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Elaphoidella stygobiotica (Copepoda: Harpacticoida: Canthocamptidae), a new species of cave-dwelling copepod from western Thailand

Santi **Watiroyram**[1*] & Kamonwan **Koompoot**[2]

Abstract. A sampling campaign of cave-dwelling copepods between 2016 and 2022 in Thailand resulted in the discovery of a new *Elaphoidella* species found in the Lawa cave. The cave is located in the Tenasserim Hills within Kanchanaburi Province in the western part of Thailand. The new species has been found exclusively in that location and therefore appears to be endemic to the region. The new species has been assigned to group X proposed by Lang (1948) and can be distinguished from three other species within the group present in Southeast (SE) Asia, namely *E. elegans*, *E. cornuta*, and *E. javaensis*, based on several morphological characteristics. The most similar species within the genus is *E. elegans* from Java, Indonesia, but they differ in ornamentation of the urosomites and armature of the antennae and legs. The other SE Asian species within group X are also compared and differentiated.

Key words. taxonomy, freshwater copepod, Southeast Asia, tropical fauna, stygobionts, caves

INTRODUCTION

High species richness and endemism have long been observed in the northern mountains (Thanon Thongchai and Daen Lao ranges) and western mountains (Tenasserim Hills range) of Thailand, for instance, within dipterans, fishes, geckos, snails, and snakes (Kottelat, 1988; Nabhitabhata & Chan-ard, 2005; Ellis & Pauwels, 2012; Plant, 2014; Jarapatrasilp et al., 2022). The Tenasserim Hills range is included in two major zoogeographic regions of Southeast Asia (SE Asia): the Indo-Himalayan region in the north and the west and the Malaysian region in the south. Geologically, this region is characterised by limestone massifs with various distinct and specific karstic phenomena, such as cliffs, caves, sinkholes, and springs, which support expansive biodiversity and abundance (Sawangproth et al., 2020). The Kanchanaburi Province located in the Tenasserim Hills exhibits the highest abundance of caves, which are composed of Permian limestone strata dating to c. 286–245 million years ago (Sedwisai et al., 2012; Suwannapoom et al., 2018; Singtuen et al., 2021). Many obligatory or facultative cave inhabitants have been discovered in the Kanchanaburi Province, including molluscs, arthropods, amphibians, reptiles (geckos, lizards, snakes), and mammals (bats, porcupines) (Apiwathnasorn et al., 2011; Sawangproth et al., 2020).

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The Lawa cave is one of the oldest and largest touristic caves within Kanchanaburi Province and has historical, geological and biological importance for Thailand. At least 14 species belonging to six taxonomic groups have been reported within the cave: five species of Arachnida (*Fangensis spelaeus* [Schwendinger & Giribet, 2005]*; *Dhanus siamensis* [With, 1906]*; *Uthina luzonica* [Simon, 1893]; *Uthina ratchaburi* [Huber, 2011]; *Stygophrynus* (*Stygophrynus*) *cavernicola* [Thorell, 1889]*), one species of Chilopoda (*Thereuopoda longicornis* [Fabricius, 1793]), one species of Diplopoda (*Plusioglyphiulus jaydee* [Golovatch, Geoffroy, Mauries & Van den Spiegel, 2011]), one species of Collembola (*Troglopedetes dispersus* [Deharveng & Gers, 1993]), five species of Insecta (*Isoaedes cavaticus* [Reinart, 1979]; *Uranotaenia sumethi* [Peyton & Rattanarithikul, 1970]*; *Nemopalpus vietnamensis* [Quate, 1962]; *Sergentomyia quatei* [Lewis, 1978]; *Sergentomyia* (*Parrotomyia*) *brevicaulis* [Quate, 1962]), and one species of Mammalia (*Hipposideros lylei* [Thomas, 1913]) (* = endemic to type locality) (Schwendinger & Giribet, 2005; Apiwathnasorn et al., 2011; Golovatch et al., 2011; Ellis, 2018; Surakhamhaeng et al., 2021). However, all of these species are classified as terrestrial fauna, and not all of them are strictly cave-dwelling organisms (troglobionts). During the field trips that took place between 2016 and 2022 in the caves of the Tenasserim Hills, a new species of aquatic animal belonging to the class Copepoda was found in the Lawa cave and is presented in this study.

MATERIAL AND METHODS

Study area. The Lawa cave is located in Sai Yok National Park, Wang Krachae Subdistrict, Sai Yok District,

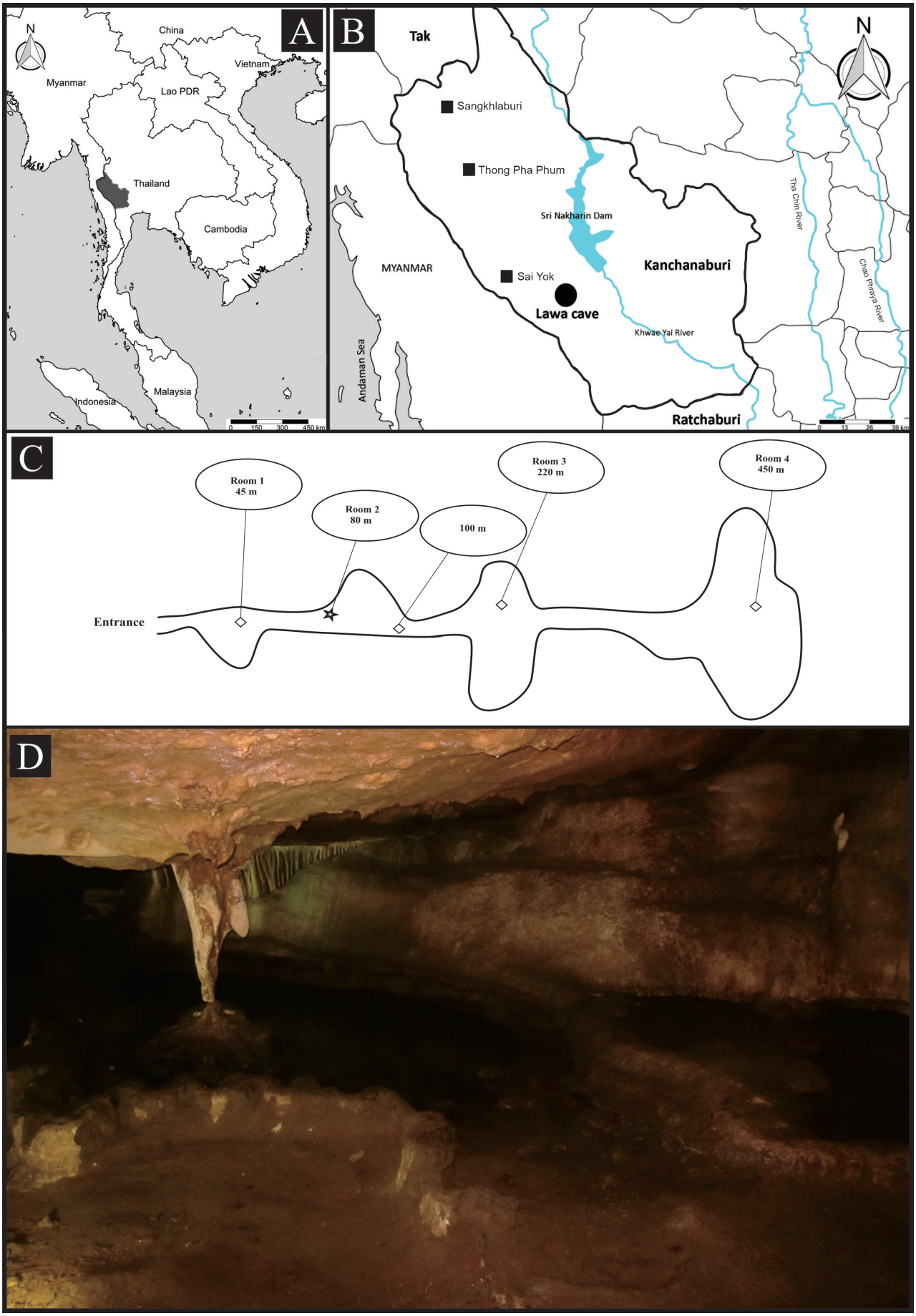

Fig. 1. Map of the sampling site of *Elaphoidella stygobiotica*, new species: A, location of Kanchanaburi Province; B, location of the Lawa cave [square (■) = capital city, circle (●) = cave location]; C, location of sampling sites inside the cave [diamond (◊) = pools of stagnant water, star (★) = sampling site]; D, photo of the sampling site.

Kanchanaburi Province. It is 530 m long, 17 m deep and located at an altitude of 120 m. The cave is divided into four consecutive chambers (typically called rooms) that are interconnected with narrow galleries. The four chambers contain five pools with dripping water located about 45, 80, 100, 220, and 450 metres from the cave entrance, respectively; however, only the pool 80 m from the entrance was sampled. Just above the sampling site, there is a large stalactite (resembling a crocodile perched on the ceiling) and below it are rimstone pools which are fully filled with water during the rainy season (Fig. 1).

Specimen sampling and study. The sample was collected using a hand net (mesh size of 60 µm) from the rimstone pool in room 2 (Fig. 1C, D) and fixed in 70% ethanol on-site. In the laboratory, only adult copepods were selected for examination and type deposition and preserved in 70% ethanol in a 1.5 mL microtube. Specimens were dissected under an Olympus SZ51 stereomicroscope in a mixture of glycerol and 70% ethanol (ratio ~ 1:10 v/v). Dissected specimens were mounted in pure glycerol on permanent slides sealed with transparent nail polish, and examined using an Olympus compound microscope (CX31) at 1,000× magnification. The pencil drawings were made using a drawing tube (Olympus U-Da) mounted on a compound microscope (Olympus CX31). The final drawings were made using the CORELDRAW® X7 graphic programme. Type specimens were deposited at the Thailand Natural History Museum in Pathum Thani, Thailand (THNHM) and at the Faculty of Science in Nakhon Phanom University, Thailand (NPU). Photos of specimens were taken using scanning electron microscopy (SEM) based on Watiroyram's (2018) protocol, specifically using the LEO 1450 VP microscope.

The morphological terminology adheres to that proposed by Huys & Boxshall (1991). The following abbreviations are used throughout the text and figures: A = aesthetasc; Enp = endopod; Exp = exopod; Exp-n or Enp-n = exopodal segment n or endopodal segment n; P1–P6 = swimming legs 1–6.

TAXONOMY

Order Harpacticoida Sars, 1903

Family Canthocamptidae Brady, 1880

Genus *Elaphoidella* Chappuis, 1929

Elaphoidella stygobiotica, new species
(Figs. 2–8)

Material examined. Holotype: adult female dissected and mounted on one slide (THNHM-IV-20187); coll. S. Watiroyram, 10 October 2017. Allotype: adult male dissected and mounted on one slide (THNHM-IV-20188); locality, date and collector the same as for holotype. Paratypes: three un-dissected adult females stored in 70% ethanol (NPU 2023-001); locality, date and collector the same as for holotype.

Type locality. The Lawa Cave, 14°17′57.6″N, 98°58′55.7″E, elevation 120 m a.s.l., Wang Krachae Subdistrict, Sai Yok District, Kanchanaburi Province, Thailand. A pool approximately 3 metres in diameter and containing 20 litres of water was located in room 2 in a completely dark zone and filled with drip water only.

Etymology. The specific name *stygobiotica* is derived from the term 'stygobiont' meaning "aquatic obligate in subterranean groundwaters and cave streams", which itself is derived from the Ancient Greek words 'stygios' (of the River Styx) and 'bios' (mode of life), and refers to the new species being a cave-dweller.

Distribution. The species is known only from the type locality.

Description of adult female (holotype). The total body length, measured from the anterior margin of the rostrum to the posterior margin of the caudal rami, is 390 µm. The habitus (Fig. 2A) is elongated and cylindrical, and the prosome is slightly wider than the urosome. The preserved specimens are colourless. A naupliar eye is not discernible. The rostrum is small. Cephalothorax dorsally with very finely serrated posterior margin, with numerous pairs of sensilla organised symmetrically; the dorsal integumental window is long and narrow. Thoracic somites 1–4 and urosomites with several rows that are unequal in length in terms of the small transversal spinules on the dorsal, lateral, and ventral side; several pairs of sensilla present on the somites' surface; the anal somite has only one pair of dorsal sensilla; thoracic somites 1–4 have finely serrated free margins dorsally and laterally; there are urosomites with more pronounced serrated free margins along the entire perimeter (Fig. 2A–C). The genital double-somite is about 0.8 times longer than it is wide (Fig. 2C). The genital complex has a single large median copulatory pore and a bell-shaped copulatory duct; the seminal receptacles are symmetrical and well-developed (Fig. 2C). Urosomites 3 and 4 ventrally with a row of small spinules located proximally; the more robust spinules are unequal in length and situated in a discontinuous row on the distal margin of the segments. An anal somite with three robust spinules is situated ventrally at the base of each caudal ramus; a row of fine spinules is situated ventrally, and three robust spinules are positioned laterally (Fig. 2B, C). The anal operculum is broadly rounded, reaching the posterior end of the anal somite, with about 30 thin, long spinules within the free margin; a sensillum is situated on each side of the anal operculum base (Fig. 2D).

Caudal ramus (Fig. 2A–D) is conical, slightly divergent and about 1.3 times as long as it is wide; the dorsal keel is well developed. Each ramus has six setae; all setae except for the inner terminal seta (V) are bare (Figs. 2C, 3A). The anterolateral accessory seta (I) is inserted laterally at one third of the length of the ramus, with a spinule near its insertion. The anterolateral seta (II) is inserted laterally at about half the length of the ramus, which is as long as the caudal ramus, with two spinules near its base. The posterolateral seta (III)

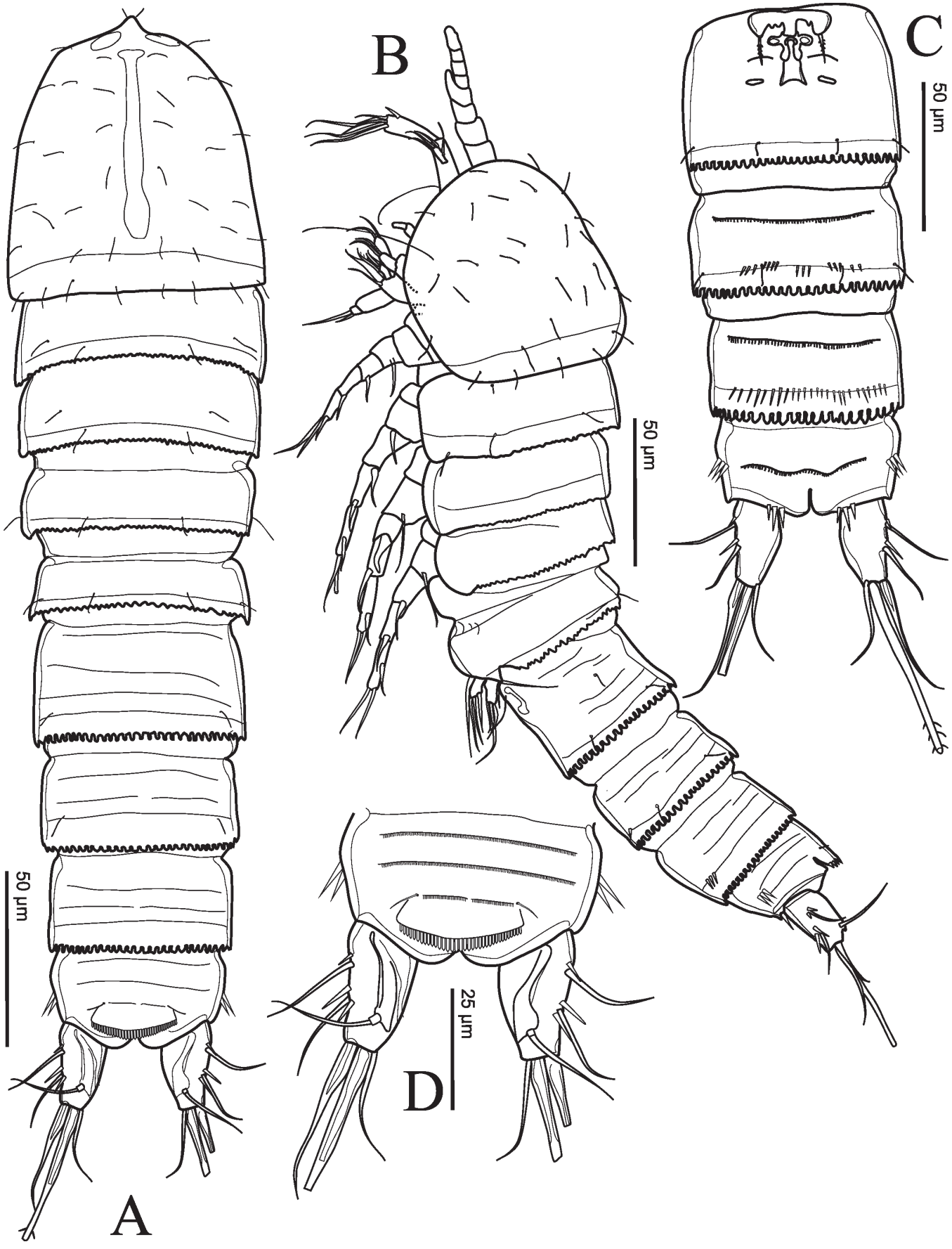

Fig. 2. *Elaphoidella stygobiotica*, new species, female (holotype): A, habitus, dorsal view; B, habitus, lateral view; C, urosome (without urosomite 1), ventral view; D, anal somite and caudal rami, dorsal view.

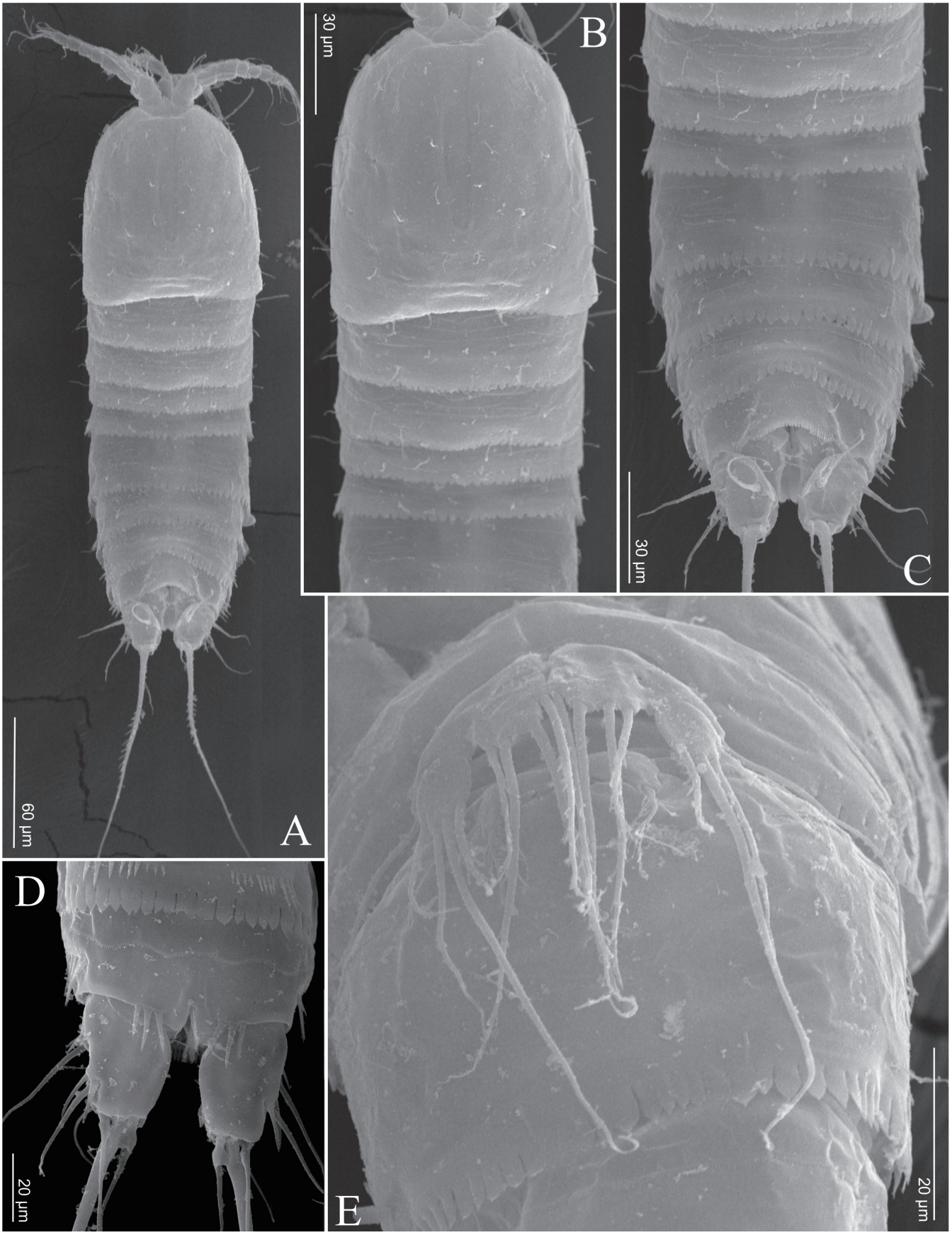

Fig. 3. *Elaphoidella stygobiotica*, new species, SEM photo of female: A, habitus, dorsal view; B, prosome and urosomite 1, dorsal view; C, prosomite 2–4 and urosome, dorsal view; D, anal somite and caudal rami, ventral view; E, urosomite 1 with P5 and urosomite 2 with P6, ventral view.

is absent. The outer terminal seta (IV) is about twice as long as the caudal ramus, without a breaking plane. The inner terminal seta (V) is the longest, is pinnate and about two-thirds of the length of a body, and has no visible breaking plane. The inner accessory seta (VI) is as long as the caudal ramus. The dorsal seta (VII) is articulated, as long as seta I, and inserted on the dorsal keel distally, at about two-thirds of the caudal ramus length.

Antennule (Figs. 3A, 4A) is short, not reaching the posterior margin of the cephalothorax, which has eight segments. Segment 1 has an oblique row of small spinules. The aesthetasc on segment 4 is cylindrical, with a rounded tip, overreaching the distal segment. The second aesthetasc on segment 8 is similar in shape to the former one but is shorter and thinner. Each aesthetasc is fused with a seta at its base, forming an acrothek. The setal formula is as follows: 1, 8, 5, 1+(1+A), 1, 2, 2, 6+(1+A).

Antenna (Fig. 4B) is comprised of the coxa, basis, and one-segmented Exp and Enp. The coxa is shorter than it is wide, and it is unarmed. The basis has three robust spines on the inner margin. Exp has two pinnate setae apically and one pinnate seta laterally. Enp has two robust spines and several spinules on the inner margin; one robust spine, one normal seta, and three bare geniculate setae apically; and a row of tiny spinules subapically.

Mandible (Fig. 4C) has eight strongly chitinised teeth and short dorsal setae on the gnathobase. It has a two-segmented palp; segment 1 is unarmed; segment 2 has one seta laterally, three smooth setae apically, two apical setae that are equal in length and a longer one that is twice as long as the shorter ones.

Maxillule (Fig. 4D) has four unipinnate spines and one smooth spine on the precoxal arthrite. The coxal endite has one pinnate and one bare seta. The basis has one pinnate and two bare setae apically. Exp and Enp are fused to the basis and are represented by one bare seta each.

Maxilla (Fig. 4E) has two syncoxal endites; the proximal endite has one unipinnate and two bare setae; distal endite has one unipinnate and one bare seta. The allobasis is produced into a robust, curved claw with robust spinules along one side. Enp is reduced into two bare setae.

Maxilliped (Fig. 4F) has unornamented syncoxa. The basis is about 2.5 times as long as it is wide, with three rows of spinules on the dorsal, ventral, and posterodistal surfaces; there is a small spinule at the dorsal margin. Enp is as long as the basis and is drawn out into a robust claw with a small proximal seta.

P1–P4 with three-segmented Exp, two-segmented Enp. Armature formula of legs 1–4 provided in Table 1.

P1 (Fig. 5A) intercoxal sclerite is bare. The coxa has few robust spinules anteriorly. The basis has one unipinnate spine on the lateral margin and one slender seta inserted distally on the posterior surface along with a row of spinules. Exp is about as long as Enp. Exp-1 and Exp-2 are about twice as long as wide, and each segment has several spinules laterally. Exp 1–3 have one outer robust unipinnate spine each. Exp-3 has an inner subapical geniculate seta, an apical geniculate seta, a normal unipinnate seta, and a robust outer unipinnate spine. Enp-1 is dilated laterally and is about 1.3 times longer than Enp-2, reaching the tip of Exp-1 and Exp-2's length combined; there is a robust inner seta, with robust spinules on the outer margins. Enp-2 has two apical setae; the inner seta is geniculate, and the outer one is normal and unipinnate.

P2 (Fig. 5B) intercoxal sclerite is bare. The coxa has few robust spinules near the outer distal margin. The basis has a robust bipinnate spine on outer margin and few robust spinules near the insertion of the spine on the anterior surface. Exp 1–3 have several robust spinules laterally. Exp-1 and Exp-2 are similar in length, and Exp-3 is the longest. Exp-1 and Exp-2 each have an outer robust spine. Exp-2 has an additional inner feather-like seta. Exp-3 is about three times as long as it is wide, with six elements: one feather-like seta at one half of the length of the inner margin; thin inner and bipinnate outer seta apically; and two robust unipinnate spines on the outer margin. Enp-1 is small, short and unarmed. Enp-2 has one seta and spine apically; an outer bipinnate seta that is shorter than the inner spiniform spine; and a spinule on the outer margin.

P3 (Fig. 5C) intercoxal sclerite and coxa are similar to those in P2. The basis has a long bare outer seta and a robust spinule near its base. Exp-1 is as long as Exp-2, each with a robust outer spine accompanied by spinules on the outer margin. Exp-2 has an additional short bare seta at the inner margin.

Table 1. Armature formula of legs 1–4 (inner-outer seta/spine; inner-apical-outer seta/spine). Arabic numerals represent setae, Roman numerals represent spines.

Leg	Coxa	Basis	Exp			Enp	
			1	2	3	1	2
1	0-0	1-I	0-I	0-I	1-2-I	I-0	0-2-0
2	0-0	0-I	0-I	1-I	1-2-II	0-0	0-1+I-I
3	0-0	0-1	0-I	1-I	2-2+I-I	0-0	2-1+I-1
4	0-0	0-1	0-I	1-I	2-2-II	0-0	1-1+I-0

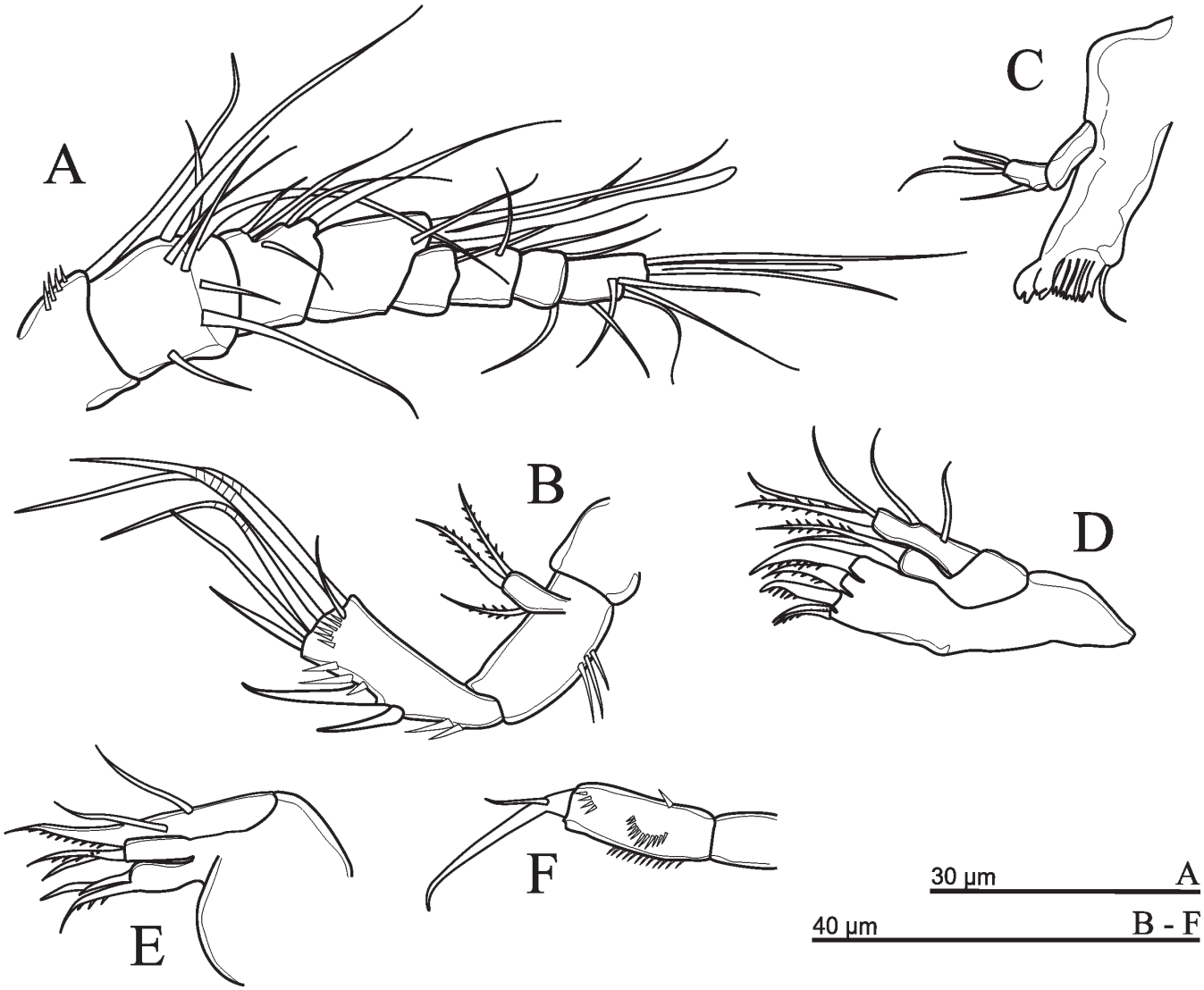

Fig. 4. *Elaphoidella stygobiotica*, new species, female (holotype): A, antennule; B, antenna; C, mandible; D, maxillule; E, maxilla; F, maxilliped.

Exp-3 is about three times as long as it is wide, with five elements: two inner feather-like setae, one thin inner seta and one bipinnate seta apically; two robust spines on the outer margin, the distal one is unipinnate and the proximal one that is bare. All three Exp segments have spinules on the outer margin. Enp-1 is shorter than it is wide and is unarmed. Enp-2 has two short spiniform setae on the inner margin; one bipinnate seta and one bipinnate spine apically; the seta that is about 0.5 times longer than the spine; and a spinule on the outer margin.

P4 (Fig. 5D) intercoxal sclerite, coxa and basis are similar to those in P3. Exp-1 and Exp-2 each have a robust unipinnate spine on the outer margin; Exp-2 has a bare seta on the inner margin; both segments have spinules on the outer margin. Exp-3 is about 2.5 times as long as it is wide, with six elements: bare and feather-like setae on the inner margin; two bipinnate setae that are unequal in length apically; two robust spines on the outer margin, including a unipennate distal one and a bipinnate proximal one. Enp-1 is shorter than it is wide and is unarmed. Enp-2 has a relatively long feather-like seta on the inner margin; a bipinnate seta and a bipinnate spine apically; and a seta as long as the spine.

P5 (Figs. 3E, 5E) baseoendopod and Exp are separated. The baseoendopod is well-developed, reaching one half of the Exp's length, with four long bipinnate setae, one on the outer margin, two apically, and one on the inner margin; the three innermost setae that are subequal in length are the longest, and the outermost seta is the shortest. Exp is small, sub-oval and about 1.5 times as long as it is wide, with the following four elements: one on the outer margin, two apically, and one on the inner margin; a bipinnate innermost seta, with the other setae bare; two apical setae that are the longest and equal in length and an outermost seta that is the shortest. The baseoendopod has a long bare seta on the outer margin.

P6 (Fig. 2C) is reduced to a small plate on each side of the copulatory pore, and each plate has a short bipinnate seta.

An egg sac was not observed.

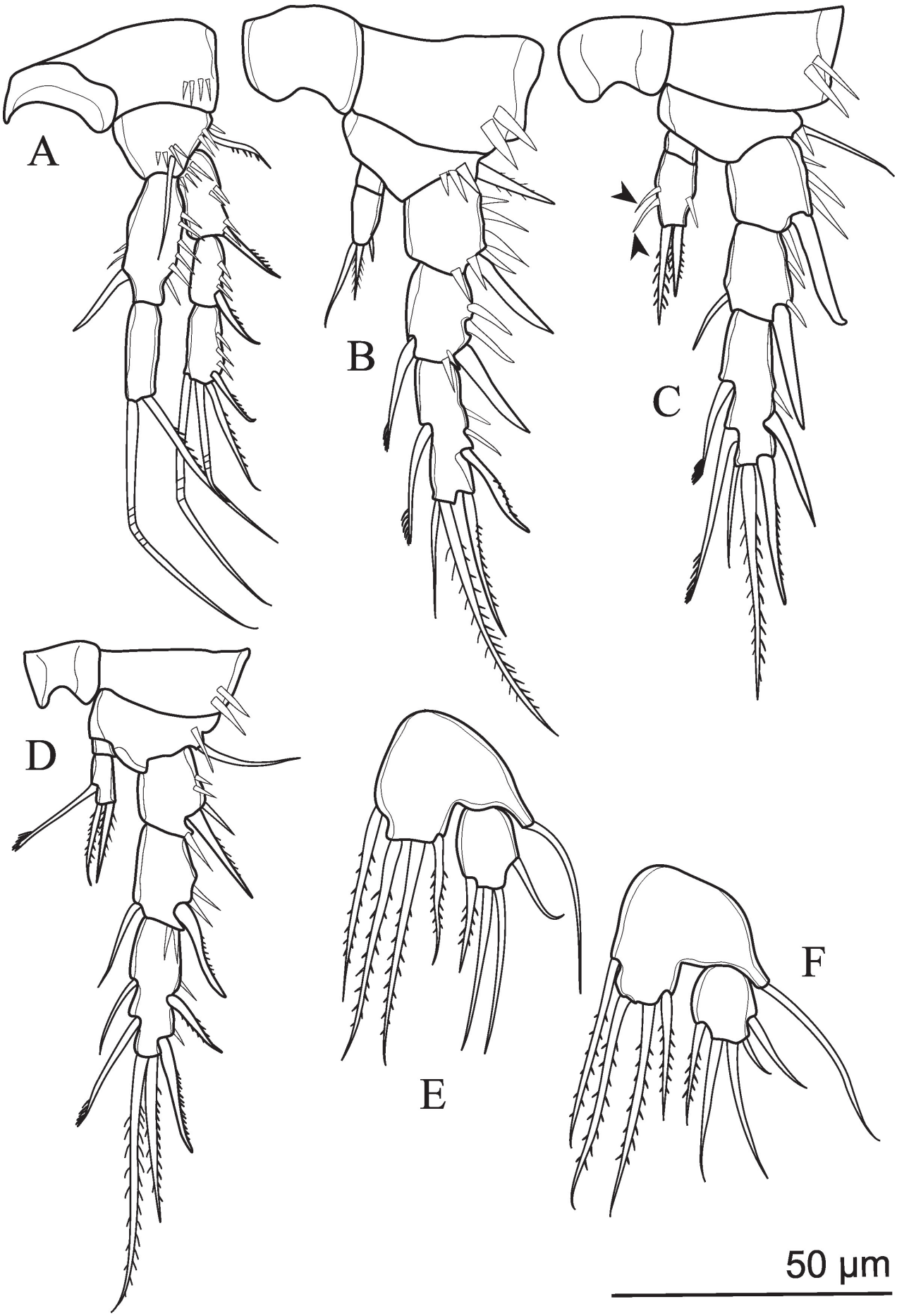

Fig. 5. *Elaphoidella stygobiotica*, new species, female (holotype): A, P1; B, P2; C, P3 (black arrows indicate inner setae); D, P4; E, P5; F, P5 variation.

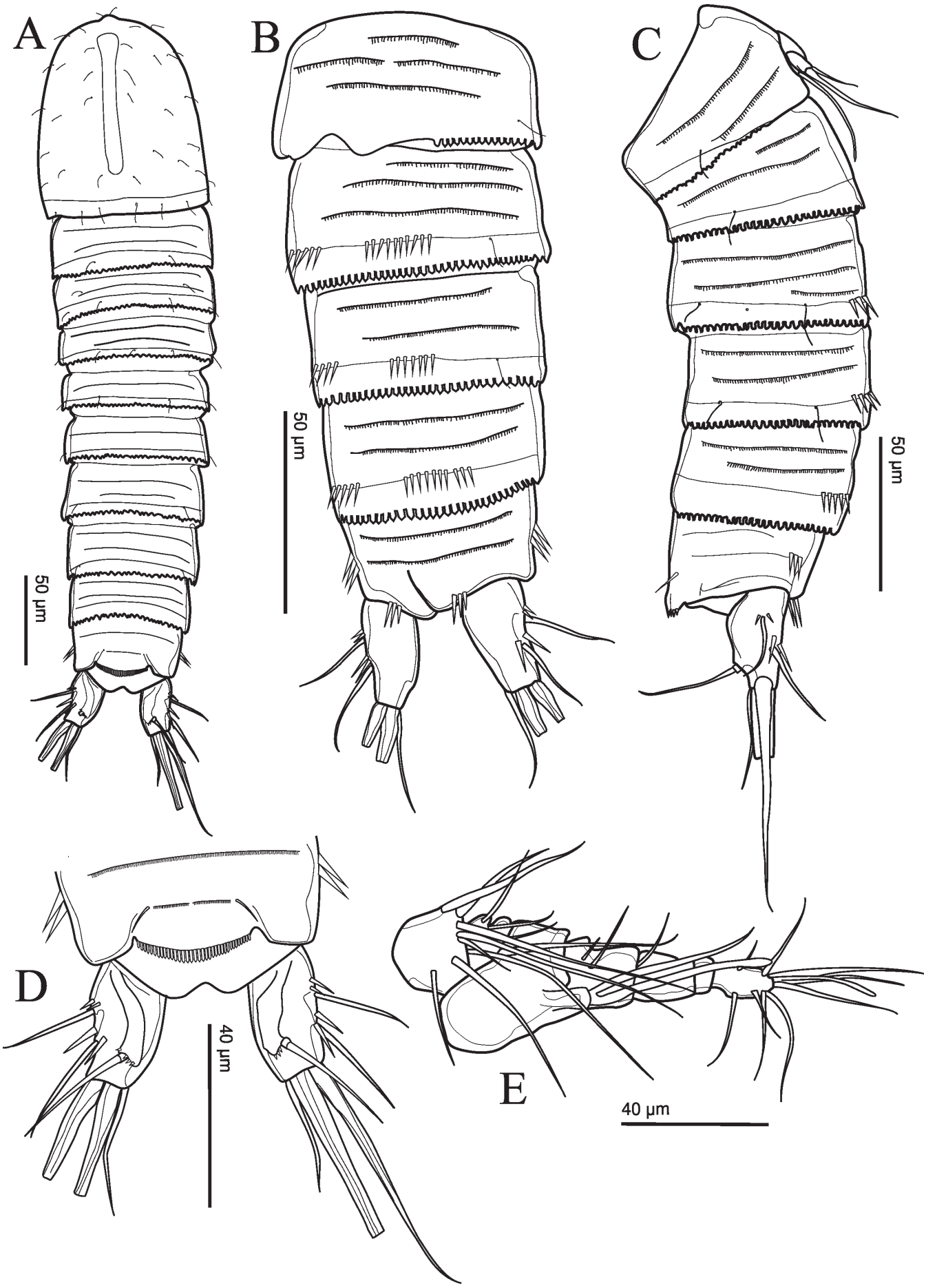

Fig. 6. *Elaphoidella stygobiotica*, new species, male (allotype): A, habitus, dorsal view; B, urosome, ventral view; C, urosome, lateral view; D, anal somite and caudal rami, dorsal view; E, antennule.

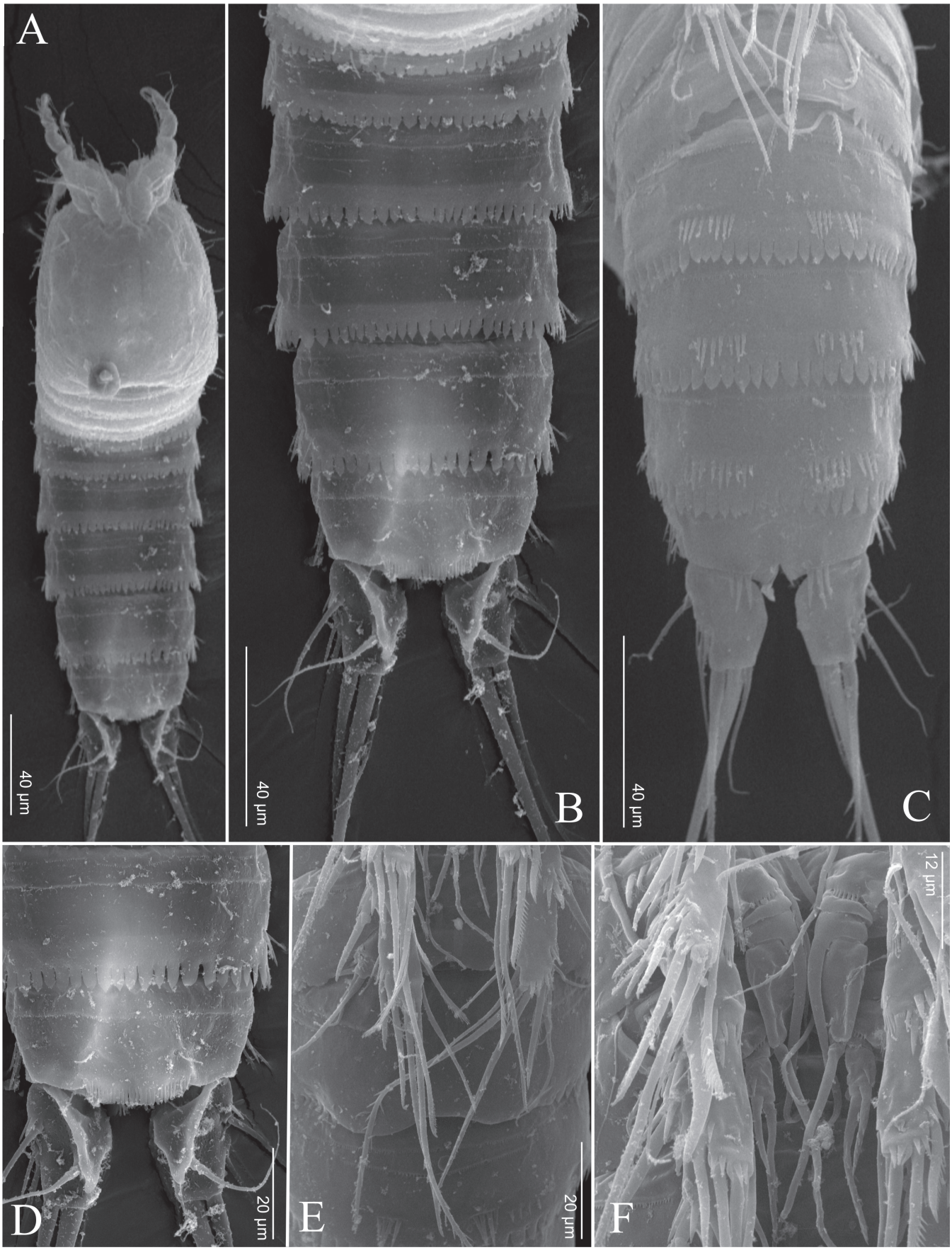

Fig. 7. *Elaphoidella stygobiotica*, new species, SEM photo of male: A, habitus, dorsal view; B, urosome (without urosomite 1), dorsal view; C, urosome (without urosomite 1), ventral view; D, urosomite 5, anal somite, and caudal rami, dorsal view; E, urosomite 1–2 with P5 and P6, ventral view.

Description of adult male (allotype). The body length is slightly shorter than that of a female; specifically, it is 380 µm when measured from the anterior edge of the rostrum to the posterior edge of the caudal rami. The body is colourless and a naupliar eye is not discernible. The cephalothorax and thoracic somites 1–4 have ornamentation similar to that of females (Figs. 6A, 7A). The genital somite and urosomites 2–5 have serrate posterior margins similar to those of females, each with a discontinuous row of robust spinules on the disto-ventral margin. There are rows of fine spinules on the ventral surface of each somite in the medial region (Figs. 6B, C, 7B, C).

Anal somite (Figs. 6D, 7D), caudal rami (Figs. 6C, D, 7C, D), antenna, mouthparts, P2 and P3 intercoxal sclerite, coxa, basis, and Exp are similar to those of females except for the length of the setae and spines on the segments bearing them (Fig. 8B, C). The anal operculum has about 30 spinules, reaching the posterior margin of the somite bearing it (Fig. 6C).

Antennule (Fig. 6E) is seven-segmented and geniculated, with two long cylindrical aesthetascs fused with a seta at their bases (forming an acrothek). The setal formula is as follows: 8, 4, 1+A, 3, 0, 0, 9+(1+A).

P1 (Fig. 8A) basis has a bare seta inserted on the inner margin. The seta on the outer margin is bipinnate. Exp is similar to that of the female. Enp-1 has a bipinnate seta on the inner margin; Enp-2 has an inner unipinnate seta and an outer geniculate seta, the latter longer than the former.

P2 (Fig. 8B) Exp-3's inner bare seta is located apically and shorter than that of females. Enp is two-segmented; Enp-1 is shorter than wide and unarmed, Enp-2 carries one bipinnate seta apically, about 2.5 times longer than the segment, accompanied by two robust spinules at outer margin.

P3 (Figs. 7F, 8C) Exp-1 and Exp-2 have robust spines and are curved outward with rounded tips. Exp-3 has an inner seta apically and is substantially shorter than in the female. Enp-1 is shorter than it is wide and is unarmed. Enp-2 is characterised by apophysis with a harpoon-like tip, not reaching the end of Exp-3. Enp-3 is about 1.5 times as long as it is wide, with one long bare seta apically.

P4 (Fig. 8D) Exp-3 does not have transformed setae or spines. Enp-1 is shorter than it is wide and is unarmed. Enp-2 is about three times longer than Enp-1, with a bipinnate seta and an apical spiniform bipinnate spine apically and a seta longer than the spine, about 1.5 times as long as the segment bearing it.

P5 (Fig. 8E) Exp and baseoendopod are completely separated. The baseoendopod has a single long seta on the outer margin. Exp is small and as long as it is wide, with three setae. The setae on the inner margin are pinnate and are the shortest; the two bare setae are situated apically, and the inner one is the longest.

P6 (Figs. 6B, 7E) is reduced into a shallow plate and is unarmed.

Variability. The body length ranged from 350 to 400 µm in females (n = 5) and 350 to 390 µm in males (n = 5). The spinules at the base of the anal somite ventrally ranged from 3–4 in females (n = 5) and 3–5 in males (n = 5). P5 Exp of females with four setae rather than five (one out of five examined females, Fig. 5F). P1 Enp of the male is longer than Exp (one out of four examined males).

Differential diagnosis. *Elaphoidella stygobiotica*, new species, belongs to the genus *Elaphoidella* sensu Chappuis (1929); it has an eight-segmented antennule and a two-segmented P1 Enp; the male P3 Enp-2 has a spine transformed in an apophysis; P4 and P5 have a particular armature in both sexes (the P4 and P5 exhibit sexual dimorphism, related to the armature of Exp-3 and Enp-2; the male P5 baseoendopod is unarmed, in contrast to the female that carries 3–4 setae). The new species belongs to the *armata* group (group X) sensu Lang (1948), since it has a two-segment P1 Enp in both sexes, the P4 Exp-3 of the male lacks the transformed spine and has an armature similar to the female, the P5 of the female has four setae on the baseoendopod and Exp, and the P5 baseoendopod is extended to the middle half of the Exp's length. There are three species belonging to group X that Lang (1948) recorded in SE Asia: *E. elegans* (Chappuis, 1931), *E. cornuta* (Chappuis, 1931), and *E. javaensis* (Chappuis, 1928). Based on keys to the species of SE Asia in Watiroyram (2021), *E. stygobiotica*, new species, is morphologically similar to *E. elegans*, which is from Java, as their females have 3–4 spinules ventrally on the anal somite, caudal rami without ornamentation on the inner margin, P2–P4 Enp-1 without setae on the inner margin, P5 Exp with four setae and a similar length to the caudal rami. They are different from each other, as the new species has three setae on the Exp of the antenna, in contrast to four setae in *E. elegans*; the posterior margins of the urosomites are serrated in the new species, while they are smooth in *E. elegans*; the armature formula for P1 through P3 in the new species is 2.2.4, as opposed to 3.3.5 in *E. elegans*; and the P5 baseoendopod of the new species has outermost setae longer than Exp, while they are shorter in *E. elegans*. The *E. elegans* male is currently unknown; thus, a comparison of differences between males could not be performed.

The female *E. stygobiotica*, new species, differs from *E. cornuta* and *E. javaensis* in terms of the ornamentation of the urosomites. The new species has serrated urosomites in the free margin, while *E. cornuta* and *E. javaensis* have smooth ones; the caudal rami of the new species is without ornamentation on the inner margin but has a robust spine-like structure in *E. cornuta*; the armature formula on P1 through P3 of the new species is 2.2.4, as opposed to 3.3.5 in *E. cornuta* and *E. javaensis*; the P5 Exp of the new species has four setae versus three setae in *E. cornuta* and *E. javaensis*; the P5 baseoendopod of the new species is one half of the length of Exp, while *E. cornuta* and *E. javaensis* are the entire length; the P5 baseoendopod of the new species has an outermost seta that is longer than Exp's length; conversely,

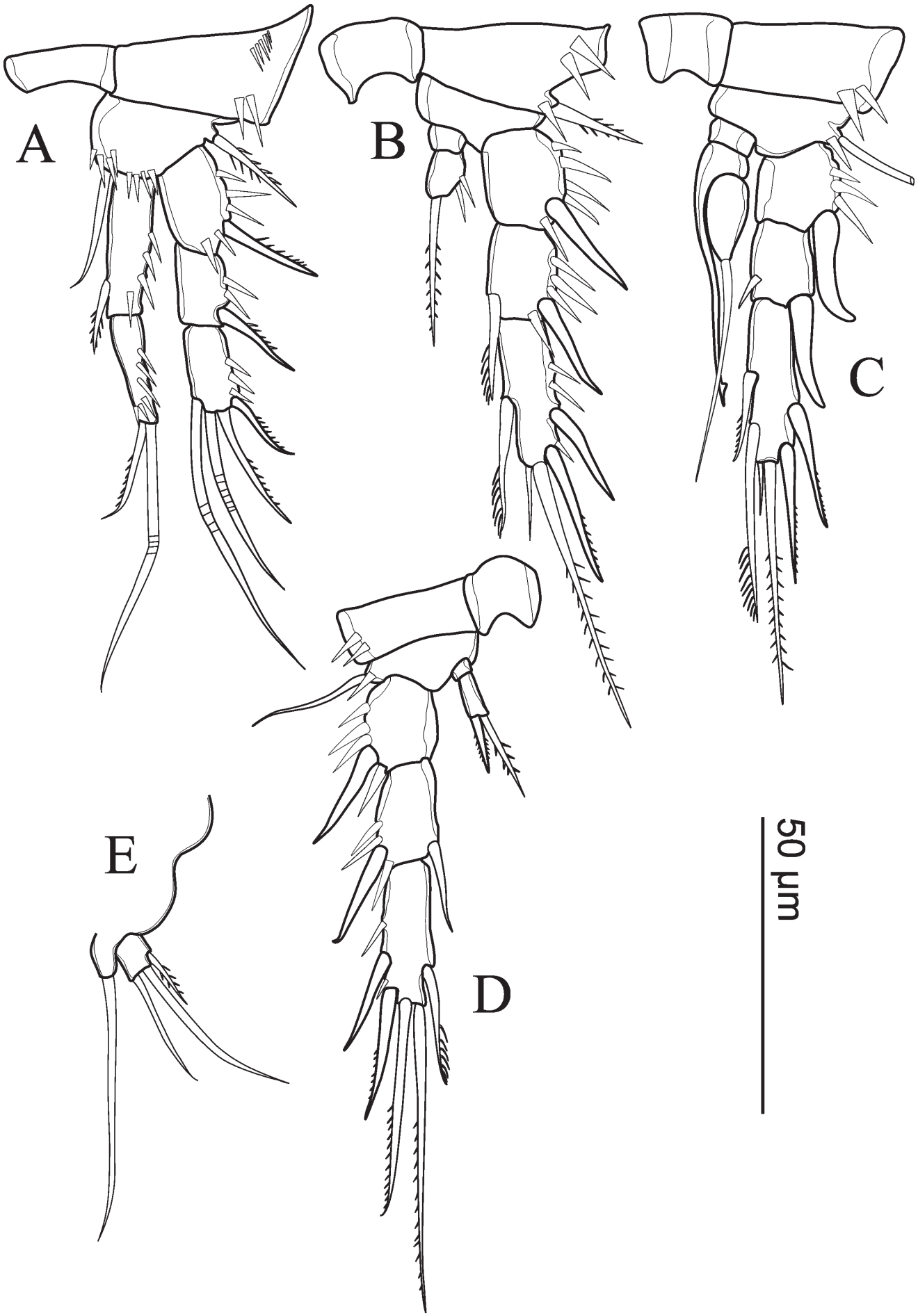

Fig. 8. *Elaphoidella stygobiotica*, new species, male (allotype): A, P1; B, P2; C, P3; D, P4; E, P5.

Table 2. The major morphological differences of the group X according to Lang (1948) of *Elaphoidella* from SE Asia.

Characters	*E. stygobiotica*, new species	*E. elegans* (Chappuis, 1931)	*E. cornuta* (Chappuis, 1931)	*E. javaensis* (Chappuis, 1928)
FEMALE				
Antenna				
Number of setae on Exp	3	4	3	unknown
Urosomites				
Posterior margin	serrated	smooth	smooth	smooth
Anal segment				
Number of ventral spinules	3–4	3–4	1	2–4
Caudal ramus				
Inner margin	bare	bare	with robust spine-like structure	bare
Legs				
Number of setae & spines of P1–P4 Enp-2	2.2.4.3	3.3.5.3	3.3.5.3	3.3.5.3
Number of setae on P5 baseoendopod & Exp	4.4	4.4	4.3	4.3
Length ratio of P5 baseoendopod vs. Exp	0.5:1	0.5:1	1:1	1.1
Length of outermost seta on P5 baseoendopod compared to Exp	longer	shorter	much shorter	equal
MALE				
Number of setae & spines of P2 and P4 Enp-2	1.2	unknown	unknown	2(3*).2
Number of setae & spines of P3 Enp-2	1	unknown	unknown	2
Number of setae & spines of P1–P4 Exp-3	4.5.6.5	4.5.6.6	4.5.6.6	4.5.6.6
Number of setae on P5 Exp	3	unknown	unknown	2

*Borutzky (1967) reported three elements on P2 Enp-2 of *E. javaensis*.

it is shorter in *E. javaensis* and the shortest in *E. cornuta*. Additional differences were also found in the male's legs; specifically, the new species has three setae on P5 Exp, as opposed to two setae in *E. javaensis* (see Table 2). The male of *E. cornuta* is unknown.

DISCUSSION

Out of the 30 *Elaphoidella* species that have been discovered in SE Asia, 13 species have been found in Thailand, including the new species described herein (Watiroyram et al., 2015, 2017, 2021, 2022; Watiroyram & Brancelj, 2016; Fefilova & Alekseev, 2018; Watiroyram, 2018, 2021; Sanoamuang & Watiroyram, 2021). Many species recorded in unpublished documents have been informally described in relation to Thailand, particularly in research reports and dissertations from the same study area (Boonyanusith, 2013). *Elaphoidella stygobiotica*, new species, shares many morphological characteristics with *Elaphoidella* sp. 4, which was recorded by Boonyanusith (2013) and discovered at the Lawa cave; however, the new species clearly differs from *Elaphoidella* sp. 4 in terms of several major characteristics. They have a different pattern of urosomal serration on the posterior margin; specifically, the pattern is oblong in the new species and triangular in *Elaphoidella* sp. 4 (see Fig. 3C; Boonyanusith, 2013: fig. 33A); there is a different shape and number of spinules on the distal free margin of anal operculum; specifically, there are approximately 30 oblong spinules in the new species as opposed to 19 to 21 triangular spinules in *Elaphoidella* sp. 4 (see Figs. 2D, 7D); the caudal ramus of *Elaphoidella* sp. 4 has 'denticulated hyaline' structure on the distal inner margin (see Boonyanusith, 2013: fig. 33C), while the margin is bare in the new species; the length of the P5 baseoendopod in females of the new species is clearly shorter than in *Elaphoidella* sp. 4; there is a different number of setae and spines in the male P3 Enp-3, specifically one long seta in the new species as opposed to 0–2 short setae in *Elaphoidella* sp. 4 (see Fig. 7F; Boonyanusith, 2013: fig. 34E). Regarding *Elaphoidella* sp. 4, the species was also collected in two other caves (Prathun and Chom Pon caves in Kanchanaburi and Ratchaburi Province, respectively), and many morphological variations were observed among their populations. Thus, the re-examination of specimens from both caves is necessary to determine the species.

Conclusion. *Elaphoidella stygobiotica*, new species, is clearly different from the known species from SE Asia, and it is most similar to *E. elegans*. The new species also differs from other species across the world based on the key published by Wells (2007). Based on field sampling between 2016 and 2022 and data from 364 visited caves, the species was only found in one cave in the Tenasserim Hills of Thailand, suggesting that it is endemic to the region and inhabits only the type locality.

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LITERATURE CITED

Apiwathnasorn C, Samung Y, Prummongkol S, Phayakaphon A & Panasopolkul C (2011) Cavernicolous species of phlebotomine sand flies from Kanchanaburi Province, with an updated species list for Thailand. Southeast Asian Journal of Tropical Medicine and Public Health, 42(6): 1405–1409.

Boonyanusith C (2013) Species diversity and distribution of copepods in caves in the western part of Thailand. Unpublished PhD Thesis, Khon Kean University, Khon Kaen, 232 pp.

Borutzky EV (1967) Freshwater Copepoda Harpacticoida of North Vietnam. Zoologicheskii Zhurnal, 46: 1015─1023.

Brady GS (1880) A monograph of the free and semiparasitic Copepoda of the British Islands 2. The Ray Society, London, 83 pp.

Chappuis PA (1928) Neue Harpacticiden aus Java. Treubia, 10: 271–283.

Chappuis PA (1929) Révision du genre *Canthocamptus* Westwood (Note préliminaire). *Buletinul Societatii de Stiinte din Cluj*, 4(2): 41–50.

Chappuis PA (1931) Copepoda Harpacticoida der deutschen limnologischen Sunda-expedition. Archiv für Hydrobiologie, 8(1): 512–584.

Ellis M (2018) The recorded fauna of the limestone caves of Thailand to April 2018. Technical Report, 107 pp. https://www.researchgate.net/publication/324991597 (Accessed 10 March 2023).

Ellis M & Pauwels OSG (2012) The bent-toed geckos (*Cyrtodactylus*) of the caves and karst of Thailand. Cave and Karst Science, 39(1): 16–22.

Fefilova EB & Alekseev VR (2018) A new species and new records of harpacticoids (Crustacea: Copepoda: Harpacticoida) from North-Eastern Borneo. Zoosystematica Rossica, 27(2): 205─217.

Golovatch SI, Geoffroy J-J, Mauriès J-P & VandenSpiegel D (2011) The millipede genus *Plusioglyphiulus* Silvestri, 1923 in Thailand (Diplopoda, Spirostreptida, Cambalopsidae). Zootaxa, 2940: 1–63.

Huys R & Boxshall GA (1991) Copepod evolution. The Ray Society, London, 468 pp.

Jarapatrasilp P, Sutcharit C & Panha S (2022) Annotated checklist of the operculated land snails from Thailand (Mollusca, Gastropoda, Caenogastropoda): the family Pupinidae, with descriptions of several new species and subspecies, and notes on classification of *Pupina* Vignard, 1829 and *Pupinella* Gray, 1850 from mainland Southeast Asia. Zookeys, 1119: 1–115.

Kottelat M (1988) Two species of cavefishes from northern Thailand in the genera *Nemacheilus* and *Homaloptera* (Osteichthyes: Homalopteridae). Records of the Australian Museum, 40: 225–231.

Lang K (1948) Monographie der Harpacticiden. Häkan Ohlssons Boktryckeri, Lund, 1682 pp.

Nabhitabhata J & Chan-ard T (2005) Thai Red Data: mammals, reptiles and amphibians. Office of Natural Resources and Environmental Policy and Planning. Bangkok, Thailand, 180 pp.

Plant AR (2014) Areas of endemism in Thailand: has historical partitioning between seasonally dry lowland and aseasonal moist mountain forests shaped biodiversity in Southeast Asia? Raffles Bulletin of Zoology, 62: 812–821.

Sanoamuang L & Watiroyram S (2021) Description of *Elaphoidella brancelji* sp. nov. (Crustacea: Copepoda) a new species from a cave in Northern Thailand. Tropical Natural History, 21(2): 321–336.

Sars GO (1903) An account of the Crustacea of Norway with short descriptions and figures of all the species. Copepoda Harpacticoida. Parts I and II, Misophriidae, Longipediidae, Cerviniidae, Ectinosomidae (part). Bergen Museum, 5: 1–28.

Sawangproth W, Paejaroen P, Phankamolsil Y & Chanseetis C (2020) Mollusc diversity in the plant genetic protection area of Srinagarind Dam, Sisawat District, Kanchanaburi Province**.** KKU Science Journal, 48(3): 333–341.

Schwendinger PJ & Giribet G (2005) The systematics of the south-east Asian genus *Fangensis* Rambla (Opiliones: Cyphophthalmi: Stylocellidae). Invertebrate Systematics, 19: 297–323.

Sedwisai P, Changbunjong T, Chamsai T, Tangsudjai S, Rittem S, Weluwanarak T, Jiemtaweeboon S, Lekcharoen P, Tonchiangsai K, Triwitayakorn K, Waengsothorn S, Buddhirongawate R & Chaichoen K (2012) Species diversity of cave dwelling bats in Kanchanaburi Province. Journal of Applied Animal Science, 5(3): 16–23.

Singtuen V, Phajuy B & Galka E (2021) Characteristics and assessment of selected waterfalls formed in different geological basements in Thailand. GeoJournal of Tourism and Geosites, 37(3): 880–887.

Surakhamhaeng K, Deharveng L & Jantarit S (2021) Three new species of cave *Troglopedetes* (Collembola, Paronellidae, Troglopedetinae) from Thailand, with a key to the Thai species. Subterranean Biology, 40: 129–174.

Suwannapoom C, Sumontha M, Tunprasert J, Ruangsuwan T, Pawangkhanant P, Korost DV & Poyarkov NA (2018) A striking new genus and species of cave-dwelling frog (Amphibia: Anura: Microhylidae: Asterophryinae) from Thailand. PeerJ, 6: e4422.

Watiroyram S (2018) *Bryocyclops asetus* sp. n. and the presence of *Bryocyclops muscicola* (Menzel, 1926) from Thailand (Crustacea, Copepoda, Cyclopoida, Cyclopidae). Zookeys, 793: 29–51.

Watiroyram S (2021) Cave-dwelling copepods in Thailand. KKU Printing House, Khon Kaen, Thailand, 254 pp.

Watiroyram S & Brancelj A (2016) A new species of the genus *Elaphoidella* Chappuis (Copepoda, Harpacticoida) from a cave in the south of Thailand. Crustaceana, 89(4): 459–476.

Watiroyram S, Brancelj A & Sanoamuang L (2015) Two new species of *Elaphoidella* (Crustacea: Copepoda: Harpacticoida) with comments on geographical distribution and ecology of harpacticoids from caves in Thailand. Zootaxa, 3919(1): 81–99.

Watiroyram S, Sanoamuang L & Brancelj A (2017) Two new species of *Elaphoidella* (Copepoda, Harpacticoida) from caves in southern Thailand and a key to the species of Southeast Asia. Zootaxa, 4282(3): 501–525.

Watiroyram S, Sanoamuang L & Brancelj A (2021) New species of *Elaphoidella* Chappuis, 1929 and *Schizopera* Sars, 1905 (Copepoda: Harpacticoida) from two caves in northeastern and southern Thailand. Zootaxa, 5051(1): 550–569.

Watiroyram S, Wongduan J & Sanoamuang L (2022) *Elaphoidella longiramus* sp. nov. (Copepoda: Harpacticoida, Canthocamptidae), a new species of cave-dwelling copepod from central Thailand. Zootaxa, 5138(2): 152–166.

Wells JBJ (2007) An annotated checklist and keys to species of Copepoda Harpacticoida (Crustacea). Zootaxa, 1568: 1–872.