, with a water temperature of 19.4°C, pH of 8.8, and a conductivity of 741 μS cm^{-1}.

TAXONOMIC ACCOUNT

Order HARPACTICOIDA Sars, 1903

Family CANTHOCAMPTIDAE Sars, 1906

Genus *Elaphoidella* Chappuis, 1929

Elaphoidella namnaoensis n. sp. (figs. 1A–D, 2A–F, 3A–E)

Material examined. — Holotype: adult female, completely dissected and mounted on a slide in glycerol and sealed with nail polish; collected on 2 November 2007 in the cave Tam Yai (Nam Nao National Park, Thailand); deposited in The Natural History Museum (London), registration no.: NHM 2008.4623.

Paratypes: 21 ♀♀ without egg sacs and 6 ♀♀ with egg sac (stored in 70% alcohol) collected in the cave Tham Yai (Nam Nao National Park, Thailand) on 2 November 2007; 7 ♀♀ and 2 ♀♀ with egg sac deposited in The Natural History Museum (London), registration no.: NHM 2008.4624-4632; 7 ♀♀ and 2 ♀♀ with egg sacs deposited in the Science Museum of Khon Kaen University, Thailand;

registration nos.: KKU-COP-2007-001 through 2007-009. The remaining material (2 ♀♀ and 2 ♀♀ with egg sac) are deposited in the senior author's collection (AB).

Additional material: 1 ♀ collected from the Buddha pot at the entrance of the cave Tham Yai Nam Nao on 2 November 2007 (in the senior author's collection: AB).

Description. — Female, body length, measured from tip of rostrum to posterior margin of caudal rami, 623-682 μm (mean: 645 μm; n = 10); elongated, with cephalothorax wider than the rest of the body, colourless (fig. 1A). Naupliar eye not discernible. Rostrum small. Cephalothorax with two pairs of sensilla on distal half of somite and well developed integumental window (Nackenorgan, nucal organ) (fig. 1A). Close to base of antennule a spine-like sensillum, oriented forward. Posterior margins of thoracic and abdominal somites dorsally smooth. Genital double-somite with a row of 7-8 robust spinules on dorso-ventral side (fig. 1B–C). Posterior margin of genital double-somite with two pairs of sensilla dorsally, one pair ventrally, and additional pair of sensilla dorsally at the middle of the genital double-somite (fig. 1B–C). Genital complex (fig. 1C) with a single large copulatory pore, sclerotized, bell-shaped; seminal receptacles small and rigidly sclerotized. Fused plate with reduced sixth legs positioned well above seminal receptacles.

Ventro-distal margin of third abdominal somite with 5-6 strong spinules and fourth abdominal somite with 3-4 strong spinules laterally and a continuous row of small spinules ventrally. Both somites with four and two rows, respectively, of very small spinules dorsally (fig. 1B). Anal somite ventrally with one strong spinule at base of caudal ramus (fig. 1C); dorsally with two longitudinal rows of small spinules; anterior row slightly oblique and interrupted in the middle, distal one with stronger spinules just above the base of anal operculum, with small sensillum at each end (fig. 1B, D).

Anal operculum large, rounded, slightly overreaching distal end of anal somite, with some 20 well developed spinules along distal margin (fig. 1B, D).

Caudal rami asymetrically conical, with inner margin parallel, outer margin widely rounded; each about 1.5 times as long as wide, with weak dorsal keel (fig. 1A–D). Inner distal corner dorsally with a chitinous protrusion covering the insertion of the terminal setae (fig. 1D). Inner margin smooth. Anterolateral seta (II) inserted at about the middle of the caudal ramus; anterolateral accessory seta (I) short and thin. Posterolateral seta (III) as long as anterolateral (II) and slightly shorter than terminal accessory (VI) seta, ventrally with two spinules near its insertion. Terminal accessory (VI) seta as long as caudal ramus, strong and spiniform, pointed backward. Dorsal seta (VII) as long as caudal ramus, inserted laterally at about two-thirds of caudal ramus length. Outer terminal seta (IV) about three times as long as caudal ramus, with several strong spinules along outer margin; fracture plane not visible. Inner terminal seta (V) long, distal two-thirds with spinule row on both margins, with no discernible fracture plane.

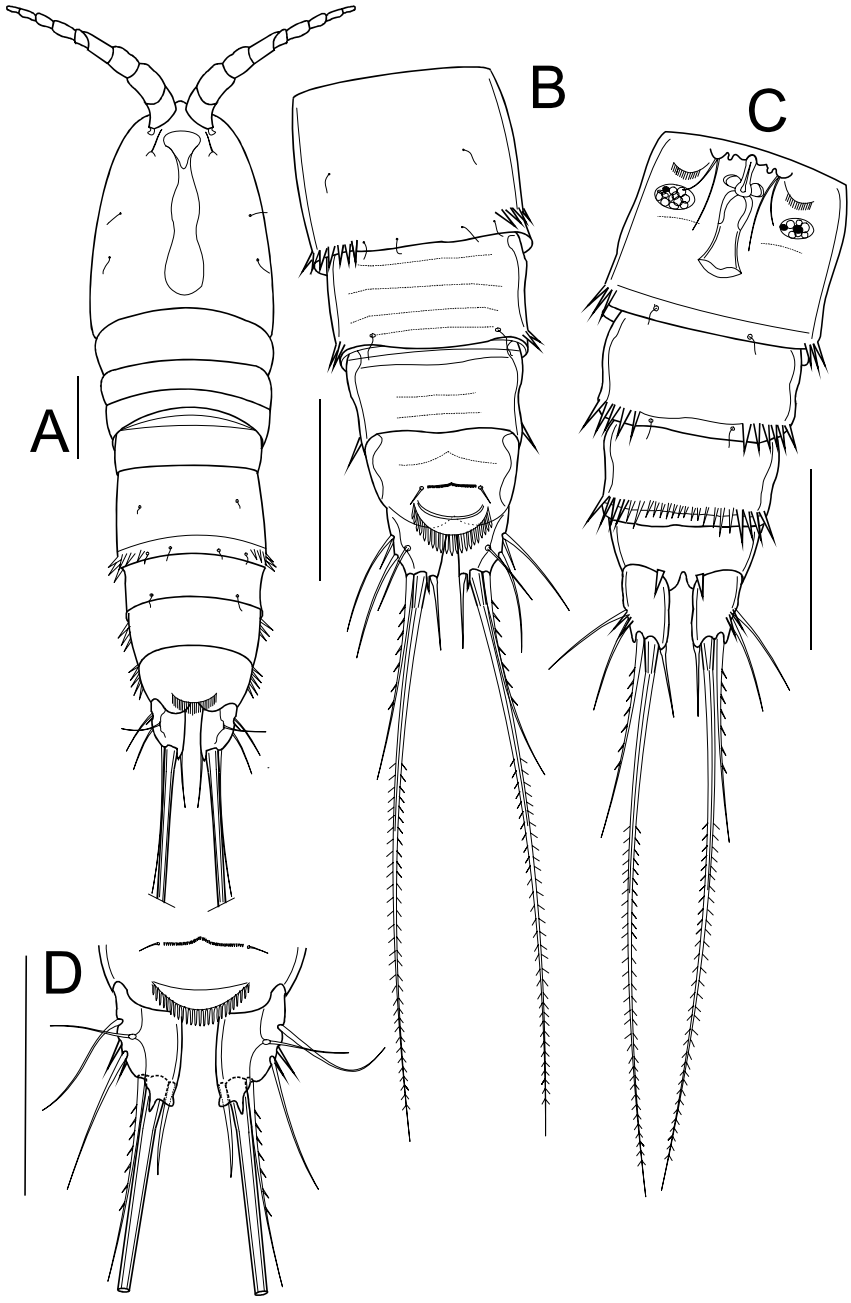

Fig. 1. *Elaphoidella namnaoensis* n. sp., female: A, habitus, dorsal view; B, genital double-somite, abdominal somites, and anal somite, dorsal view; C, genital double-somite, abdominal somites, and anal somite, ventral view; D, anal somite and caudal rami, dorsal view — details. Scale bars: A–D, 100 μm.

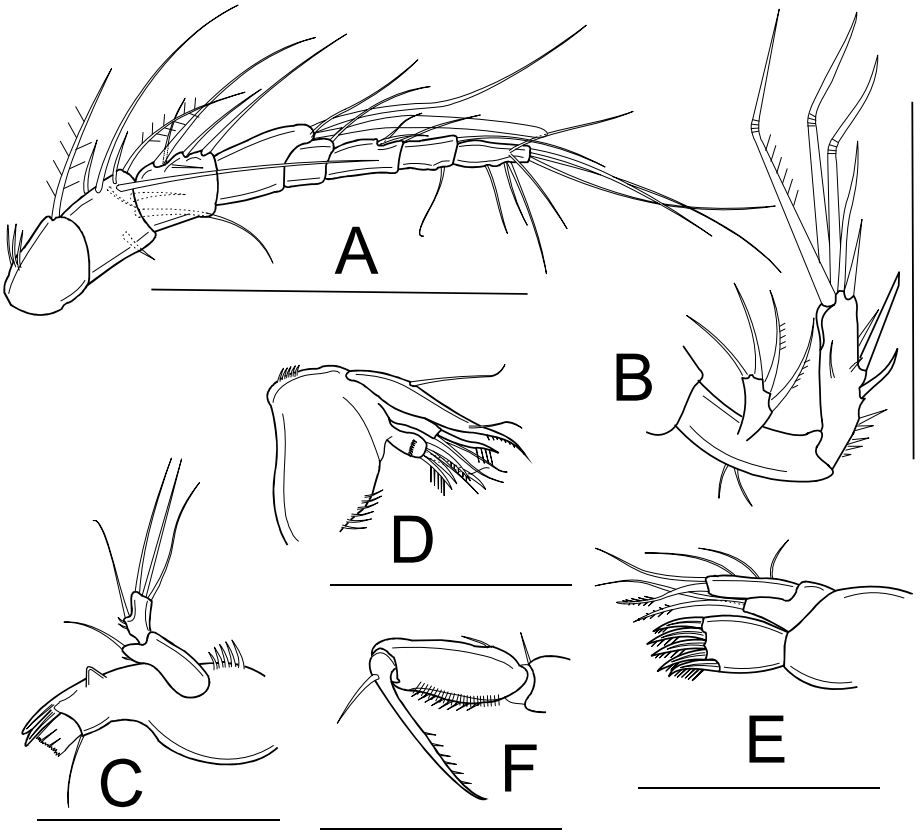

Fig. 2. *Elaphoidella namnaoensis* n. sp., female: A, antennule; B, antenna; C, mandible; D, maxillule; E, maxilla; F, maxilliped. Scale bars: A–B, 100 μm; C–F, 50 μm.

Antennule (fig. 2A) relatively long, eight-segmented. Aesthetasc on fourth segment cylindrical, slightly curved, with rounded tip and reaching past end of antennule. Second aesthetasc on terminal segment as long as first one; setal formula: 1.9.5.2.1.3.2.7. Three strong spinules on the first segment.

Antenna (fig. 2B) with allobasis, and robust; one-segmented Exp and Endp. Two strong spines on outer margin of Endp accompanied by several strong, shorter spinules of different lengths; terminal armature consisting of one short spine, one normal, and three geniculate setae. Exp with four spiniform setae, two of them ornamented with spinules on one margin.

Mandible (fig. 2C) short and robust, with three strongly chitinized teeth on gnathobase. One dorsal seta near gnathobase. Mandibular palp relatively long, two-segmented, with one seta on proximal segment (basis) and three setae, sub-equal in length, on distal segment (= endopod).

Maxillule (fig. 2D) with strong and robust spine on praecoxal arthrite. Coxa with strong, chitinized spines. Basis with one strong, beak-like outgrowth, with one long seta proximally and a shorter distally.

Maxilla (fig. 2E) two-segmented; syncoxa with 4 + 1 short and robust endites. Basis apically with strong spine and long seta. Endp reduced to three setae.

Maxilliped (fig. 2F) comprising syncoxa, basis, and one-segmented Endp. Syncoxa with one spinule distally. Basis twice as long as wide, with about 20 spinules positioned near palmar margin dorsally, equal in length. Ventrally an additional row of about 10 robust spinules. Endp drawn out into strong, acutely curved claw; slightly longer than basis and armed with several spinules in distal half; armature represented by a short seta.

P1 (fig. 3A) with three-segmented Exp and three-segmented Endp. Endp longer than Exp. Basis with strong and slender inner seta and stout outer basal spine. Exp-1 and Exp-2 with one strong outer spine. Exp-3 with one strong spine laterally, one spine and two long geniculate setae terminally; inner terminal seta as long as Exp. Endp-1 with long seta with brush-like tip at two-thirds length of inner margin. Endp-2 with long bristle at inner distal corner. Endp-3 with three setae; innermost soft, as long as outer, terminal seta long and geniculate, outer one spiniform, with spinules on outer margin.

P2 (fig. 3B) with spiniform outer seta on basis. Three-segmented Exp and two-segmented Endp. Endp as long as Exp-1 and Exp-2 combined. Exp-1 is 1.3 times as long as wide, with one strong, blunt spine at distal corner. Exp-2 with one strong outer spine with rounded tip and one long inner brush-like seta. Exp-3 is 5 times as long as wide, with two outer spines, two terminal setae, and one long, brush-like seta inserted midway along inner margin. Outer terminal seta soft, shorter than inner, inner one about 1.5 times as long as Exp-3. Endp-1 shorter than wide, with one spine on inner margin. Endp-2 is 2.5-times as long as wide, with two setae along inner margin, one soft and long subterminal seta, and one long, soft and one short, spiniform outer terminal setae.

P3 (fig. 3C) with outer basal seta long and thin. Exp similar to that of P2 but with additional seta on inner margin of terminal segment. Endp two-segmented; proximal segment shorter than wide, with relatively long and soft inner seta. Terminal segment with two apical setae; unequal in length; outer one strong, shorter than segment, and pinnate; terminal seta 3 times as long as distal segment of End, with long spinules on distal half; inner sub-apical seta similar to terminal seta; inner margin with three short setae.

P4 (fig. 3D) with outer basal seta long and thin. Three-segmented Exp and two-segmented Endp. Exp-1 and Exp-2 similar to those of P3 but with longer segments. Exp-3 is 4 times as long as wide, with two relatively weak spines on outer and two long, brush-like setae on inner margin. Two terminal setae: outer spiniform,

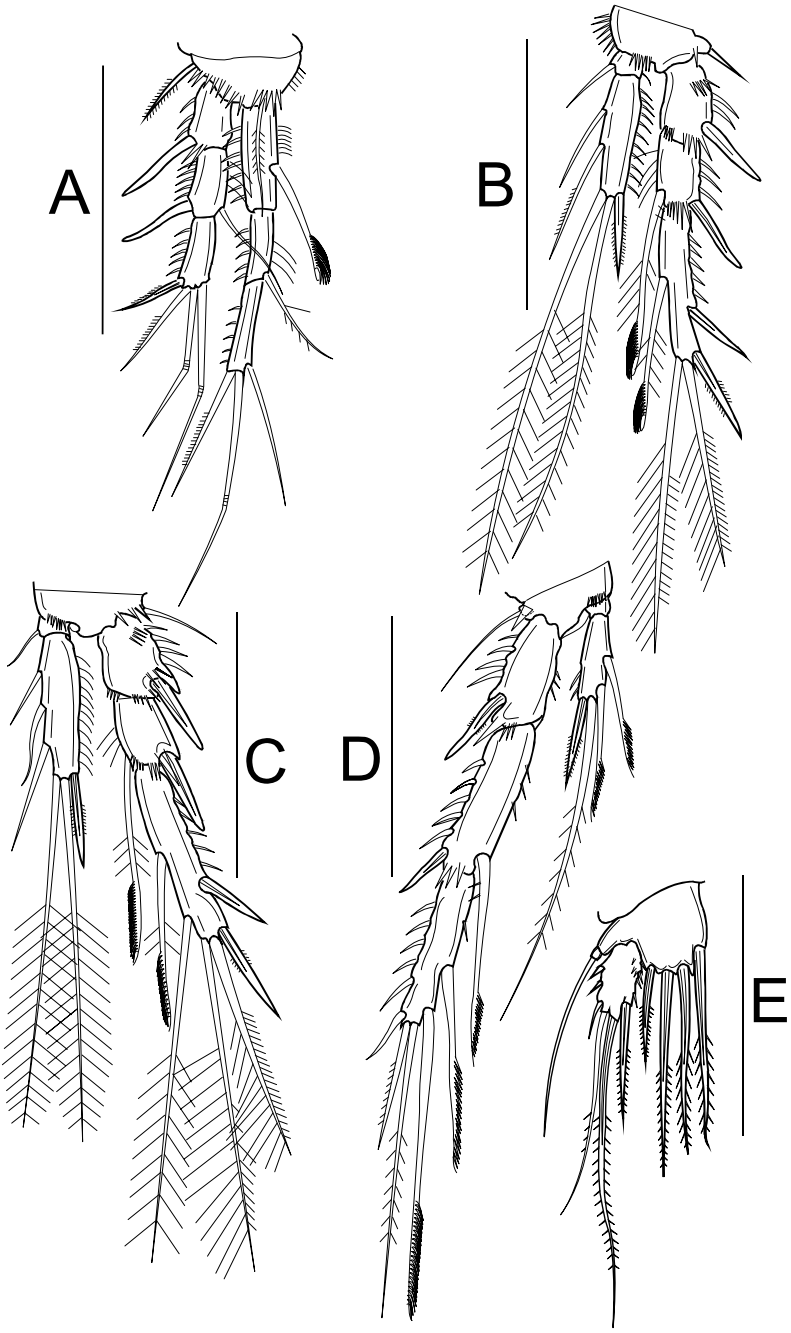

Fig. 3. *Elaphoidella namnaoensis* n. sp., female: A, P1; B, P2; C, P3; D, P4; E, P5. Scale bars: A–E, 100 μm.

shorter than terminal segment, with spinules along one margin; inner terminal seta 1.5 times as long as terminal segment, soft. Proximal segment of Endp very short, without inner seta. Endp-2 with one long, brush-like seta on inner margin and one subterminal, brush-like inner seta. Two terminal setae; inner one c. 3.5 times as long as terminal segment, outer one spiniform, as long as terminal segment.

Additional ornamentation of P1-P4 as in fig. 2C–G.

P5 (fig. 3E) with distinct Exp and baseoendopod; baseoendopod well developed, with four long, strong pinnate spines of unequal length; the innermost three of equal length, outer one half the length of the inner ones. Exp as long as baseoendopod, about 2 times as long as wide, with three apical setae of unequal length; innermost slightly longer than segment, robust; middle one about 5 times as long as segment; outer one about 4 times as long as segment. Outer margin with three additional short and robust spines. Outer lateral seta on baseoendopod long and bare.

P6 (fig. 1C) fused, small, forming simple plate; each armed with two thin, bare setae; outer seta about twice as long as inner one.

Egg sac: slightly longer than genital double-somite, oval, with 8-10 eggs.

Variability. — No variability was observed in females other than minor variation in number of spinules on abdominal somites.

Male not known.

Etymology. — The new species is named after Nam Nao National Park, the place where it was first found. The name is an adjective agreeing in gender with the (feminine) generic name.

RELATIONSHIPS

With two-segmented Endp-P1 and two-segmented Endp-P4, *E. namnaoensis* n. sp. clearly fits into the genus *Elaphoidella* Chappuis, 1929, s. str. The armature of P5 of the female (fig. 3E) puts the species into the IV (-*elaphoides*) group sensu Lang (1948).

The new species is clearly distinguished from the epigean taxa described from Java (i.e., *E. bromeliaecola* (Chappuis, 1928), *E. malayica* (Chappuis, 1928), and *E. javanensis* (Chappuis, 1928)) in many characters on P1-P5 and the shape of the caudal rami.

With elongated segments of the exopodites, especially Exp-3 of P2 and P3, the new species is clearly distinguished from *E. margaritae* Pesce & Apostolov, 1985, described from wells in southern Thailand. *E. margaritae* has shorter terminal segments of Exp P2-P4 compared to those in *E. namnaoensis* n. sp. Differences between both species are also in armature morphology of P5. On the

TABLE I
Differential characteristics among four *Elaphoidella* species from SW Asia

Character (females only)	*E. namnaoensis* n. sp.	*E. margaritae* Pesce & Apostolov, 1985	*E. vietnamica* Borutzky, 1967	*E. intermedia* Chappuis, 1931
Shape of furcal rami	Asymmetrically conical	Sub-conical	Sub-conical	Asymmetrically conical
Spinules on operculum	c. 20	13-16	18-20	c. 30
Spinules at the base of furcal ramus	1	3-5	3	?
Outgrowth on tip of furcal ramus	Yes	No	Yes	No
Inner spine on Endp-1 P4	Absent	Absent	Absent	Present
No. of seta/spines on Exp P5	3	2	4	5
Inner marginal seta on Endp-2 P4	Longer than Endp-2 P4	Very short	Very short	Longer than Endp-2 P4
Inner terminal seta on Endp-2 P2	3×	2×	2.2×	3×
Inner terminal seta on Endp-2 P3	2.2×	1.3×	1.2×	2×
Inner terminal seta on Endp-2 P4	3.5×	2×	2×	3.5×
Length of Exp P5 vs. tip of the baseoendopodite	Exceeding the tip	Exceeding the tip	Shorter than the tip	Exceeding the tip

Legends. — Endp, endopod; Exp, exopod; Endp-1, proximal segment; Endp-2, middle segment; P2-P5 thoracic appendages.

baseoendopodite, there is a relatively short outer spiniform seta in *E. margaritae* but this is long and pinnate in *E. namnaoensis* n. sp. The main difference is in the armature of Exp P5. In *E. margaritae* there are one long inner spiniform seta and one short outer spine, while in *E. namnaoensis* n. sp. there are one rather long inner pinnate seta and two long outer setae.

There are also clear differences with regard to *E. vietnamica* Borutzky, 1967 in the shape of the terminal segments of Exp P3 and P4, which are shorter than those of *E. namnaoensis* n. sp. Shape, and especially armature, of Endp P2-P4 in *E. namnaoensis* n. sp. differ clearly from those in *E. vietnamica* (see table I).

The new species closely resembles *E. intermedia* Chappuis, 1931 in shape and armature of Endp P2-P4, anal somite, and furcal rami, as well as in the shape of the anal operculum, but with a somewhat higher number of spinules on the operculum in the latter species (table I). Compared with the original description of *E. intermedia* given by Chappuis (1931), the new species differs in the more elongate terminal segments of Endp P2-P4 and the longer setae on their inner margins. The two species differ markedly in the presence of a discernible fracture plane in *E. intermedia* (see Borutzky, 1967, fig. 4), which is completely absent in the new species. There are also differences in shape and armature of Exp P5, which

is about twice as long as wide in *E. namnaoensis* n. sp. but less than 1.5 as long as wide in *E. intermedia*. In *E. intermedia*, there are two long setae and one very short spine on the outer margin of Exp P5, versus three additional short and robust spines in *E. namnaoensis* n. sp. (present also in *E. margaritae*, and not described in *E. vietnamica*).

The listed similarities/differences of the four known subterranean species from Asia (table I) reveal a close affinity between *E. namnaoensis* n. sp. and *E. intermedia*, while the remaining species differ in several characters. However, the most distinctive character between *E. namnaoensis* n. sp. and *E. intermedia* resides in the absence of the inner spine on Endp-1 P4 in *E. intermedia*. In addition, there are three short, spiniform setae present on the outer margin of Exp P5 in *E. namnaoensis* n. sp., which are absent in *E. intermedia*.

DISCUSSION

Ecology of tropical *Elaphoidella* species from groundwater

Four groundwater species of *Elaphoidella* from southern Asia were collected from two different types of aquifers. *E. margaritae* was collected from porous aquifers (= alluvium) and found so far only in Thailand (Pesce & Apostolov, 1985). The three other species are known from karstic aquifers (*E. vietnamica*, *E. intermedia*, *E. namnaoensis* n. sp.) and found in caves in Thailand (this paper), Vietnam (Borutzky, 1967), and Java (Chappuis, 1931). Little information on their ecology (actually: habitat) is available based on information derived from the original descriptions. In particular, *E. margaritae* was found in a well together with several other taxa, including *Mesocyclops leuckarti* (Claus, 1857), which is a typical inhabitant of epigean permanent water bodies. The most probable origin of that species is transport by contaminated water containers from one water body to another for water supply. In Vietnam, *E. vietnamica* was found in a cave water reservoir (Borutzky, 1967); the accompanying fauna was already known from epigean habitats of Sumatra and Java, or was even cosmopolitic, living in different habitats (*Epactophanes richardi* Mrazek, 1893 and *Phyllognathopus vigueri* (Maupas, 1892)).

Information on the possession of the eyes is absent for all three species of *Elaphoidella* mentioned above. This would have made our knowledge on their ecology (actually their degree of adaptation to groundwater habitats) more clear, as anophthalmy is one of the most recurrent characteristics of stygobionts (Camacho, 1992; Brancelj & Dumont, 2007). At the moment, the only species with confirmed absence of an eye is *E. namnaoensis* n. sp., which characterizes the species as a true stygobiont. The second indication that the new species is a stygobiont, is

deduced from the habitat where it was collected. Dripping water from a ceiling in caves appears to be an indication of a very specific habitat in epikarst, inhabited by a highly specialized stygobiotic fauna, with Harpacticoida being frequently the dominant group (for more details see Brancelj & Culver, 2005; Brancelj, 2006, 2009). The new species of *Elaphoidella* was collected in the same cave, in two pools filled by percolating water, and it is unlikely to hypothesize any direct transfer of water from one pool to another. This observation further supports the hypothesis that the new species is a true stygobiont, inhabiting the unsaturated zone of the karst.

Morphological adaptations of *Elaphoidella* from the unsaturated zone of karstic aquifers: tropics vs. temperate zone

The large number of species belonging to the genus *Elaphoidella* and to other genera (i.e., *Morariopsis*, *Paramorariopsis*), filtered from drippings in unsaturated karstic zones (epikarst including) in the temperate zone of Europe and especially in Slovenia, provides considerable information on the morphological adaptations of stygobiotic species to this peculiar habitat. They include, apart from eye reduction or absence, reduction in numbers of segments of swimming legs, and reduction in length of setae or their transformation into spine-like elements (for more information see: Brancelj, 2006, 2009). Short antennules and an elongated body are also characteristics shared by harpacticoids from unsaturated karst in the temperate zones. These morphological adaptations clearly differentiate strict epikarst inhabitants from species living in other types of groundwater habitats, where reduction in length of setae and antennules, reduction of segments of swimming legs, and adaptation of body shape are not always observable. Similar morphological adaptations may be found in some interstitial species living in unconsolidated sediment in porous aquifers, where the main constraint is represented by a reduced "vital space" (Galassi et al., 2009).

The new *Elaphoidella* from the cave in Thailand has no such adaptations, apart from the previously mentioned anophthalmy. The body shape is cylindrical, with the cephalosome distinctly wider than the rest of the body. The antennules are relatively long and oriented obliquely forward. The leg segments, especially the terminal segments of Exp and Endp P2-P4, are much more elongated than in many epigean taxa, both in tropical and temperate zones. Elongation of some body parts (legs, antennules) is known from many stygobionts living in the saturated zone of karstic aquifers (Camacho, 1992). Such extreme elongation is also known in two strict groundwater groups, inhabiting both karstic and porous aquifers: the genus *Parastenocaris* (Harpacticoida), and the order Bathynellacea (Syncarida). Compared with the body size of *Elaphoidella*, the taxa are slightly larger or of

the same size (Bathynellacea), or much smaller (*Parastenocaris*). Both taxa are occasionally found in dripping water in Slovenia (A. Brancelj, pers. obs.). This is an indication that, in some aquatic arthropods, reduction is not a compelling factor for living in a narrow space.

A unique morphological feature, the feather-like transformed setae, which might be a specialization for subterranean environments, can be observed on Exp P2-P3, Endp P1, and Exp- and Endp P4 in *E. namnaoensis* (fig. 3A–D). The feather-like formation is also illustrated in the figure of Endp P4 of *E. intermedia* (cf. Chappuis, 1931, fig. 68). The same feather-like formation could be observed also on End P4 in the female of *E. tarmani* Brancelj, 2009, and less developed in *E. millennii* Brancelj, 2009, both from epikarst in Slovenia (Brancelj, 2009). The feather-like formation has (probably) its origin in a seta with a unilateral row of spinules, which get flattened. It probably plays role in collecting food particles, like fine detritus or bacteria.

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