

A NEW SPECIES OF BENNINI (HEMIPTERA, CIXIIDAE) FROM GRANITIC SUBTERRANEAN ENVIRONMENT IN VIETNAM, AN UNDER-INVESTIGATED BIOTOPE

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Abstract.— A new species of the planthopper taxon Bennini (Hemiptera: Fulgoromorpha: Cixiidae) was discovered in the wide interstitial voids of a granitic blockfield in Vietnam. A key to the species of the Vietnam-endemic Bennini genus *Sanghabenna* is provided and *Sanghabenna florenciana* **sp. nov.** is described and illustrated. Molecular data including 18S in part and CO1 barcode sequences of the species, as well as for the first time a detailed description of nymphal morphology of a Bennini are provided. According to the ecological parameters of its habitat and its morphological configuration, *Sanghabenna florenciana* **sp. nov.** is classified as an exapted eutroglophile taxon.



Key words.— *Sanghabenna*, new species, eutroglophile, subterranean fauna, cave ecology, granitic blockfield.

INTRODUCTION

An entomology joint expedition was organized in 2013 by research teams of the Muséum national d'Histoire naturelle (Paris, France) and the Institute of Tropical Biology (Ho Chi Minh City, Vietnam) in the South East extremity of the Anamitic range in the Hon Ba Nature Reserve, Kh-nh Sýn District, Kh-nh Hòa Province in Southeast Vietnam, ca. 280 km NE of Ho Chi Minh City ("crow-fly" distance). During this mission one particular biotope of granitic blockfield

consisting of large rounded boulders was being inventoried for its invertebrate fauna. Indeed, as the granite blocks are loosely piled up, they form a three-dimensional maze of voids of varying sizes and shapes, but in some places wide enough to allow a person to get down and crawl inside several meters to some ten meters. Within the voids, level of daylight rapidly decreases from the surface to the bedrock and surface habitats quickly give way to an underground mineral environment. However, the voids are energy-rich with long and strong roots and organic debris accumulated from

the surface, and they provide ample food resources for supposedly facultative cavernicolous (troglophilic) species. This unexpected and under-investigated biotope already revealed the existence of at least one new species of Ptomaphagini cave beetle (Perreau & Faille 2015). We add here a second one: a new species of planthopper taxon Bennini Metcalf, 1938 (Hemiptera: Fulgoromorpha: Cixiidae).

Species of the cixiid tribe Bennini are characterized by a conspicuous paired rod-like abdominal appendage unique in insects (Hoch *et al.* 2014). The LASSO (lateral abdominal sensory and secretory organ, i.e.) bears a highly complex sensory unit as well as wax glands in its distal cup-shaped dilated portion. Although the function of the organ is yet unknown, the presence of the LASSO is considered synapomorphic and defines the Bennini as a monophyletic group (Hoch 1988, 2013). A recent monography predominantly based on specimens from the major entomological collections listed 125 species, 101 of which were described as new (Hoch 2013). Although the Bennini are widely distributed in the Indo-Australian Archipelago and the Solomon Islands, Fiji and Western Australia, all species apparently have restricted ranges, the majority are single-island endemics. Based on a simple species/area relationship, and taking into account the habitat richness of SE Asian biota, Hoch (2013: 285) predicted a two – to fivefold increase of currently known species (125) and estimated the total number of extant Bennini species to be at least 600. Especially, continental Southeast Asia must be regarded vastly underinvestigated: there are no records from Laos and Cambodia, both highly likely to house Bennini species, and only two species have been recorded from mainland Malaysia, and one from Thailand.

From Vietnam, due to recent field studies by French and Russian researchers, three species of Bennini species have hitherto been documented (Hoch 2013). They are considered to represent a monophyletic unit, for which the genus *Sanghabenna* has been established (Hoch 2013). The configuration of vertex and frons observed in *Sanghabenna*, i.e., the presence of a distinct frontal carina continuously extending to the posterior margin of the head, the vestigial posterior compartments of the vertex, as well as a male genital character, i.e., aedeagus shaft with a ventral membranous fold enclosing a spinose process, are considered synapomorphies for the genus. Hoch (2013) observed the same head configuration as in *Sanghabenna* in 3 additional female Bennini specimens from Vietnam. These apparently represent three additional *Sanghabenna* species (“*Sanghabenna* spec. 1-3” in Hoch 2013: 228) – according to body size, hind leg configuration and colouration – but were not formally described as the male genital character configuration, needed for genus and species concepts, could not be assessed.

The Bennini species from Hon Ba Nature Reserve shares the synapomorphies of genus *Sanghabenna* (Hoch 2013), endemic to Vietnam, but displays a unique configuration of the male genitalia. The species is new to science, and described below as *Sanghabenna florenciana* sp. nov.

MATERIAL AND METHODS

Collecting, preservation, permanent storage.

The specimens were collected by hand, and either preserved dry or transferred immediately in vials containing 96% ethanol. For permanent storage, after dissection and examination, abdomen and genitalia were transferred to polyethylene vials, and individually associated with the specimen vial.

Depository. MNHN, Musée national d'Histoire Naturelle, Paris.

Morphology. Measurements and examinations of external body features were made from specimens preserved dry (adults) or in ethanol (nymph), without further manipulation. Measurements of body length refer to the distance between anterior margin of head to posterior margin of tegmen in adults, or to posterior tip of the abdomen in the nymph.

To prepare male genitalia for dissection, the genital capsule was removed from the specimen, macerated for 20 min. in hot 10% KOH to which a few drops of Chlorazol black were added, subsequently washed in water, and transferred to glycerine for storage, or to glycerine-jelly for drawings. Examinations and drawings were made using a Leitz stereomicroscope with *camera lucida* attachment. Morphological terminology follows Bourgoin & Huang (1990) and Hoch (2013), Bourgoin (1997) and Bourgoin *et al.* (2015) respectively for male and female genitalia, and tegminal venation interpretation.

Abbreviations. LspF: left spinose process of the flagellum, RspF: right spinose process of the flagellum, Rsp1S: right spinose process 1 of the shaft, Rsp2S: right spinose process 2 of the shaft, VspS: ventral spinose process of the shaft.

Habitus photograph. The photograph in Fig. 1 was obtained from an image-stack taken with the aid of a Leica MZ 16 with a camera (Canon EOS 450D) attachment and Combine ZP software, and subsequently processed with Adobe Photoshop CS3. The photograph was taken from a specimen preserved dry.

Molecular data. Extraction of single specimen leg was non-destructive, using the DNeasy Tissue Kit (Qiagen GmbH, Hilden, Germany). We amplified fragments of one mitochondrial gene (cytochrome c oxidase subunit 1, *cox1*) and one nuclear (18S small ribosomal RNA subunit gene, SSU). To amplify *cox1* we used two primers pairs including the standard barcode primers

LCO1490 / HC02198, known to be efficient for various invertebrates, including Hemiptera (Folmer *et al* 1994, Gwiazdowski *et al* 2015). In addition to the barcode ones, we used the Pat & Jerry primers for *cox1* (Simon *et al* 1994) and 18S 5' and b5.0 for SSU (Shull *et al* 2001). Sequences were assembled and edited with Sequencher 4.9 (Gene Codes, Inc., Ann Arbor, MI). New sequences have been deposited in GenBank with Acc. No. KX784930-KX784931 for *cox1* (P/J and LCO/HCO, respectively, and KX784932 (SSU).



Figure 1. *Sanghabenna florenciana* sp. nov., habitus (female paratype). Body length 10.0 mm.

TAXONOMY

Diagnosis. Medium-sized to large Bennini (some species nearly reaching 1 cm body length), vertex and frons with distinct median longitudinal carina, but without a distinct transverse carina towards vertex. Anterior compartment of vertex faintly recognizable, posterior compartments of vertex very narrow, medially merging, configuration as in Hoch 2013: fig. 4. Tegmina stout, ca. $2.2 \times$ as long as maximally wide, distal margin broadly rounded. Tegmina with a vividly coloured, in posterior half reticulate pattern.

Sanghabenna Hoch, 2013 is distinguished from all other Bennini by the unique combination of characters of the head (median carina of frons extending towards posterior margin of head) and the male genitalia: genital and anal segments bilaterally symmetrical, parameres with distal dilation hammer-shaped, apically rounded and bent dorsocaudally, caudally concave; aedeagus shaft tubular, with one rigid and two movable subapical spinose processes one of which is partly enclosed by membranous ventral fold, flagellum of aedeagus tubular, in repose bent dorsally and to right side (Hoch 2013: 227).

Key to the described species of *Sanghabenna* Hoch, 2013

(see Hoch 2013: pp. 223–224)

1. Clavus of tegmen with distinct dark brown marks, forming longitudinal streaks (Fig. 1); flagellum of aedeagus with 2 or 3 spinose processes **2**
- . Clavus of tegmen without any conspicuous colour elements, but with a distinct dark roundish spot at apex of posterior subapical cell; flagellum of aedeagus with 5 spinose processes ***Sanghabenna dima***
Hoch, 2013 (Hoch 2013: fig 142)
2. Shaft of aedeagus not notably expanding towards aedeagal joint, flagellum expanding distally **3**
- . Shaft of aedeagus distinctly expanding towards aedeagal joint; shaft with 1 spinose process arising ventrally, and a rigid subapical shaft spine on right side directed dorsally; flagellum not expanding distally, with two spinose processes
..... ***Sanghabenna chana***
Hoch, 2013 (Hoch 2013: fig 141)
3. Shaft of aedeagus ventrally with 2 spinose processes, and rigid subapical shaft spine on right side directed straight caudally; flagellum distinctly expanding distally, with 3 spinose processes
..... ***Sanghabenna thaya***
Hoch, 2013 (Hoch 2013: fig 140)
- . Shaft of aedeagus ventrally at midlength with a hook-shaped spinose process and right laterally near apex with two spinose processes: one of which is movable, the other rigid; flagellum only slightly expanding in distal half, with two spinose processes (Fig. 2E) ***Sanghabenna florenciana*** sp. nov.

Family Cixiidae, Spinola, 1839

Tribe Bennini Metcalf, 1938

Genus *Sanghabenna* Hoch, 2013

Sanghabenna florenciana Hoch and Bourgoin sp. nov.
(Figs 1–3)

Description. Adults. Body length. Male. 8.5 mm (n=1). Female. 9.4–10.0 mm (n=3).

Colouration (Fig. 1). Head including antennae dark brown, except lighter portions anteriorly of compound eyes and below antennae; compound eyes dark reddish-brown, lateral ocelli pale red, median frontal ocellus white. Pro- and mesonotum including tegulae dark brown; carinae of mesonotum and posterior portion of tegulae medially slightly darker. Legs sordid yellowish brown. Tegmina subhyaline, yellowish, veins dark brown, CuA base, CuP and anal veins paler, with a vivid pattern of dark brown elements in proximal half, and a reticulate colour pattern in distal half. Costal vein

including pterostigma and basal cell dark brown as well as a short streak in proximal portion of cubital cell directly adjacent to basal cell, and a long streak between posterior margin of tegmen and Y-vein, so as to create the impression of a single dark brown median longitudinal streak in dorsal aspect. Anterior portion of tegmen with a row of 3 small, distinct, but irregularly delimited small roundish spots (on anterior branch of Y-vein, in cubital cell and on media, at level of anterior subapical cell), a rather large, irregularly delimited spot at the apex of posterior subapical cell, and a small, more or less ovate spot in distal portion of cubital cell, near posterior margin of tegmen. Proximal and distal transverse veinlets accompanied by narrow dark brown bands. Distal portion of tegmen with 4 irregular dark brown transverse bands: one rather broad, at level of apex of the median subapical cell, the other 3 narrower: one at level of apices of distal marginal cells, one across the center of distal marginal cells, parallel to distal margin of tegmen, and one accompanying the distal margin of tegmen, the latter three enclosing in each distal marginal cell two ovate or roundish yellowish areas. Legs yellowish brown. Lateral abdominal appendages sordid dark brown, distal wax hood conspicuously white.

Head. General configuration as described for the genus (Hoch 2013: 227): vertex and frons with a distinct median longitudinal carina, but without a distinct transverse carina towards vertex. Anterior compartment of vertex faintly recognizable, posterior compartments very narrow, medially merging (Hoch 2013: 15, fig. 4). Frons $2.0 \times$ longer than maximally wide (widest slightly below level of antenna), and ca. $1.4 \times$ longer than post- and anteclypeus together. Lateral carinae of frons sharply ridged. Post- and anteclypeus with a distinct median carina. Frontoclypeal suture nearly straight. Compound eyes, ocelli (1 median, 2 lateral) well developed. Antennae as in other Bennini with scape short, ca. half the length of pedicel; pedicel cylindrical, ca. $1.4 \times$ longer than wide (Hoch 2013: 16f).

Thorax. Pronotum as in other Bennini with posterior margin deeply emarginate, dorsally with 3 longitudinal carinae: median carina short, straight, lateral carinae curved anteriorlaterally, extending to level of ventral margin of compound eyes. Pronotum ca. $1.33 \times$ wider than maximum width of head (incl. eyes). Mesonotum as in other Bennini tricarinate, ca. $1.2 \times$ wider than medially long. Tegmina slender, ca. $2.34 \times$ longer than maximally wide. Venation very similar to *Sanghabenna thaya* (Hoch 2013: 228, fig. 139) with typical Bennini pattern: RP 3-branched, MP with 5 terminals: MP_{11} , MP_{12} , MP_2 , MP_3 and crooked MP_4 , CuA 2-branched.

Legs. Metatibia laterally unarmed, distally (as in all other Bennini) with 6 teeth, arranged in two groups

(1 and 4 longest) (Hoch 2013, 17f, fig. 6). Metabasitarsus distally with 8, 2nd metatarsal joint with 9 teeth.

Abdomen. Lateral abdominal sensory and secretory organ (LASSO) as in other Bennini (Hoch 2013, Hoch *et al.* 2014).

Male genitalia (Fig 2). General configuration as described for *Sanghabenna* (Hoch 2013). Genital segment in lateral aspect broadly trapezoidal; posterior margin more or less straight, dorsally receding in a ca. 45° angle, dorsocaudally rounded; medioventral process with dorsal and ventral surfaces distinctly separated by a sharp transverse carina, in ventral aspect slender, triangular, irregularly tapering, apically rounded, dorsal surface flat, smooth (Fig. 2B). Anal segment bilaterally symmetrical, in dorsal aspect ca. $4 \times$ as long as wide at base, lateral margins more or less parallel, only proximally of epiproct slightly diverging, without ventral paraproct lobes, caudal margin subtruncate, laterally rounded; anal segment ventrally concave. Gonostyli with distal dilation slender, caudally distinctly concave, distal finger-shaped process directed more or less straight caudally. Perandrium (= aedeagus shaft) slender, tubular throughout, in ventral aspect slightly expanding distally of midlength on its left side, and in basal and distal third on its right side. Laterally and dorsally more strongly sclerotized; lateral basal projections small, rounded, slightly asymmetrical, well separated from shaft base. As in other *Sanghabenna* species with three spinose processes: one arising ventrally, the other two right laterally, respectively. Ventral spinose process (VspS) arising at midlength of shaft, sturdy, more or less terete, hook-like, in repose curved basally and to right side, its proximal portion enclosed by a membranous ventral fold of the shaft. Right lateral spinose process arising near aedeagal joint movable, slender, terete, at rest reaching midlength of shaft, directed basoventrally, in distal portion slightly curved medially (Rsp1S). Right lateral spinose process arising from distal margin of strongly sclerotized shaft portion rigid, sturdy, more or less terete, gradually tapering, slightly sinuate, directed apically (Rsp2S). Endosoma (= flagellum) at rest bent dorsally, slightly surpassing midlength of shaft, tubular, narrow at base, in distal half slightly expanding towards apex, with dorsal portion more strongly sclerotized. Two spinose processes, one arising left laterally (LspF), slightly proximally of midlength, slender, terete, shallowly S-shaped, at rest directed basally and to right side, well surpassing tip of endosoma, the other, arising right laterally (RspF) near aedeagal joint, sturdy, irregularly tapering, less than half the length of left lateral flagellum spine, at rest directed ventrobasally. Distal part of endosoma rugose; phallotreme as in other *Sanghabenna* species situated apically, at rest exposed basally.

Female genitalia. General configuration as in all other Bennini (Hoch 2013: 23): pregenital sternite in ventral aspect more or less triangular; ovipositor orthopteroid, functionally representing the piercing type (*sensu* Müller 1942); gonapophyses VIII and IX long, slender, curved dorsally; anal segment in dorsal aspect more or less rectangular, slightly longer than wide, dorsoventrally depressed. Tergum of abdominal IX segment erected, caudally with a distinct wax plate.

Immatures. Fifth instar nymph, female (Fig. 3). Body length. 5.8 mm ($n=1$).

Habitus. Body ca. $2.2 \times$ longer than maximally wide; maximum width at lateroposterior margins of forewing pads, mesonotum. Vertex short; compound eyes small, but well developed. Rostrum elongate, slightly surpassing hind coxae. Hind legs comparatively long: metatibiae ca. $1.4 \times$ longer than mesotibiae. Head, thorax and abdominal tergites 3–8 with numerous sensory pits, and abdominal tergites 6–8 with conspicuous wax pore plates, as in other nymphs of Cixiidae (see also Yang & Yeh 1994).

Colouration. Frons and vertex sordid dark brown; head laterally, clypeus and antennae slightly lighter; compound eyes red; pro- and mesonotum incl. wing pads, legs and abdominal tergites and genital segments dorsally sordid dark brown; abdominal sternites translucent, whitish.

Head. Vertex short, ca. $6 \times$ wider than medially long; posterior compartments smooth, devoid of sensory pits, laterally narrow, medially expanding anteriorly, separated from anterior compartments by a rounded bulge; anterior compartments of vertex extending laterally to ventral margin of compound eyes; anterior compartments of vertex separated from frons by a distinct, sharply ridged transverse carina; each compartment densely beset with sensory pits (ca. 21, of varying size), arranged in two transversal rows. Frons with an indistinct median carina, ca. as long as maximally wide (widest slightly below dorsal margin of compound eyes), apically rounded; frons ca. $1.2 \times$ longer than post- and anteclypeus together; lateral frontal carinae sharply ridged; frontoclypeal suture more or less straight, medially only slightly vaulted towards frons. Frons laterally on each side with numerous sensory pits of varying size, arranged in short, oblique rows, each consisting of 2–4 sensory pits. Post- and anteclypeus smooth, devoid of median carina and sensory pits. Evans' organ (Evans 1973, Bourgoin 1986) well visible on the maxillary plate (Fig. 3C). Antennae with scape short, ring-like, pedicel ovoid-subcylindrical, ca. $2.5 \times$ the length of scape, with 7 sensory plate organs, arranged in two rows on frontal portion of pedicel.

Thorax. Thoracal tergites medially divided by a wide, longitudinal, median membraneous furrow. Pronotum short, ca. $1.8 \times$ wider than maximum width of head (incl. eyes), posterior margin more or less

straight, only medially slightly sinuate anteriorly; anterior portion of pronotum separated from dorsal portion by an indistinct carina, devoid of sensory pits. Dorsal and lateral portions of pronotum with numerous sensory pits of varying size, arranged as follows: on each side 3 sensory pits along midline, 9 larger sensory pits forming an anteriorly directed arc, enclosing 6 smaller sensory pits in 2 short rows; ventral portion of pronotum medially with a short, slightly arched row of 4 minute sensory pits, and posteriorly with a field of 4 larger and 4 smaller sensory pits (not visible in dorsal aspect). Mesonotum medially ca. $1.4 \times$ longer than pronotum, with lateroposterior margin laterally angularly incised; fore wing pads well developed, ca. $2.3 \times$ longer than mesonotum medially, posteriorly not reaching posterior margin of hind wing pads; fore wing pads laterally in anterior half with an indistinct longitudinal carina separating dorsal and lateral wing pad portions. Mesonotum with numerous sensory pits arranged as follows: on each side, dorsally near midline, two posteriorly converging rows of 4, resp. 5 larger sensory pits, and wing pad dorsally with 8 smaller sensory pits (2 groups of 3, resp. 5 sensory pits) and laterally (not visible in dorsal aspect) in anterior portion with 11 densely grouped sensory pits of varying sizes. Metanotum medially about as long as mesonotum, hind margin gradually expanding laterally; hind wing pads well developed, their posterior margin reaching the posterior margin of the 2nd abdominal tergite. Metanotum dorsally on each side, between midline and inner margin of forewing pad with 7, resp. 8 sensory pits, arranged in an arched row. Hind wing pads devoid of sensory pits.

Legs. Hind coxae as in most other Fulgoromorpha families (except Tettigometridae: Asche 1988) with ca. 14 curved cog-like strips of opposing ledges, the conspicuous „coupling apparatus” (Emeljanov 1979) which aid in synchronizing hind legs during jumping (Burrows & Sutton 2013). Metatibiae laterally unarmed, distally with 6 teeth in a shallowly arched row (3rd and 6th longest). Pro- and mesotarsi with 2 joints, metatarsi with 3 joints. Metabasitarsus distally with 6, 2nd metatarsal joint with 4 teeth; metabasitarsus ca. $1.2 \times$ longer than 2nd and 3rd metatarsal joints together.

Abdomen. Ovoid, in cross section roundish, not notably depressed or compressed; medially ca. $1.2 \times$ longer than head and thorax together; abdominal tergite 1 medially with a wide membraneous portion, tergites 2–8 medially with a very fine crest, medially with a narrow membraneous fold. Abdominal tergites 1 and 2 narrow, devoid of sensory pits. Abdominal tergite 3 medially ca. $1.5 \times$ longer than abdominal tergite 2, with one sensory pit on each side, close to midline; abdominal tergites 4 and 5 medially ca. twice as long as abdominal tergite 3, with anterior and posterior margins straight, more or less parallel, on each side with

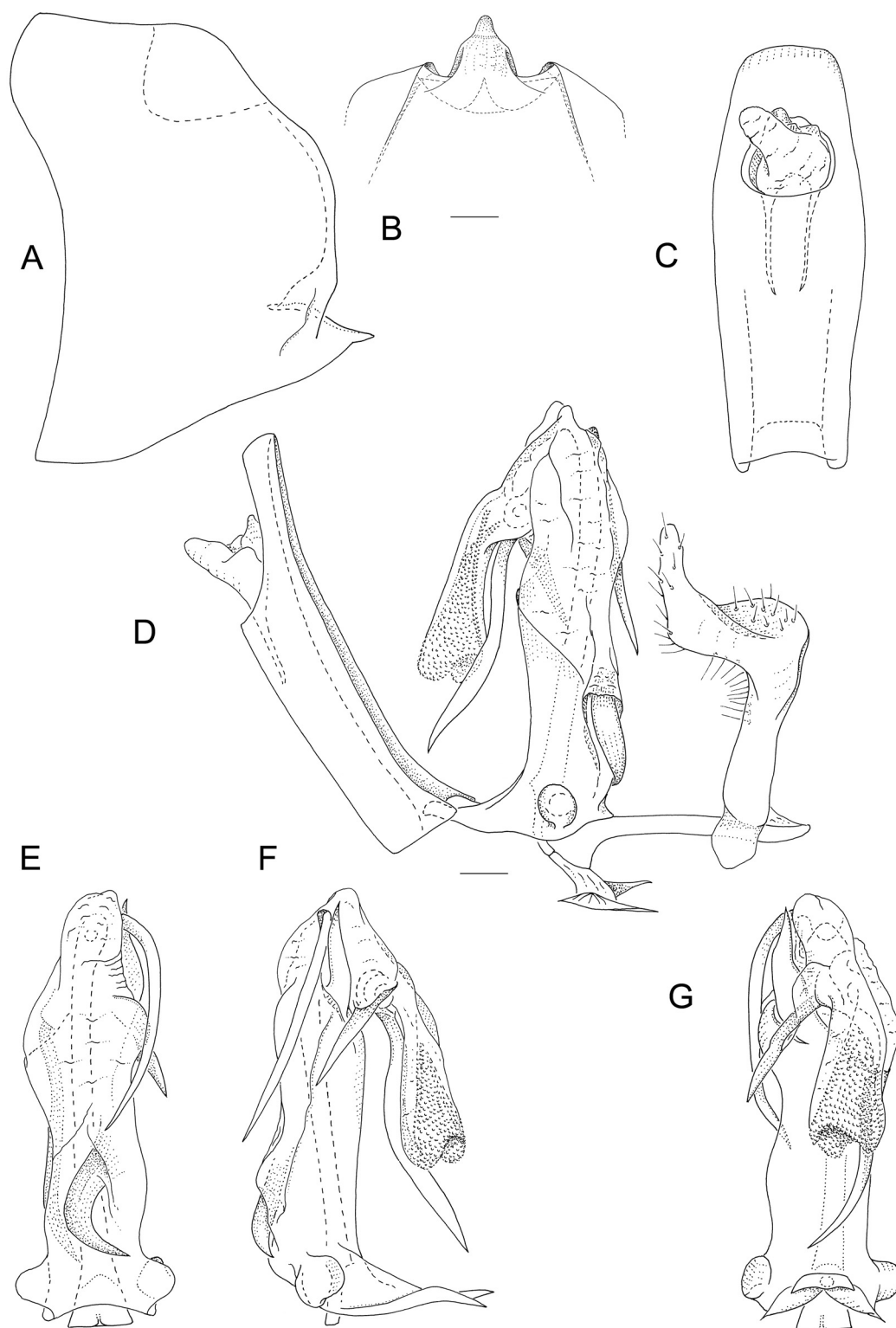


Figure 2. *Sanghabenna florenciana* sp. nov., male genitalia. (A) Genital segment, left lateral aspect; (B) medioventral process, strict ventral aspect; (C) anal segment, dorsal aspect; (D) anal segment, aedeagus, gonostyli, in situ, left lateral aspect; (E) aedeagus, ventral aspect; (F) same, right lateral aspect; (G) same, dorsal aspect. Scale bars: 0.1 mm.

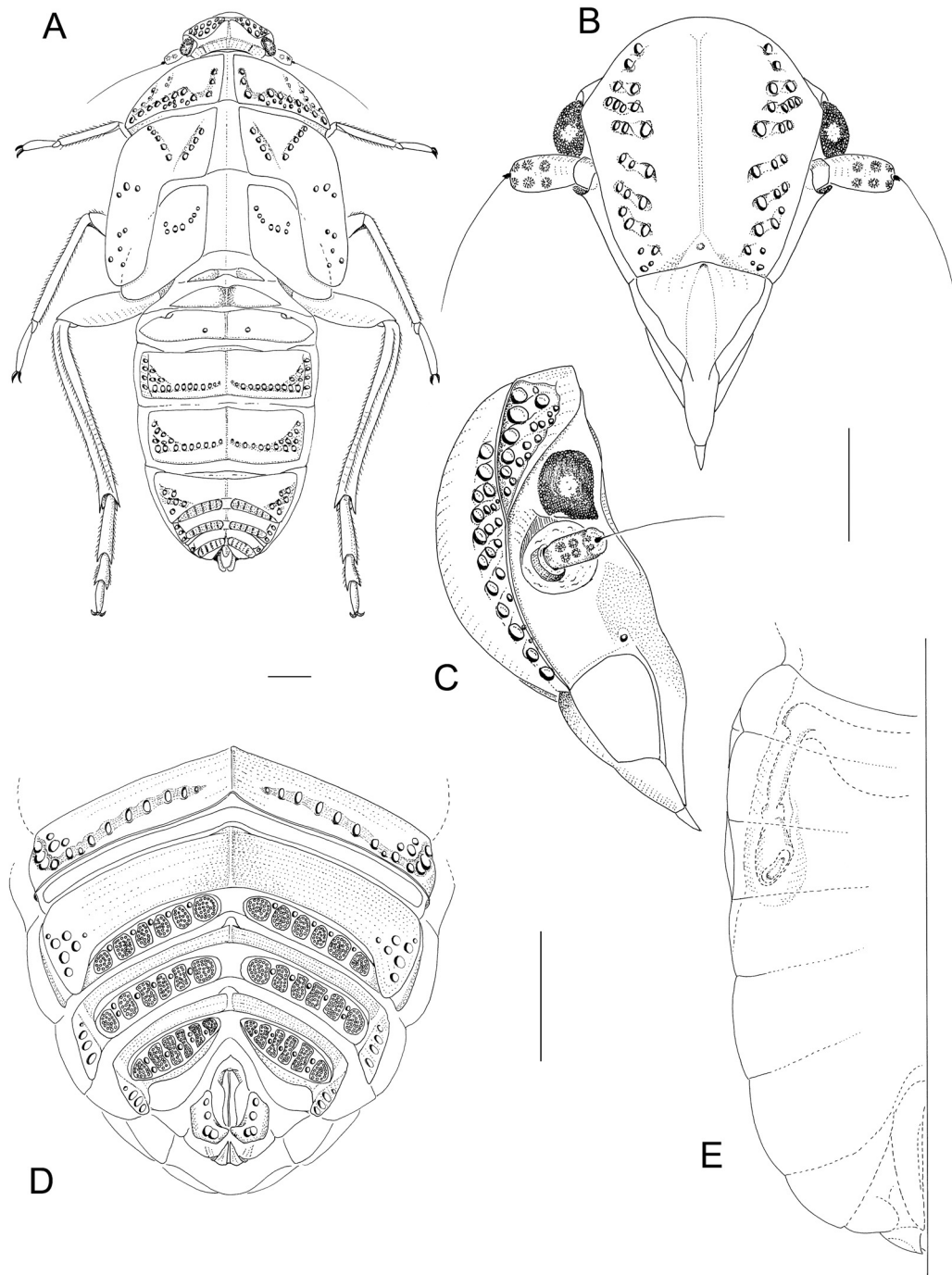


Figure 3. *Sanghabenna florenciana* sp. nov., nymph (V. instar). (A) habitus, dorsal aspect; (B) head, ventral aspect; (C) same, left lateral aspect; (D) posterior abdomen, dorsocaudal aspect; (E) anlage of lateral abdominal sensory and secretory organ (LASSO), right lateral portion of abdomen, ventral aspect. Scale bars: 0.5 mm.

14, resp. 15 sensory pits of varying sizes, arranged in a slightly sinuate row along posterior and lateral margins of tergite; on abdominal tergite 4, lateral portion separated by a distinct longitudinal carina, with additional 4 sensory pits of laterotergite. Abdominal tergites 6–8 gradually shorter and narrower than preceding tergites of segments 4–5, posterior portions distinctly truncate, with caudally exposed portions bearing wax plates (see Emeljanov 2001). Abdominal tergite 6 anterior of wax plate sublaterally with 7 sensory pits arranged in a triangularly shaped group; in abdominal tergites 7 and 8, tergites laterally with a distinct but blunt longitudinal carina, separating the tergite into a dorsal and a lateral portion; lateral portions of tergites 7 and 8 each bearing a row of 4 large sensory pits. Wax plates on abdominal tergites 6–8 on each side with 6 distinctly separated pore plates which are interspersed with small sensory pits as follows: 5 near cephal margin of wax plate on abdominal tergite 6, all pore plates roundish, 6 sensory pits (1+1+1+1+1+2) centrally among pore plates, lateral 2 pore plates roundish, median pore plates medially incised to accommodate sensory pits, and 7 sensory pits (1+2+1+1+2) also centrally among pore plates, lateral pore plates roundish, median pore plates elongate and medially incised to accommodate sensory pits.

LASSO (involving derivatives of abdominal segments 3 and 4: Hoch 2013, Hoch *et al.* 2014) only visible in lateral and ventral aspect, well developed, rod-like and cup-shaped dilation exposed underneath the nymphal cuticle.

Female genitalia. Abdomen in ventral aspect with distinctly differentiated ovipositor bud, the cephal margin of which at level of posterior third of abdominal tergite 8. Abdominal segment 9 laterally on each side with 4 large sensory pits.

Diagnosis. Large Bennini (8.5–10.0 mm), with tegmina and wings steeply tectiform; tegmina vividly coloured with dark brown marks (basal cell dark brown, clavus with distinct brown marks forming longitudinal streaks), in posterior half with reticulate pattern. Within *Sanghabenna*, *S. florenciana* sp. nov. resembles *S. thaya* and *S. chana* in colouration of the tegmen, but differs from these as well as from *S. dima* in characters of the male genitalia as follows: anal segment tongue-shaped, bilaterally symmetrical, caudal margin rounded, subtruncate (*versus* bilaterally asymmetrical, with distal margin medially incised in *S. dima*), and aedeagus shaft tubular, not expanding towards apex (as in *S. thaya* and *S. dima*) *versus* shaft notably expanding towards apex as in *S. chana*. Aedeagus shaft as in all other *Sanghabenna* species with 3 spinose processes, but these differing from the congeners in shape and topology as follows: in *S. florenciana* shaft ventrally near base with one spinose

process enclosed by a membranous fold, and two spinose processes right laterally near apex, one rigid, the other movable (*versus* – in *S. thaya* – shaft ventrally with two spinose processes, and right laterally with one rigid spinose process, or – in *S. chana* and *S. dima* – shaft ventrally near base with one spinose process, left laterally with one movable, and right laterally near apex with one rigid spinose process). Flagellum of aedeagus with two spinose processes in *S. florenciana* sp. nov. (*versus* 3 in *S. thaya*, 2 in *S. chana*, and 5 in *S. dima*).

Etymology. *Sanghabenna florenciana* sp. nov. is dedicated to our late colleague and friend, Florence Richard (Fig. 4b, far left), who was with us when we discovered this new species, and who died recently too prematurely.

Distribution. Vietnam. So far only known from Khanh Hoa Province, Hòn Bà Massif.

Material examined. Holotype ♂. VIETNAM: Khanh Hoa Province, Hòn Bà massif; 12°6.961'N, 108°58.734'E, 20.XI. 2013, 700 m, under granitic chaos cavities. Th Bourgoin leg., Mission Hòn Bà MNHN 2013" (MNHN).

Paratypes. 3 ♀ ♀, same data as holotype, MNHN; 1 ♀, same data as holotype A. Soulier-Perkins leg., MNHN. 4 ♀ ♀, VIETNAM: Province Khanh Hoa, massif du Hòn Bà, N12°6.885' E108°59.005', Chaos granitique, 700m, 20/21.XI.2013, Th. Bourgoin leg., MNHN. 1 ♀, VIETNAM: Province Khanh Hoa, massif du Hòn Bà, N12°06'37" E108°58'55", PL 670 m, 18 & 20.XI.2013, Th. Bourgoin leg., MNHN.

Additional material. 1 nymph, V. instar, VIETNAM: Province Khanh Hoa, massif du Hòn Bà, N12°6.885' E108°59.005', Chaos granitique, 700m, 20.XI.2013, A. Soulier-Perkins leg., preserved in ethanol. 4 nymphs, V. instar, VIETNAM: Province Khanh Hoa, massif du Hòn Bà, N12°6.885' E108°59.005', Chaos granitique, 700m, 20/21.XI.2013, Th. Bourgoin leg. MNHN; 5 nymphs, III. instar, (presumably also Bennini, although LASSO not visible) VIETNAM: Province Khanh Hoa, massif du Hòn Bà, N12°6.885' E108°59.005', Chaos granitique, 700m, 20/21.XI.2013, Th. Bourgoin leg., MNHN; preserved dry.

Ecology. During the period we collected, the forest was dripping with water with often some mist rising by the end of the afternoon and the humidity was high. Yersin (1925) surveyed for seven years the weather at the top of the Hòn Bà and noticed that it rains twice as much on the Hòn Bà (4040 mm for 234 days of rain) than in Nhatrang (2075 mm for 134 days of rain) at sea level, although the two stations are only about 30 km ("crow-fly" distance) apart from each other. The temperature is dropping slowly with the altitude, and at the summit (1500 m) Yersin (1925) registered the extremes at 6.5°C and 26.4°C. Accordingly, the climate can be considered as temperate.



Figure 4. A–C Biotope of *Sanghabemma florenciana* sp. nov. Granitic blockfield with large rounded boulders, covered by dense vegetation consisting of large and old trees.



Figure 5. A–B Biotope of *Sanghabenna florenciana* sp. nov. Granitic blocks show different sizes and shapes, loosely piled up forming a three-dimensional maze of voids where daylight rapidly decreases. Long, strong roots (arrows) of surface vegetation penetrate the maze and provide a food resource for the phytophagous planthoppers.

The locality (Figs 4–5) where the specimens were collected is situated at mid elevation, between 650 m and 750 m, in a chaos of big granite blocks. Vegetation is dense and covers most of the boulders. The area is difficult to access with mature forest having substantial root networks extending around the mossy granitic blocs and deeper inside the blockfield (Fig. 5b). Some roots hang into those large fissures and cavities, and they run as well along the walls. At the time of our visit, a stream ran at several meters in the bottom of the granitic blockfield, not visible but clearly audible.

The nymphs were collected deeper on the running roots in the cracks while the adults were collected on the very damp walls inside the cavities or on walls outermost but then inclined and never facing daylight. The only specimen caught at light trap was also collected in the shadow, on the side of the trap.

Several other arthropod species, frequently observed in limestone caves of this part of the world were also observed: Araneae: Sparassidae, Orthoptera: Rhaphidophoridae, Coleoptera Leiodidae (Perreau & Faille 2015), and several other planthoppers of the families Cixiidae and Meenoplidae.

DISCUSSION

Very little is known about the biology and ecology of any Bennini species. According to field observations and label information, Bennini species apparently occur in the undergrowth of primary and secondary rainforest, ranging in altitude from 0–2000 m a.s.l. (Hoch 2013: 285). All but one species were collected in surface environments, however, *Celebenna*

thomarosa Hoch & Wessel (Hoch *et al.* 2011) from Sulawesi is known only from (adult) specimens from a limestone cave in Maros Karst. The species does not show any significant troglomorphies, however, Hoch *et al.* (2011) assumed that adult specimens of *C. thomarosa* found in the cave are accidentals or troglomorphs, perhaps in search for cool and moist habitats to feed, to mate, oviposit and/or to reduce predation risk.

The only other Bennini species from which nymphs are known is *Bennaria samara* Hoch (Hoch 2013), from Bohol Island, Philippines. Adults and nymphs were collected from roots of an unidentified plant in the entrance/transition zone of a cave. Adults were also observed in surface environments and do not display any conspicuous troglomorphies. According to the ecological classification suggested by Sket (2008) both species, *Celebenna thomarosa* and *Bennaria samara* are regarded as *exapted eutroglophile accidentals* (Hoch *et al.* 2011, Hoch 2013) and a similar situation might apply for *Sanghabenna florenciana* sp. nov.

However, it is interesting that in Philippines and Vietnam, Bennini were always collected by the authors (TB, ASP pers. obs.) in the darker places, close to humid rocky sections, never facing daylight. When collected by light trap and although they are obviously attracted, specimens were always caught at the periphery of the light and in the shadow of the substrate where the specimens stand. Like in *C. thomarosa* and *B. samara*, *S. florenciana* adults do not display any troglomorphies, and may have wandered from surface habitats into the interstitial void system among granitic boulders, which constitute a subterranean environment and equal the entrance/transition zone of

a “classical” cave. Accordingly, this type of habitat might be the rule for Bennini. Accordingly, we here omit the term “accidental” as it implies a random occurrence of an otherwise epigean species in underground environments.

Bennini seem attracted to the shadow areas, obviously they flee from direct light. Like most Cixiidae planthoppers they probably lay and insert their eggs in the plant tissues, here the root system, with their orthopteroid ovipositor (Müller 1942). Once hatched, the larvae as for many species of cixiids remain in the interstitial or underground environment feeding on roots. It is even conceivable that an adult may be able to survive and reproduce in complete darkness. It has been argued that the ability of planthoppers to communicate by substrate-borne vibrations is one of the crucial prerequisites for the permanent colonisation of cave environments (Hoch 2000, Hoch and Wessel 2006). The lateral appendages with the LASSO may or may not play a role in orientation in darkness. *Sanghabenna florenciana* sp. nov. is thus also considered an exapted eutroglophile (*sensu* Sket 2008) and may even be in the early stages of an adaptive shift to a permanent life underground. Adaptive shifts to exploit novel food resources and habitats with the subsequent development of troglomorphies have been postulated as the driving force for the evolution of obligately cavernicolous organisms in the tropics (Howarth 1986, Howarth and Hoch 2005). Generally, subterranean environments in Southeast Asia, except for Thailand, are hardly investigated (Deharveng & Bedos 2000). The recent discovery of the granitic subterranean environment as habitat of hitherto unknown species in Vietnam’s Hon Ba Nature Reserve opens up a new and exciting venue for research in organismic biology and may hold answers to many questions pertaining to the evolution of cave organisms, and to the origin of evolutionary novelty in general.

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