

Celebenna thomarosa gen. n., sp. n. (Hemiptera, Fulgoromorpha, Cixiidae, Bennini) from Indonesia: Sulawesi with notes on its ecology and behaviour

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Abstract

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A new species of the cixiid tribe Bennini from Sulawesi is described and a new genus is erected to accommodate it. This is the first record of a Bennini from Sulawesi and the first discovery of this group in a subterranean environment. We report preliminary observations of its ecology and behaviour. According to the ecological parameters of its habitat and its morphological configuration, *Celebenna thomarosa* is ecologically classified as an exapted eutroglophile accidental.

Key Words

Taxonomy
Southeast Asia
Island endemism
Root community
Cavernicole
Sensory organ
Vibrational communication

Introduction

A systematic survey of Maros Karst caves in Indonesia: Sulawesi in summer 2009 by T. von Rintelen and A. Wessel, Museum für Naturkunde, Berlin, Germany, revealed the existence of the first known root community in Southeast Asia (Wessel et al. 2010; cf. Deharveng & Bedos 2000). Among the invertebrates observed in the dark zone were cixiid planthoppers (Hemiptera, Fulgoromorpha). As sap-sucking primary consumers, planthoppers are common elements of root communities in many parts of the world, of which those from Hawaii (e.g., Howarth 1981; Hoch & Howarth 1993; Hoch & Howarth 1999; Wessel 2008), Australia (e.g., Hoch & Howarth 1989; Stone et al. 2005), and the Canary Islands (e.g., Hoch & Asche 1993) are comparatively well-studied. The majority of troglobitic (obligate cavernicolous) and trogliphilic (facultative cavernicolous) planthopper species belong to Cixiidae (Hoch

& Wessel 2006) (Fig. 1), as does the newly discovered species in Sulawesi. These Maros cave planthoppers are the first representatives of the tribe Bennini ever recorded in a subterranean environment (Fig. 2). As a group, Bennini are confined to Southeast Asia and are characterized by a structure unique in the insects: paired rod-like lateral appendages arising from the base of the abdomen which are distally produced into an egg-cup-shaped dilation, the latter being slightly concave and bearing wax-covered sensillae (Fig. 3). Superficially, these appendages resemble the halteres of Diptera. The function of these benninid appendages, which in life are directed dorsoanteriorly, is unknown as the general biology of this group is poorly studied. 21 species have been described from Singapore, the Philippines, Borneo, New Guinea, Buru, Taiwan, Sula, Amboina, Sumba, Western Caroline Islands, Palau, and the Solomon Islands (Walker 1857a, b, 1870; Stål 1870; Melichar 1914a, b; Schmidt 1926; Matsumura 1938;

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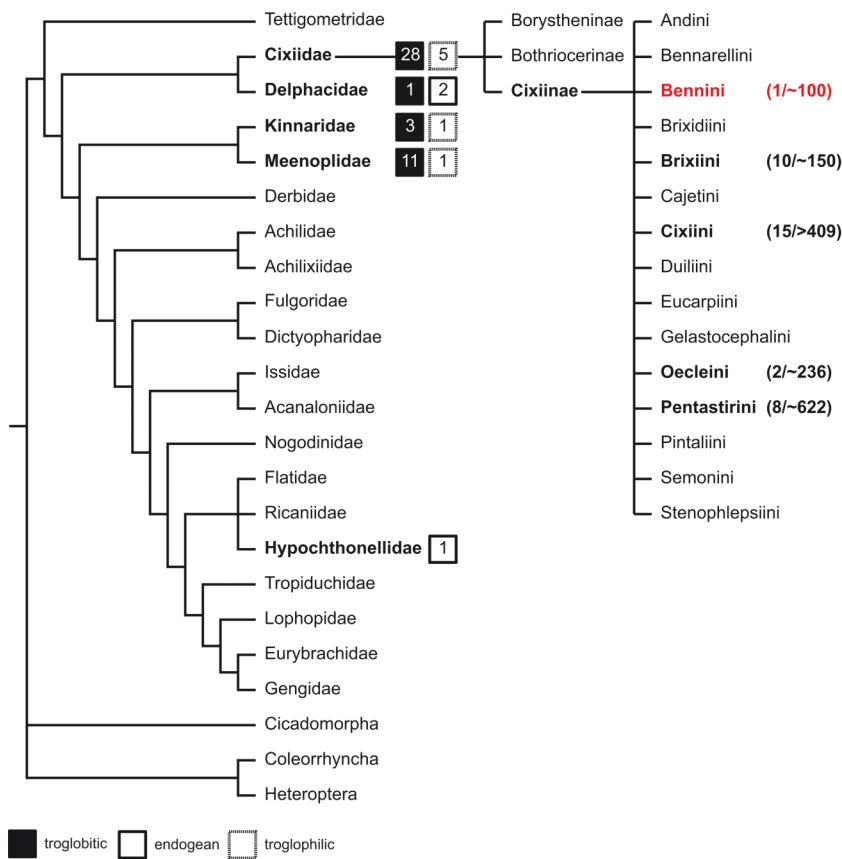


Figure 1. Taxonomic distribution of hypogeic (troglitic, endogean, trogliphilic) Fulgoromorpha species (modified after Hoch et al. 2006). For the tribes of Cixiinae, the relation of hypogeic to epigeal species numbers is given.

Van Duzee 1940; Nast 1950; Lallemand & Synave 1953; Fennah 1954, 1970; Emeljanov 1989) in the genera *Benna* Walker (Walker 1857a) and *Bennaria* (Melichar 1914a). A taxonomic revision is underway (by H. Hoch) which will raise the number of species to more than 100. Here, we describe as new the first Bennini species from Sulawesi. Since it cannot be placed in either of the existing genera, a new genus is established. Preliminary notes on its ecology and behaviour are given.

Material and methods

Collecting, preservation, permanent storage. The specimens were collected by hand, and (except for one male and one female) transferred immediately into vials containing 96% ethanol. For permanent storage, after dissection and examination, the genitalia and abdomen were transferred to polyethylene vials, and individually associated with the specimen vial. One male and one female were kept alive, associated with roots (of an unidentified plant) from the type locality and fresh soy bean sprouts, and hand-carried by A. W. back to Berlin, Germany, for further observation.

Morphological examination techniques, visualization. Measurements and examinations of external body features were made from specimens in alcohol without further manipulation.

Genital capsules were removed from the specimens, macerated in 10% KOH (24 h) at room temperature, washed in water, transferred to glycerine for storage, or to glycerine-jelly for drawings. In order to manipulate morphological structures for drawing, dissections were made using stainless steel insect pins (no 3). Examinations and drawings were made using a Leitz stereomicroscope with a camera lucida.

Recording of vibrational signals. Recordings of intraspecific vibrational communication signals were made on August 19, 2009, in Berlin, Germany, using a gramophone pick-up (BSR X5H cartridge) and a simple 9 V preamplifier (RIAA standard, Star-Kit SK 61), and registered by a Roland Edirol R-09HR ultralightweight wave/mp3 recorder (sample rate 16 bit, 44.1 kHz). Ambient temperature was ca. 25 °C, at dim light. For sound recordings the animals were placed on soy bean sprouts and transferred into a small plastic container. Signal analysis was carried out using Raven Lite 1.0 (Charif et al. 2006) and Avisoft-SAS Lab Pro, v. 5.1.16 (Specht 2011). The sound files are in repository of the Animal Sound Archive (= Tierstimmenarchiv), Museum für Naturkunde, (accession numbers TSA: *Celebenna thomarsa*_DIG0133_01 and TSA: *Celebenna thomarsa*_DIG0133_02).

Taxonomy

Cixiidae

Cixiinae

Bennini

Bennini Metcalf, 1938: 289

Celebenna Hoch & Wessel gen. n.

Type species. *Celebenna thomarsa* sp. n. Type-locality: INDONESIA: Sulawesi, here designated.

Description. Habitus as in other Bennini; medium-sized cixiids with steeply tectiform, subhyaline tegmina, short vertex and conspicuous lateral abdominal appendages (Fig. 3).

Head. Vertex short, posterior compartments together ca. 8.6 times wider than medially long; anterior compart-

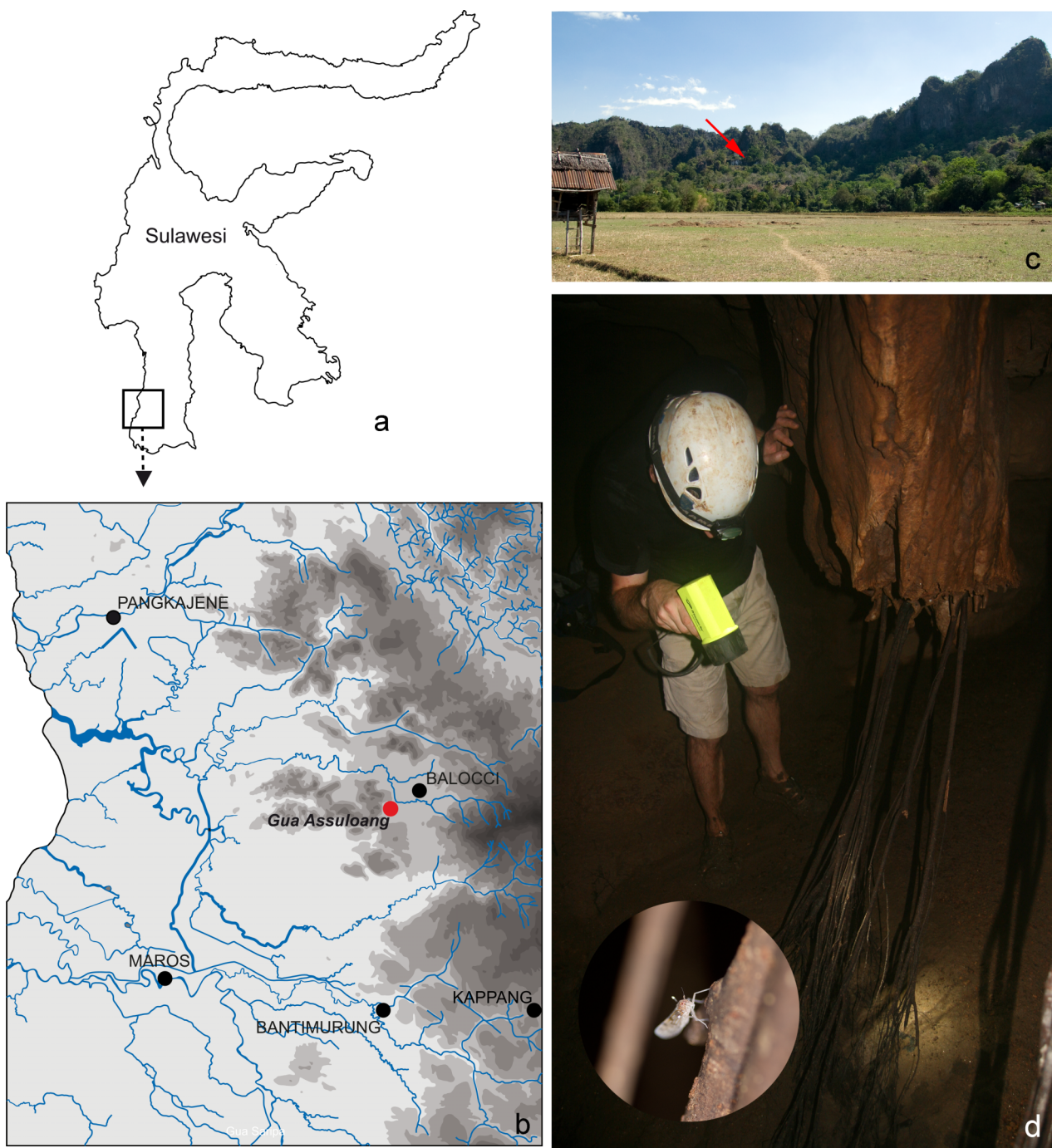


Figure 2. Type locality; **a.** Map of Sulawesi, Indonesia. Inset: Maros Karst Area; **b.** Maros Karst, detail, location of Gua Assuloang; **c.** Maros Karst landscape, east of Balocci, the arrow indicates the position of Gua Assuloang; **d.** Interior of Gua Assuloang, dark zone, with roots; inset: *Celebenna thomarsa* sp. n., adult male. Photos by A. Wessel.

ment of vertex separated from frons by a distinct transverse concave carina.

Carination of frons intraspecifically variable in the type-species: smooth in males, medially with a faint median longitudinal carina in at least one female, lateral carinae of frons strongly ridged. Frons long, narrow, widest slightly below level of antennae; medially 2.34 times longer than maximum width; ca. 1.07 times longer than post- and anteclypeus together; frontoclypeal suture shallowly arched. Post- and anteclypeus with a distinct median longitudinal carina, vanishing to-

wards frontoclypeal suture. Compound eyes and 3 ocelli well developed. Antennae with scape short, ring-like, pedicel cylindrical, ca. 2.5 times as long as wide.

Thorax. Pronotum short, tricarinate: median carina straight, lateral carinae curved laterally; pronotum ca. 1.4 times wider than maximum width of head (incl. eyes). Mesonotum subpentagonal, dorsally tricarinate, ca. as wide as medially long, lateral portions steeply oblique. Tegmina narrow proximally, distally widening; slightly longer than maximum width, surpassing tip of abdomen with ca. 1/3 their total length; costal vein of



Figure 3. *Celebenna thomarosa* sp. n., adult male. Photo by E. Wachmann.

anterior margin emarginate near base (enabling movement of lateral abdominal appendage), wide, without distinct pterostigma; apex of anterior subapical cell proximally of apex of posterior subapical cell, intercubital transverse vein elongate and directed obliquely longitudinally (the latter character according to Emeljanov (2002) a potential synapomorphy for the clade Bennini + Brixidiini). Metatibiae laterally with 1 tooth, distally with 6 spines, arranged in two groups. Metatarsus distally with 6–8 teeth (individually variable), and 2nd metatarsal joint distally with 8–9 teeth (individually variable).

Male genitalia. Genital segment bilaterally symmetrical, caudal margin smooth, without any conspicuous protrusions; medioventral process triangular. Anal segment bilaterally symmetrical, rectangular, ca. 2 times as long as basally wide, lateral margins more or less parallel, distal margin in caudal aspect rounded. Parameres expanding in distal portion, dilated part medially concave, apically with an acute tip directed medially. Aedeagus with shaft tubular, wide at base, lateral

basal projections bilaterally symmetrical; flagellum long, in repose well surpassing midlength of shaft, bent dorsally and to right side; phallosome exposed left laterally.

Female genitalia. tergite IX truncate, wax-producing area well developed, anal segment long, narrow, ovipositor ensiform.

Diagnosis. Distinguishable from other representatives of the tribe Bennini by the unique colouration of the tegmina and by the configuration of the male genitalia, especially the shape of the parameres (see description of *C. thomarosa* sp. n.).

Remarks. The two existing Bennini genera *Benna* and *Bennaria* have been separated mainly by the presence (*Benna* species) or absence (*Bennaria* species) of a median frontal carina by earlier authors (e.g., Melichar 1914; Nast 1950; Emeljanov 1989). The Bennini species from Sulawesi described here is, however, not only inconsistent in this character (see description of head configuration in *C. thomarosa* sp. n.), but also cannot

be identified using the key to the species of *Bennaria* provided by Nast (1950) based on the colouration of the tegmina. Considering external dissimilarities and the particular configuration of the male genitalia, it seems justified to erect this new genus here. The type species, *Celebenna thomarosa* sp. n., is unique amongst all other Bennini species in the colouration of the tegmina and characters of the male genitalia; especially the spine-configuration of the aedeagus and the shape of the parameres (distal dilation apically produced into a claw-like acute tip directed medially). The latter is considered an autapomorphy for *Celebenna*.

Etymology. The genus name is a combination of the former name of Sulawesi, *Celebes*, and the suffix *-benna*, to indicate the taxonomic placement of the genus into the Bennini.

Celebenna thomarosa Hoch & Wessel sp. n.

Figures 3, 4–5

Description

Body length. Male. 8.1–8.2 mm (n = 2). Female. 8.8–9.2 mm (n = 3).

Proportions and carination of head, thorax and tegmina as described for the genus.

Colouration. Head. Posterior compartments of vertex and head laterally light yellowish, anterior compartment of vertex, frons medially, clypeus as well as antennae brownish; carinae dark brown. Thorax. Pro- and mesonotum brownish, dorsal portions slightly darker; carinae of pro- and mesothorax dark brown; tegulae light brown. Thorax ventrally yellowish, legs brownish. Tegmina translucent, in proximal half hyaline, in distal half subhyaline, yellowish; venation except for costal vein in proximal half yellowish, distally dark brown; tegmen with basal cell, costal vein and hind margin in proximal half dark brown; transverse veins accompanied by dark brown bands; posterior margin of distal marginal cells with narrow, concave dark brown bands. Wings opaque, farinose, venation dark brown. Abdomen. Pregenital abdomen in both sexes with lateral appendages dark brown, apically with conspicuous white waxy exudations, sternites and tergites in males yellowish-brown, genital capsule brownish. In females, pregenital sternites yellowish, medially and laterally with dark brown portions, tergites dark brown, sternite VII light brown, tergite IX, anal segment, and ovipositor dark brown.

Male genitalia (Figs 4–5). Genital segment bilaterally symmetrical, in lateral aspect subtriangular, posterior margin medially slightly concave, dorsally slightly receding, laterodorsally with distinct angles; medioventral process broadly triangular, apically rounded, dorsal surface slightly vaulted, smooth. Anal segment bilaterally symmetrical, in dorsal aspect 2 times longer than wide at base, lateral margins slightly converging distally, without ventral lobes; distal portion of anal segment bent ventrally, distally rounded; anal segment ven-

trally concave. Parameres narrow, subtubular at base, distally expanding into a club-like dilation which is medially strongly concave and distally produced into a claw-like acute tip directed medially. Aedeagus. Shaft more or less bilaterally symmetrical, dorsoventrally compressed, wide at base, abruptly narrowing distally of base; lateral basal projections bilaterally symmetrical, integrated into shaft base, apically rounded; shaft in proximal third as well as laterally and dorsally throughout more strongly sclerotized; shaft with 4 spinose processes: one arising left laterally at apex (long, terete, double-S-shaped, in repose directed basally, distal third directed ventrally), one subapically on right side (slender, terete, semicircularly curved basoventrally), and two arising ventrally from a common subapical base, both terete, one directed more or less laterally, the other directed straight basally, its tip pointing ventrally. Flagellum long, in repose well surpassing midlength of shaft, bent dorsally and to right side, sharply bent at midlength, distal half directed left laterally; flagellum tubular, narrow throughout, strongly sclerotized over proximal 4/5 of its length, apical portion membranous; distal margin of strongly sclerotized portion of flagellum slightly expanding and dorsally produced into a claw-like spine; membranous apical portion rugose; phallotreme situated apically, in repose exposed ventrally. Female genitalia. Sternite VII with caudal margin straight, IX tergite truncate, ceriferous, anal segment rectangular, narrow, ca. 4 times as long as wide; ovipositor ensiform.

Etymology. Named in honour of the collector, *Thomas von Rintelen*, Berlin, and the type locality in Sulawesi, *Maros Karst*.

Distribution. Indonesia. Endemic to Sulawesi. So far found only in Gua (= cave) Assuloang (upper entrance), Maros Karst near Balocci, Kepulauan Pangkajene, Sulawesi Selatan (South Sulawesi) (Fig 2).

Material examined. Holotype ♂ INDONESIA: Sulawesi, near Makassar, Maros Karst, Gua Assuloang, 15.viii.2009, 04° 55, 574 S, 19° 40, 716 E; T. von Rintelen leg., Museum Zoologicum Bogoriensis, Bogor, Indonesia (MZB).

Paratypes: 1♂, 1♀, same data as holotype; 1♂, 2♀♀, same data as holotype, except 17.viii.2009; T. von Rintelen & A. Wessel leg., Museum für Naturkunde, Berlin, Germany (MFN).

Ecology

The unique cone karst of Maros hosts the richest hotspot of tropical cave biodiversity recorded so far – the more than 24 km of underground passages of the Gua Salukkan Kallang-Towakkalak (Deharveng & Bedos 2000). The terrestrial cave fauna is dominated by diverse Guano communities with 19 recorded species (Deharveng and Bedos 2004). The exploration of the upper passage of Gua Assuloang, *locus typicus* of *C. thomarosa*, revealed among the more than 150 described caves of Maros Karst the first known terrestrial

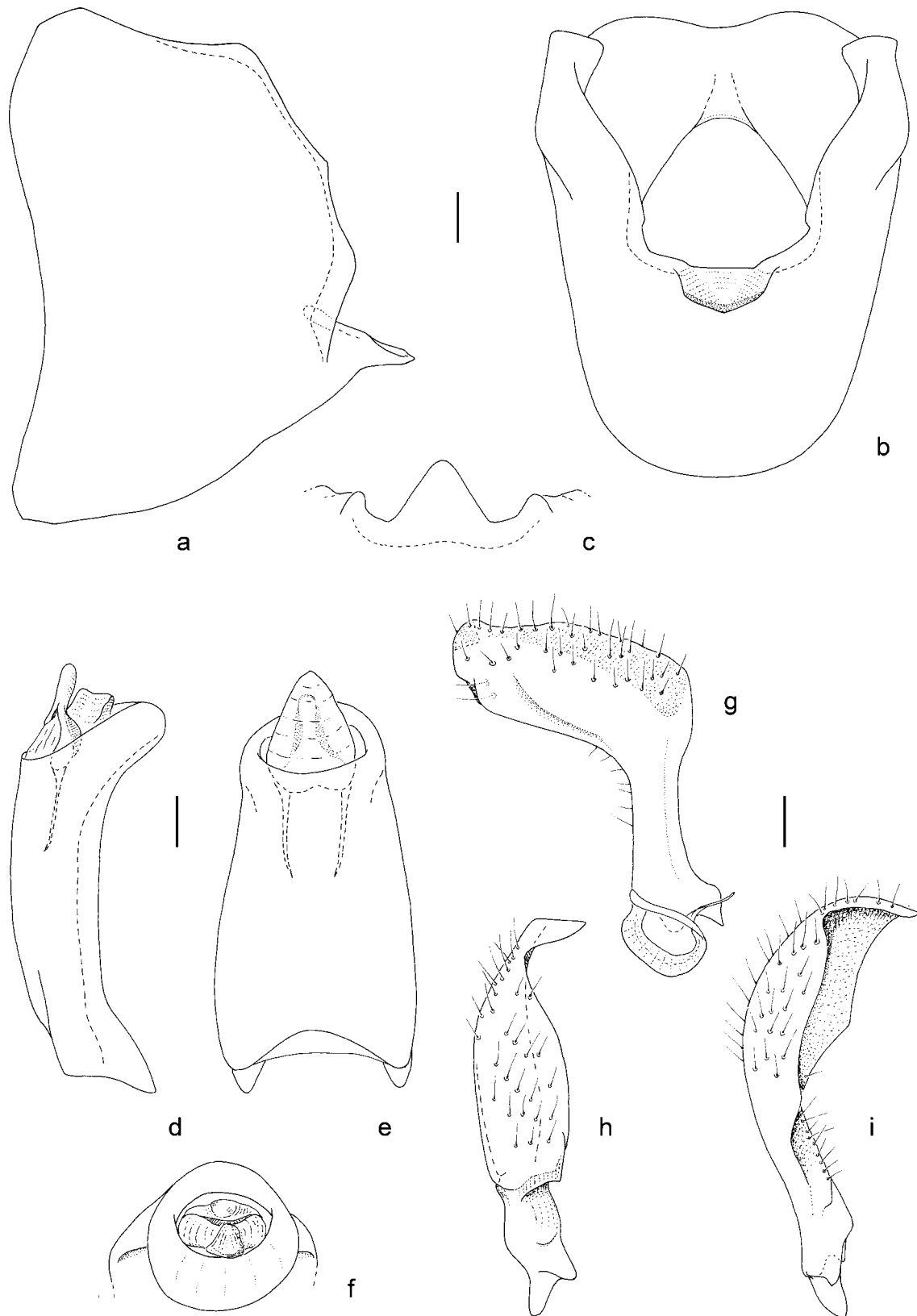


Figure 4. *Celebenna thomara* sp. n., male genitalia; **a.** Genital segment, left lateral aspect; **b.** Genital segment, ventrocaudal aspect; **c.** Medioventral process of genital segment, ventral aspect; **d.** Anal segment, lateral aspect; **e.** Anal segment, dorsal aspect; **f.** Anal segment, caudal aspect; **g.** Left paramere, lateral aspect; **h.** Left paramere, ventral aspect; **i.** Left paramere, dorsal aspect. Scale bar: 0.1 mm.

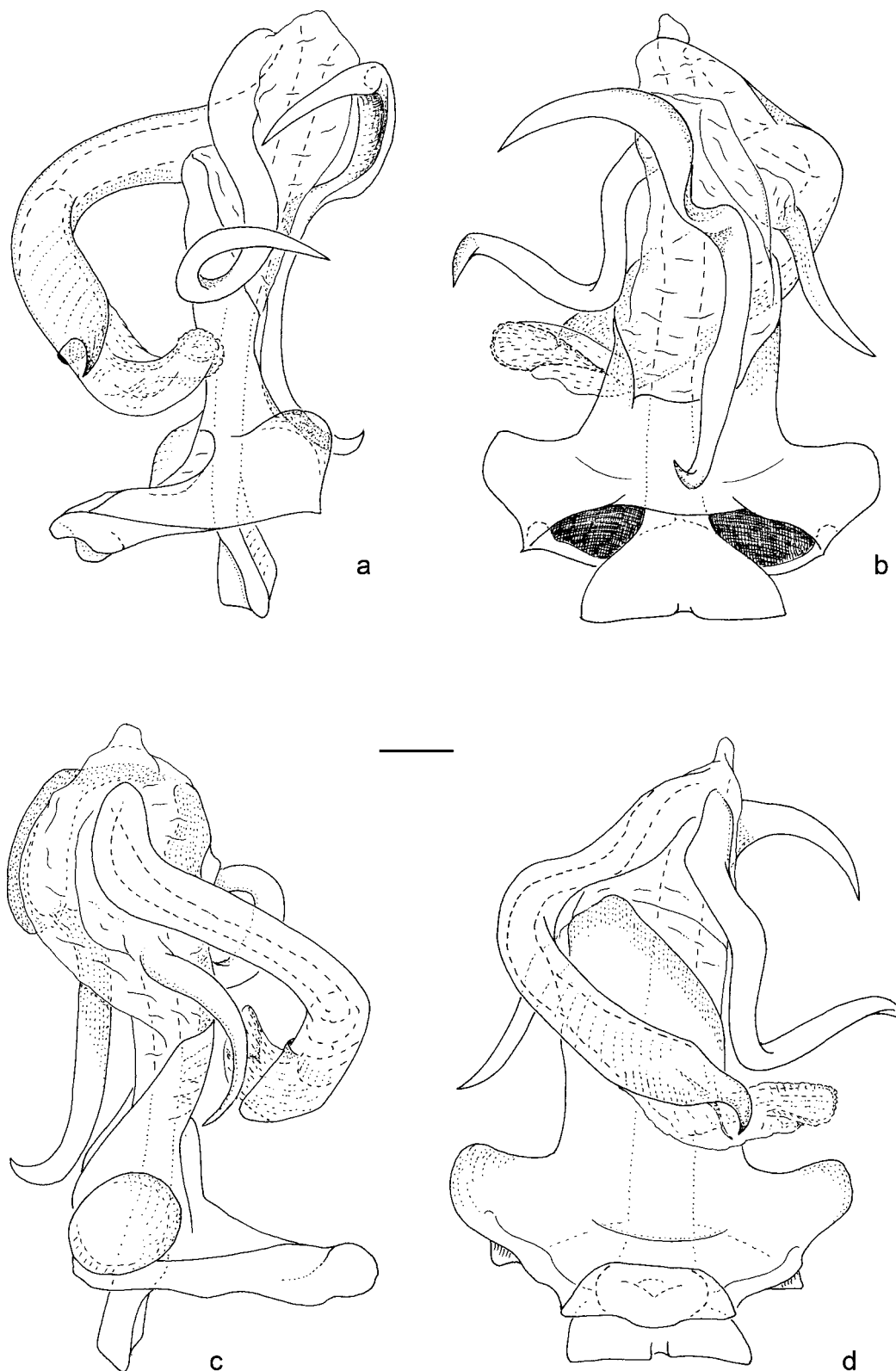


Figure 5. *Celebenna thomarosa* sp. n., male genitalia: Aedeagus; **a.** Left lateral aspect; **b.** Ventral aspect; **c.** Right lateral aspect; **d.** Dorsal aspect. Scale bar: 0.1 mm.

cave with roots in the dark zone and an associated fauna. Besides the Bennini planthoppers as sap-sucking primary consumers, the arthropod groups present in most of the Southeast Asian caves were also found here: large raphidophorid crickets, sparassid spiders,

and amblypygids, as well as several small spiders and cambalopsid millipeds; a predatory emesine bug was observed in close vicinity to the planthoppers.

The Maros Karst is of Eocene to middle Miocene age with younger basaltic and dioritic intrusions. Gua

Assuloang shares a common feature of Maros Karst caves possibly influenced by these intrusions: the cave is highly structured and forms a narrow and deep corridor in the explored dark zone passage (cf. Deharveng & Bedos 2004). The narrow (1–2 m) but high (clear height more than 6 m) fissure cave-like section was filled with mud and stagnant water pools up to the largest width, the air was saturated with moisture, temperature about 20 °C. All specimens of *C. thomarosa* were collected in the dark zone ca. 100 m away from the entrance, feeding on roots of an unidentified plant species, which were abundant at this section (Fig. 2d).

Behaviour

Intraspecific communication. Surface-dwelling planthoppers have long been known to use substrate-borne vibrations for locating and recognizing conspecific partners for mating (e.g., Ossiannilsson 1949; Claridge 1985; Drosopoulos & Claridge 2006). Although only a single pair of adult *Celebenna thomarosa* was available for live observation, we managed to obtain vibrational signals from both the male and the female (Fig. 6). The recorded calls consist of more or less homogenous pulse trains. Overall lengths of single calls have durations of 4.8 to

11.5 s (mean: 9.83 s, SD: 1.91). We did not observe any pronounced sexual dimorphism. At higher temporal resolution, single calls were seen to consist of distinct syllables, interspersed with more or less regular gaps. In the male, calls measured ($N = 1$; $n = 7$) single syllables have a mean duration of 182 ms, syllable interval is on average 267 ms. Within the syllables, interpulse intervals are 7.4 ms on average ($n = 20$). The carrier frequency is about 170 Hz, no significant frequency or amplitude modulation were observed. The general characteristics of observed vibrational signals in *Celebenna thomarosa* sp. n. are consistent with those of other Cixiidae (e.g., Hoch & Howarth 1993; Tishechkin 1997). Due to the extremely small sample size and the less than natural conditions under which they took place, these observations, however, are far too preliminary to classify the calls emitted by either sex as exploratory, courtship or mere distress. The emissions of the vibrational signals were not accompanied by any conspicuous movement of the lateral abdominal appendages. Further studies of intraspecific communication in *Celebenna thomarosa* and – most desirably – of interactive behaviour with other organisms (predators, parasites) in their natural habitat might provide us with insights on the function of the unique lateral appendage-sensory organ.

Locomotion/flight. In repose and during walking, the lateral abdominal appendages are directed dorsoanteriorly as is shown in Figure 3. As is expected from the configuration of tegmina and wings, *Celebenna thomarosa* is capable of flight. When disturbed during the behavioural observation session, the female took off into a comparatively slow, fluttering motion, resembling the locomotory pattern of moths of comparable size, covering ca. 3–4 m before assuming again a resting position. We were not able to detect any distinctive movement of the lateral appendages before, during or (immediately) after the flight.

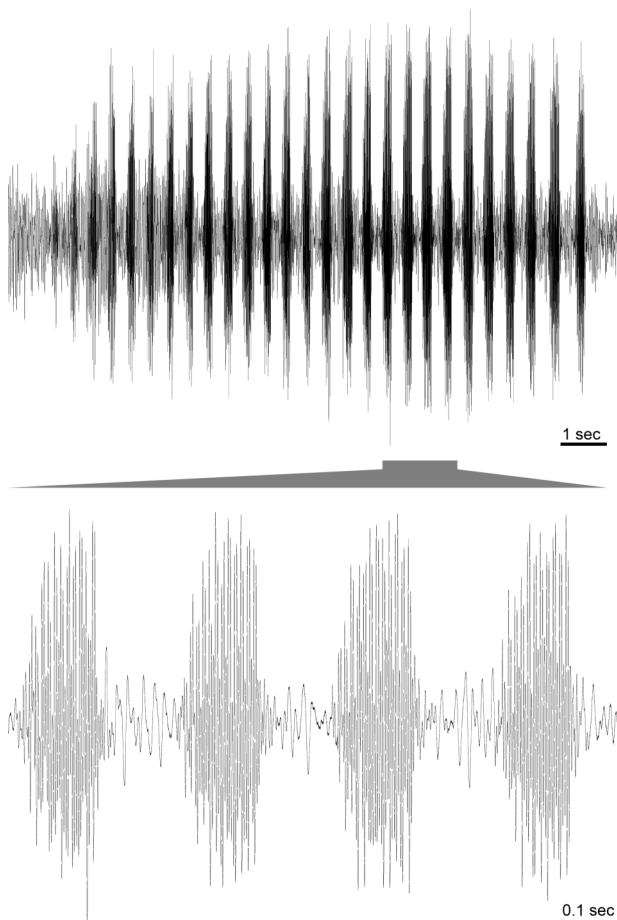


Figure 6. Time-amplitude pattern of a single male call of *Celebenna thomarosa* sp. n., shown at 1 s (above), and section of 4 syllables (below) at 0.1 s temporal resolution.

Discussion

Adult *Celebenna thomarosa* individuals do not show any significant troglomorphies, however, they are also not known from epigean environments. It is conceivable that the *C. thomarosa* specimens found in the cave are accidentals or troglophiles, perhaps in search of cool and moist habitats to feed, to mate, oviposit and/or to reduce predation risk. As the animals were found quite a distance from the entrance, it is more probable, however, that they emerged from eggs deposited in the soil, wandered into the caves (instead of towards the surface) where they may be able to survive and even reproduce, and eventually even develop troglomorphies in the course of an adaptive shift as has been postulated by Howarth (Howarth 1986; Howarth & Hoch 2005). As there have been no nymphs associated with the adults, i.e. seasonality may be (still) maintained (which is usually not the case in cavernicoles), the Maros Karst

Bennini planthoppers are, at most, in the very early stages of an adaptive shift. Adaptive shifts, in general, act in the first place on behavioural adaptations, and in comparative studies the subsequently acquired morphological troglomorphies have shown no correlation with the assumed age of cave lineages (Wessel et al. 2007). The planthopper nymphs feeding on roots can be defined as *terrestrial epikarst fauna*. Wandering in the caves, the emerging adults can survive and reproduce from the outset in the dark zone by a set of exaptations. It is assumed that the ability of planthoppers to communicate by substrate vibrations is one of the crucial prerequisites for the permanent colonisation of cave environments (Hoch 2000; Hoch & Wessel 2006). Furthermore, the ability to produce excessive wax may be important for coping with the constant high air humidity and for minimizing the risk of fungal infection.

According to the ecological classification suggested by Sket (2008) we could describe *Celebenna thomarosa* as *exapted eutroglophile accidentals*. The precise function of the lateral appendages and a possible role in orientation in darkness is unknown. A well-studied example from Hawaii, the blind, flightless and unpigmented cixiid *Oliarus polyphemus* Fennah, shows that populations from different lava tubes display species-specific vibrational signal patterns, eventually revealing a complex pattern of incipient subterranean speciation (Hoch & Howarth 1993; Wessel & Hoch 1999; Wessel 2008). The successful recording of vibrational signals from the Maros cave planthopper may open up a new model system for the study of the dynamics of (subterranean) evolution.

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Author contribution

A. W. carried out the cave survey (in collaboration with T. von Rintelen) in Sulawesi, collected the species, and contributed information on its ecology. H. H. provided the background information on the taxonomy and morphology of the Bennini, incl. figures of male genitalia. R. M. recorded the vibrational communication signals. R. M. and A. W. provided the signal analysis. B. S. generated the map and helped with image processing. E. W. contributed the photographs of *Celebenna thomarosa*, and assisted with behavioural observation. H. H. and A. W. wrote the manuscript.

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