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The tropical African genus *Morgenia* (Orthoptera, Tettigoniidae, Phaneropterinae) with emphasis on the spur at the mid tibia

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Abstract

The authors revised the genus *Morgenia* Karsch, 1890 which now consists of eight species, of which three are here newly described (*Morgenia plurimaculata* Massa & Moulin, **sp. n.**, *M. angustipinnata* Massa, **sp. n.,** and *M. lehmannorum* Heller & Massa, **sp. n.**). Six of the eight species occur in the Tri National Sangha (TNS) comprising Dzanga-Sangha Special Reserve and Dzanga Ndoki National Park (Central African Republic), whose high biodiversity has been recently highlighted. In particular the genus is characterised by the presence of a more or less long spur at the inner mid tibia, different in each species; in *M. modulata,* it moved lower down into a new position at about ¼ of tibia, which has a hollow underneath where the rest of the spur remains hidden. This is a unique known case in Phaneropterinae. Morphological characters distinguishing males of different species are presented. Bioacoustics of the new species *M. lehmannorum* are described. The patterns of the chromosome evolution in *M. lehmannorum* differ from other investigated African Phaneropterinae in terms of chromosome number and morphology, reduced ancestral chromosome number (2n = 25) implying a more derived condition.

Introduction

The genus *Morgenia* was described by Karsch (1890a), together with the species *M. hamuligera* (type species of the genus). Later, Karsch (1893, 1896) described *M. melica* and *M. modulata*, Griffini (1908) described *M. spathulifera* and Sjöstedt (1913) *M. rubricornis* respectively. Apart from that of Griffini (1908), the descriptions are short and, in some cases, it is very difficult to understand differences between species without examination of the types. For this reason, Massa (2013) considered that very likely some of them were synonymously described. However, more recently Massa (2017a) has shown the differences that allow *M. spathulifera*, *M. hamuligera*, *M. rubricornis* and *M. melica* to be separated, highlighting that *M. spathulifera* has narrower tegmina than the other taxa. A long series of specimens belonging to this genus were available in recent years from different countries of tropical Africa. This allowed a deeper study of their characters and the comparison with the types and photographs in Orthoptera Species File Online (Cigliano et al. 2018). In the present paper, the results of this study are reported, with the description of another three species.

Presently eight species of *Morgenia* are known in tropical Africa; six of them occur in the Tri National Sangha (TNS) comprising Dzanga-Sangha Special Reserve and Dzanga Ndoki National Park (Central African Republic). We should point out the remarkable importance of this area from the conservation and the biodiversity point of view. Recently different papers on insects of this area have been published, showing the high diversity of co-occurring species (Massa 2013, 2015, 2016, 2017b, Tortorici et al. 2016, Hemp and Massa 2017, Moulin et al. 2017).

Material and methods

Morphology

Some specimens were collected in the field during expeditions in tropical Africa. Most Orthoptera were collected at night with the aid of UV lamps, one installed above ground, the other placed under a canopy. Specimens were dried by smoke and preserved individually in paper bags each day. These bags were later sent to the Department of Agricultural, Food and Forest Sciences, Palermo University, Italy and were later mounted.

Central African Republic site: Dzanga-Ndoki National Park is part of the Sangha Trinational, a UNESCO World Heritage Site which covers an area of 4,520,000 ha and includes three national Parks: Loboke (Cameroon), Nouabale-Ndoki (Congo) and Dzanga-Ndoki (Central African Republic). Dzanga-Ndoki National Park is located in the Congo River basin, within an extensive tropical forest, approximately six days walk from the nearest inhabited village and constitutes a very rich sanctuary of biodiversity which is still poorly known. The park is bordered to the West by the Sangha River, which also borders with Cameroon and contains more than ten natural lakes of different size (from ca. 1 km by 400 m to 100 m by 150 m). Dzanga-Ndoki National Park is located in the extreme southwest of the Central African Republic, in a triangular-shaped part of the country. Established in 1990, it is divided into two non-continuous sectors: the northern Dzanga Park (49,500 ha) and the southern Ndoki Park (72,500 ha). The two are joined by the Dzanga-Sangha Rainforest Reserve (335,900 ha), where controlled hunting and other exploitation is allowed. The whole park is on alluvial sands; along streams, forest clearings can be found with marshy depressions. The Dzanga Bai (= the village of elephants) is a sandy salt lick that measures 250 m by 500 m. It is traversed through the middle by the Dzanga stream. There are three types of forest within Dzanga-Ndoki National Park: mainly dry-land, a semi-evergreen forest that contains swamp-forest areas along the rivers and a closed-canopy, mono-dominant *Gilbertiodendron dewevrei* forest. The dry-land forest is an open, mixed canopy that is dominated by Sterculiaceae and Ulmaceae; often associated with it is a dense understorey of Marantaceae and Zingiberaceae (Massa 2013).

Gabonese site: Research Station on Gorilla and Chimpanzee (SEGC-CIRMF, Station d'Etudes des Gorilles et Chimpanzés, gérée par le Centre International de Recherches Médicales de Franceville) is situated in the northern part of Lopé National Park, about 10 km south from Lopé village and the Dr Alphonse Mackanga Missandzou Training Center (CEDAMM, Wildlife Conservation Society; coordinates: 0°12'09.62"S, 11°36'05.19"E; altitude 265m). Vegetation comprises a mosaic of forest and shrub savannah. Shrub savannah is dominated by Poaceae and Cyperaceae like *Anadelphia arrecta*, *Andropogon pseudapricus*, *Schizachyrium platyphyllum*, *Hyparrhenia diplandra* or *Ctenium newtonii* and by a shrub layer with *Nauclea latifolia* and *Crossopteryx febrifuga* (White and Abernethy 1997). Forest patches are mainly secondary to mature okoumé rainforests, the dominant forest type in western Gabon, dominated by *Aucoumea klaineana* ("okoumé"), *Desbordesia glaucescens*, *Scyphocephalium ochochoa*, *Dacryodes buttneri*, *Santiria trimera*, *Sindoropsis letestui*, *Lophira alata* and *Uapaca guineensis* (Ben Yahmed and Pourtier 2004, White and Abernethy 1997).

Ivory Coast site: Research Station in the Taï Forest National Park. It is one of the last primary forests in western Africa, UNESCO Heritage, is bordered by the Sassandra river to the east, by Liberia to the west, by Peko and Saon Mts to the north and by Nieno Koué Mt. to the south. The park covers 3,300 km^2. Some entomological expeditions to Taï Forest were carried out in 2015–2017, managed by Philippe Moretto.

A series of specimens were examined from collections housed in the museums or collections cited below. Abbreviations used in this paper:

BMPC	Bruno Massa Collection, University of Palermo;
MfN	Museum für Naturkunde, Berlin;
MNHN	Museum national d'Histoire naturelle, Paris;
MRT	Museo Regionale di Storia Naturale, Terrasini (Palermo);
MSNG	Museo Civico di Storia Naturale 'G. Doria', Genoa;
NHMW	Naturhistorisches Museum, Vienna;
NHRS	Natural History Museum, Stockholm;
RBINS	Royal Belgian Institute Natural Sciences, Bruxelles.

Some specimens were photographed with a Nikon Coolpix 4500 digital camera, mounted on a Wild M5 Stereomicroscope or Leica MZ75 and photographs were integrated using the freeware CombineZP (Hadley 2008). Mounted specimens were measured with a digital calliper (precision 0.01 mm); the following measurements were taken (in mm): Body length: dorsal length from the head to the apex of the abdomen; Tegmina: length and maximum width of tegmina; Ovipositor: maximum length, subgenital plate included.

The shape of the stridulatory file under the male's left forewing and the number and arrangement of the teeth are useful characters that identify whether a species is bioacoustically separated from another one (Ragge 1980, Heller 2006). Therefore, the stridulatory file of each species was photographed and described.

Bioacoustics

Bioacoustical methods and terminology. The male calling songs of one specimen of a new species from Uganda (*Morgenia lehmannorum* Heller & Massa sp. n.) were

recorded in the laboratory using a digital bat detector (Pettersson D1000X; sampling rate 100 or 192 kHz). The sounds were analysed using the programmes Amadeus II (Martin Hairer; http://www.hairersoft.com) and Audacity (Audacity 2.1.0; http://audacity.sourceforge.net). For the frequency measurements, 8–12 ms sections were evaluated, using fast fourier transformation (FFT) analysis, hanning window, 512 points per frame, one or mean of several overlapping frames. Oscillograms of the songs were prepared using Turbolab (Bressner Technology, Germany). All recordings were made at temperatures between 20 and 21 °C. The singing insect was caged in a gauze cage with a microphone fixed at a distance of ca. 80 cm. Results are given as mean±standard deviation.

The following definitions describe the terminology used during this work:

Syllable: sound produced during one cycle of movements (opening and closing of the tegmina); syllable duration: time period measured from the first impulse to the last; impulse: a simple, undivided, transient train of sound waves (here: the damped sound impulse arising from the contact of one tooth of the stridulatory file with the scraper); pulse: undivided train of sound waves increasing in amplitude at the beginning and containing several similarly sized wave maxima and minima (cricket-like song structure).

Cytotaxonomic analysis

One male (CH7840) of *Morgenia lehmannorum* Heller & Massa sp. n. was used for cytotaxonomic analyses. The testes were incubated in a hypotonic solution (0.9% sodium citrate) and fixed in ethanol : acetic acid (3:1). The fixed material was stored in 70% ethanol at 2 °C until use. Subsequently, the testes were macerated in 45% acetic acid and squashed. The cover slips were removed using the dry ice procedure and the preparations were air dried. The C-banding examination was carried out according to Sumner (1972) and the silver staining method (with $AgNO_3$) for the nucleolar organiser region (NOR) was performed as previously reported (Warchałowska-Śliwa and Maryańska-Nadachowska 1992).

DNA barcoding

DNA barcoding, the analysis of a standardised segment of the mitochondrial cytochrome c oxidase subunit I (COI) gene, was performed on three specimens from Gabon in the project context: "ORGAA – Orthoptera of Gabon – Project 1 [ECOTROP 2014]" on Barcode of Life Data System (BOLD, Biodiversity Institute of Ontario, Canada; boldsystems.org). Tissues were sent to the Canadian Institute for DNA extraction, polymerase chain reaction (PCR) and sequencing. PCR was performed using the PCR primers C_LepFolF/C_LeFolR (Ratnasingham and Hebert 2007). Sequences were then analysed using BOLD 4.0 interface.

Results and discussion

Taxonomy

Characters of the genus *Morgenia* Karsch, 1890 (Tribe Poreuomenini Brunner von Wattenwyl, 1878)

Fastigium of vertex quite acuminate, not contiguous with fastigium of frons. Pronotum narrow, superiorly flat, anterior margin concave, posterior margin rounded, humeral sinus rounded, lateral lobes as wide as high, inferior margin rounded. Tegmina with rounded margins, wide mirror in the right tegmen. Wings exceeding tegmina a little. Legs slender, fore coxae armed, femurs inferiorly armed, fore tibiae with inner tympanum conchate, outer open; fore and mid tibiae superiorly sulcate, with spinules. Mid tibiae of males provided with an inner ventral moving spur before the apex, not exceeding the first tarsal article, longer or shorter depending on the species (with the exception of *M. modulata*, where it has a different shape); in the females, this spur is absent. Supra-anal plate nearly concave, cerci stout, curved and provided with an apical spine. Subgenital plate deeply concave, wide, without styli (Karsch 1890a, pers. obs.).

The species of the genus *Morgenia* have one of two types of cerci: a) club-shaped, with concave internal and rounded external part, armed at the apex; b) stout and incurved, with concave internal and rounded external part, armed at the apex. In addition, four lesser known facts have been highlighted: c) tegmina may be more or less wide and differences in the ratio length/width allow the separation of some species; d) costal area of tegmina may have a pattern with regularly spaced crossveins or a net of small cells; e) the inner ventral spur of the mid tibia has three different patterns; f) the stridulatory file is very characteristic for each species. Here the species are arranged by the type of cerci, according to their affinities.

The two final tables and relative photographs summarise the main characters of the species.

Annotated list of species

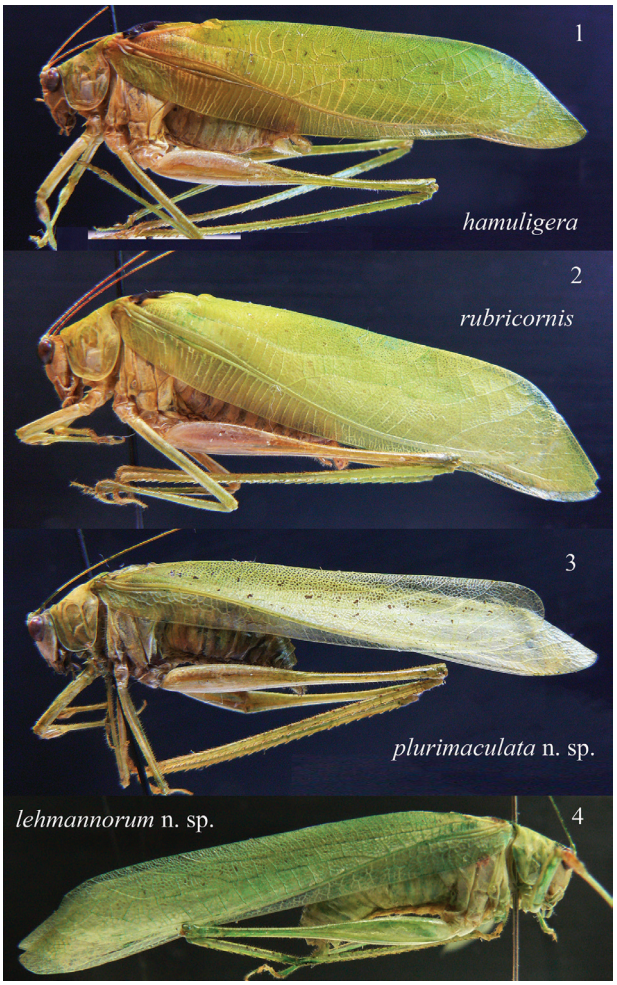
Morgenia hamuligera Karsch, 1890

Figs 1, 9, 13, 20, 27, 37, 38

Karsch, 1890a. Entom. Nachricht. 16: 263.

Type locality: Kribi (Cameroon) (MfN, Berlin).

Material examined. Cameroon, Kribi (holotype ♂) (MfN); Central African Republic, Sangha Special Reserve, Epiphyte 2008 Expedition, Camp 2, 22–23.X.2008 (light) (2♂), P. Annoyer; Central African Republic, Dzanga-Ndoki National Park, Ndoki, Lakes Region (light) 31.I.–23.II.2012 (10♂), Sangha2012 team; Mboki, 24.I.2012 (3♂), Sangha2012 team; 35 km S Bangui, env. Salanga, 28–31.XII.2008, J. Halada (1♂); Gabon, Lope National Park, SEGC-CIRMF 12.III.2013 (light), N. Moulin (1♂); Ivory Coast, Taï Nat. Park, Res. Station



Figures 1–4. Habitus of the male of *Morgenia hamuligera* (**1**), *M. rubricornis* (**2**), *M. plurimaculata* sp. n. (**3**) and *M. lehmannorum* sp. n. (**4**) (left side for the first three species, right side for the fourth species).

16–20.III.2017 (light), B. Massa (5♂); Ivory Coast, Taï Nat. Park, Res. Station 22.III-4.IV.2017 (light) (7♂, 1♀), P. Moretto (BMPC).

Distribution. *M. hamuligera* was the first species described in the genus *Morgenia*, from Kribi (Cameroon) and later reported from Barombi Station (Cameroon) (Karsch 1890a, 1890b). Griffini (1906, 1908) recorded it from Fernando Poo (Equatorial Guinea) and Umangi (Democratic Republic of Congo), Ebner (1943) from Fernando Poo and Massa (2013) from Central African Republic. It is here reported from Gabon and Ivory Coast.

Remarks. The short description by Karsch (1890a) points out the presence of a blackish spot on the stridulatory area of the left tegmen; the shape of this spot is similar to that of *M. rubricornis* (see below), but its inner margin is more or less rectangular, not triangular, as in *rubricornis* (Figs 9, 10, 13, 14). The mirror of the right tegmen is wide (Fig. 9). Antennae may be yellowish or reddish. The pattern of the costal area of the tegmina has regularly spaced crossveins (Fig. 9). The stridulatory file is 3.5 mm long, arched and composed of ca. 80 dense and evenly spaced teeth in the proximal part, followed by ca. 70 more or less widely spaced teeth in the distal part (Fig. 20). The inner ventral spur of the mid tibiae is long and does not exceed the first tarsal article; its length is about 18–20% of the tibia length. On the outer ventral margin of the mid tibiae, three close short spines are present (Fig. 27). Cerci are very stout, club-shaped, the ratio tegmina length/width is 4.0 (Figs 37–38, Table 1).

Morgenia rubricornis Sjöstedt, 1913

Figs 2, 10, 14, 20, 28, 35, 36

Sjöstedt, 1913. Ark. Zool. 8 (6): 4.

Type locality: Mukimbungu (Democratic Republic of the Congo) (NHRS Stockholm).

Material examined. Central African Republic, Dzanga-Ndoki National Park, (light) 22.X.2008 (light), P. Annoyer (1♂); same data 24.II.2012 (light), P. Annoyer (1♂); 31.I.–29.II.2012 (11♂, 1♀) (light), Sangha2012 team; **Gabon**, Lope National Park Res. Station, Ogooue-Ivindo 28–31.III.2014 (light), (2♂, BOLD LopeORT14-617 and -673) (light), ecotrop 2014 team; **Ivory Coast**, Korhogo, Kogo 21.VII.2014 (1♂) (light), P. Moretto; Man Mt. Tonkoui (1200 m) 28.VI-1.VII.2014, 18–20.VI.2015 (2♂) (light), P. Moretto; Touba, Biémasso 10–11.VII.2013 (1♂) (light), P. Moretto; Täi National Park, Res. Station 20.III.2017 (light), B. Massa (1♂) (BMPC).

Distribution. *M. rubricornis* was known only from the type locality; however, it has also been found in Central African Republic, Gabon and Ivory Coast (see material examined). Thus, its distribution probably covers central and western tropical Africa.

Remarks. According to Sjöstedt (1913), *M. rubricornis* was the largest species of the genus known at that time. He also reported measurements of the length and width of the tegmina (39.0 and 12.0) of the holotype; even if his values are much higher than those of specimens measured by us, the ratio length/width of the tegmina (3.25) lies within the variability observed in this taxon (Table 1). The male of this species is easily identifiable by its dark spot in the left tegmen; it has a larger base and a narrower tip than that of *M. hamuligera* (compare Figs 9, 10, 14). The mirror of the right tegmen is smaller than in *M. hamuligera* (Fig. 10). Antennal segments are generally reddish (from this character the name *rubricornis*). The pattern of the costal area of the tegmina has regularly spaced crossveins (Fig. 10). The inner ventral spur of the mid tibiae is short, more or less directed upwards and reaches the middle of the first tarsal article; its length is about 4.5–5.0% of the tibia length. On the outer ventral margin of the mid tibiae, three close short spines are present (Fig. 28). The stridulatory file is 2.2 mm long, arched and composed of ca. 60 dense and evenly spaced teeth in the proximal part, followed by ca. 50 widely spaced teeth in the distal part (Fig. 20). The subgenital plate of the male in ventral view is very similar to that of *M. hamuligera*, while, in the lateral view, it appears more upwards bent (compare Figs 35–36 with 37–38).

Table 1. Measurements of tegmina length and width and ratio of tegmina length/width of the eight species currently known in the genus *Morgenia*.

Species	Tegmina length	Tegmina width	Tegmina length/width
Morgenia hamuligera (n = 10)[1]	33.2±1.4 (30.3–34.9)	8.3±0.4 (8.0–9.2)	4.0±0.3 (3.5–4.2)
Morgenia rubricornis (n = 10)	29.4±1.1 (27.5–30.2)	7.5±0.5 (7.0–8.5)	3.9±0.2 (3.3–4.2)
Morgenia spathulifera (n = 5)	29.6±1.4 (27.9–31.4)	4.5±0.1 (4.3–4.6)	6.6±0.2 (6.4–6.8)
Morgenia plurimaculata sp. n. (n = 10)	34.1±0.9 (33.0–35.7)	8.0±0.2 (7.8–8.5)	4.2±0.1 (4.1–4.4)
Morgenia lehmannorum sp. n. (n = 1)	32.5	5.4	6.0
Morgenia angustipinnata sp. n. (n = 4)	32.0±1.7 (30.5–33.9)	5.0±0.4 (4.7–5.4)	6.4±0.1 (6.3–6.5)
Morgenia melica (n = 10)	34.3±2.2 (29.0–36.9)	7.6±0.3 (7.0–8.0)	4.5±0.2 (4.1–4.8)
Morgenia modulata (n = 10)	30.4±0.9 (29.1–31.4)	6.7±0.5 (6.0–7.6)	4.5±0.2 (4.1–4.9)

[1] Massa (2017a) reports 5.5–5.6 as ratio length/width of tegmina in *M. hamuligera* and *M. rubricornis*, but more accurate measurements allowed to change them to 4.0 and 3.9, respectively.

Morgenia spathulifera Griffini, 1908

Figs 5, 11, 23, 32, 43, 44

Griffini, 1908. Mem. Soc. entom. Belgique, Bruxelles 15: 209.

Type locality: Bussanga (Democratic Republic of Congo) (RBINS, Bruxelles).

Material examined. Democratic Republic of the Congo, Bussanga 14.XI.1905 (1♂ syntype); Ngowa 9.I.1939 (1♂), J. Mertens; **Cameroon**, Mukonje Farm, R. Rohde (1♀ syntype); Mt Koupé 31.I-8.II.1983 (1♂), J. van Stalle (RBINS); **Ivory Coast**, Taï Nat. Park, Res. Station 13.III.2017 (1♂) (light), B. Massa; Taï Nat. Park, Res. Station 22.III-4.IV.2017 (2♂) (light), P. Moretto (BMPC).

Distribution. *M. spathulifera* is presently known from Cameroon, Democratic Republic of the Congo and Ivory Coast (Griffini 1908, Massa 2017). We presume that it covers central and western tropical forests of Africa.

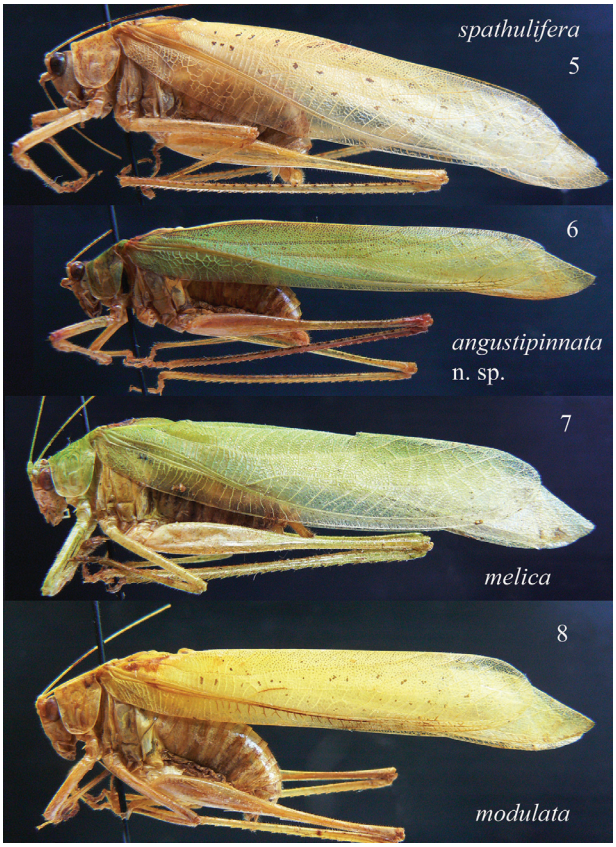
Remarks. *M. spathulifera* may be easily separated from other known species by the ratio length/width of the tegmina (6.4–6.8). It is also characterised by the presence of small grey dots on the tegmina and costal area of the tegmina with a net of small cells (Figs 5, 11). The stridulatory area of the left tegmen is protruding below its posterior margin and it is composed of the stridulatory file and has a raised parallel posterior bulge (Fig. 11). The mirror of the right tegmen is smaller than in *M. hamuligera* (Fig. 11). The stridulatory file is 1.2 mm long, arched and composed of ca. 60 densely spaced teeth (Fig. 23). The inner ventral spur of mid tibiae is more apical, short, up- and incurved and does not exceed the base of the first tarsal article; its length is about 2.5–3.0% the length of tibia. On the outer ventral margin of the mid tibiae, three close short spines are present (Fig. 32).

Morgenia plurimaculata Massa & Moulin, sp. n.

http://zoobank.org/E89917DE-ECC8-4A48-A0E5-6BA932D95018

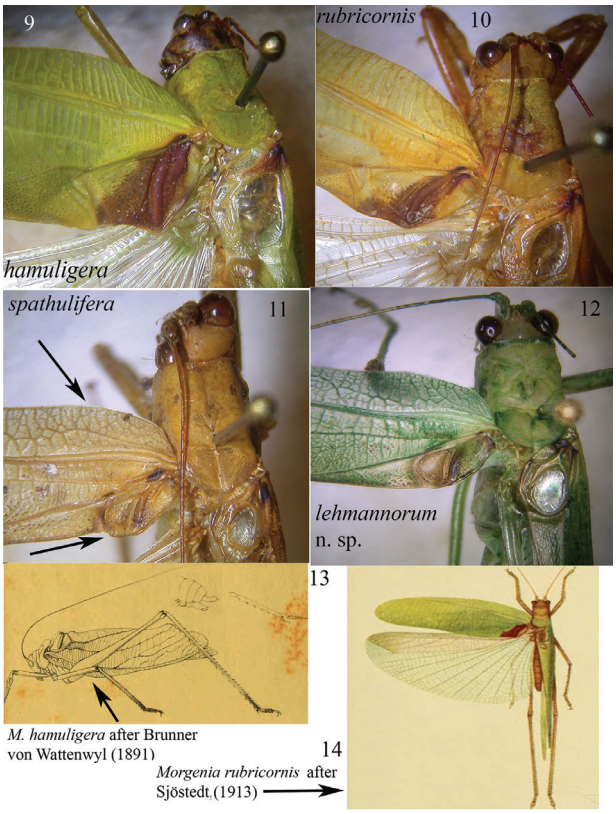
Figs 3, 15, 21, 29, 41, 42

Material examined. Central African Republic, Dzanga-Ndoki National Park, Lakes Region (02°28’40.5”N, 16°13’02.6”E) 31.I.–29.II.2012 (light), Sangha2012 team (1♂ holotype, 19♂ and 3♀ paratypes); Mboki (5°18’31”N, 25°57’16”E) 24.I.2012 (2♂ paratypes) (♂ holotype and 1♀ paratype in the MSNG, other paratypes in BMPC); Sangha Special Reserve, Epiphyte 2008 Expedition, Camp 2, 21.X.2008 (light), P. Annoyer (1♂ paratype); 30.I-4.II.2012 (light), Sangha2012 team (2♂, 1♀ paratypes) (1♂ and 1♀ paratypes in the MNHN, other paratypes in BMPC). Some specimens here listed were erroneously identified by Massa (2013) as *M. hamuligera*.

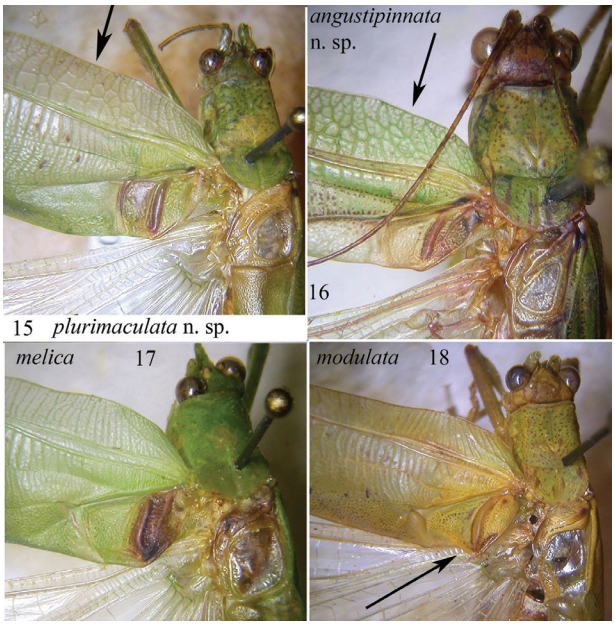


Figures 5–8. Habitus of the male of *Morgenia spathulifera* (**5**), *M. angustipinnata* sp. n. (**6**), *M. melica* (**7**) and *M. modulata* (**8**) (left side).

Distribution. At the present time, known only from the type locality, Dzanga-Ndoki National Park (Central African Republic).



Figures 9–14. Stridulatory area of left tegmen and mirror of right tegmen of the male of *Morgenia hamuligera* (**9**), *M. rubricornis* **(10)**, *M. spathulifera* **(11)**, *M. lehmannorum* sp. n. **(12)**; habitus of *M. hamuligera* after Brunner von Wattenwyl (1878) **(13)** and of *M. rubricornis* after Sjöstedt (1913) **(14)**. Arrow shows the particular net of small cells in the costal area of tegmina of *M. spathulifera*, present also in *M. lehmannorum* sp. n.



Figures 15–18. Stridulatory area of left tegmen and mirror of right tegmen of the male of *Morgenia plurimaculata* sp. n. **(15)**, *M. angustipinnata* sp. n. **(16)**, *M. melica* **(17)** and *M. modulata* **(18)**. Arrows in *M. plurimaculata* sp. n. and *M. angustipinnata* sp. n. show the net of small cells in costal area of their tegmina, while in *M. modulata* the protruding stridulatory area.

Colour. Head and pronotum yellow-green with scattered brown spots, antennae yellowish, abdomen yellow-brown, cerci yellow-blackish, tegmina with a black spot at their base, green with black stridulatory area and small brown spots between cells; in some specimens, the black area is lacking. One black spot between tympana of fore tibiae is found only in males.

Description. Males. Head and antennae. Fastigium of vertex narrow, sulcate above, not contiguous with fastigium of frons. Eyes rounded, well projecting. Antennae longer than body. Legs. Fore coxae armed with a fine spine. Fore tibiae furrowed on upper margin, distinctly widening above tympanum, conchate on inner, open on outer side. Fore femora armed on inner ventral side with 6 small spines, fore tibiae with 4 spines + 1 spur on inner side and 3 spines + 1 spur on outer ventral side, mid femora unarmed, mid tibiae with 4–5 outer and 2–3 inner ventral spines. The inner ventral spur of mid tibiae is short and does not exceed the first tarsal article; its length is about 5.0–5.5% the length of tibia. On the outer ventral margin of mid tibiae, three closely set short spines are present (Fig. 29). Hind femora armed with 3–4 small spines on outer and 2–3 on inner ventral sides, hind tibiae with many spines on ventral and dorsal sides + 3 spurs on each side. Thorax. Pronotum narrowing at the level of the humeral sinus, flat above, lateral margins rounded, anterior margin incurved, posterior rounded, humeral sinus well developed, lobes of pronotum rounded. Tegmina narrow with rounded apices (Figs 3, 15, measurements in Table 1), wings longer than tegmina. Stridulatory area of the left tegmen composed of the stridulatory file and of a raised parallel posterior bulge (Fig. 13). Mirror of the right tegmen smaller than in *M. hamuligera* (Fig. 15). Pattern of costal area of tegmina with a net of small cells; stridulatory file 2.8 mm long, arched and composed of ca. 90 widely spaced teeth (Fig. 21). Cerci club-shaped with an apical spine, the inner part is concave, the outer rounded. Subgenital plate widely concave in ventral view with tips downwards bent in lateral view (Figs 41, 42).

Females. Same characters of the males except for the following. The colour of fore legs is yellow without the black spot between tympana. Also, tegmina lack the black area but have small brown spots between cells. Interestingly, the costal area of tegmina differes from that of males by the regularly spaced crossveins. Ovipositor gently up-curved, 6.8–7.0 mm long, tips finely toothed. Cerci long and pointed, subgenital plate narrow and pointed.

Diagnosis. *M. plurimaculata* sp. n. is characterised by club-shaped cerci, a short spur on the mid tibia, the stridulatory area with a small dark spot, many small dark spots scattered on tegmina in most specimens, pattern of the costal area of tegmina with a net of small cells and a stridulatory file that is 2.8 mm long, arched and composed of ca. 90 widely spaced teeth. The stridulatory area is composed of the stridulatory file and of a raised parallel

posterior bulge. Differences to other species of the genus are summarised in Table 2.

Etymology. From Latin *plus pluris* = many and *maculata* = provided with spots.

Morgenia lehmannorum Heller & Massa, sp. n.

http://zoobank.org/D2D2EC20-466B-4F8C-A819-09FC9BEEA163
Figs 4, 12, 22, 30, 39, 40

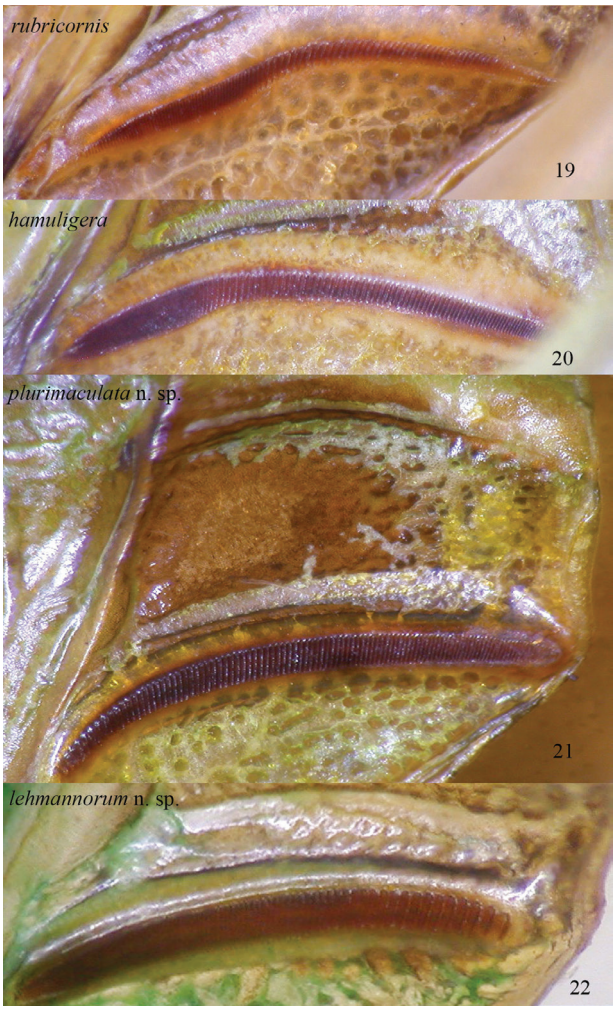
Material examined. Uganda, Semliki Forest National Park (00°49'30"N, 30°03'40"E) 1–31.VIII.2014, A. and G. Lehmann (♂ holotype) (MfN).

Distribution. Presently known only from the type locality, Semliki Forest (Uganda).

Colour. Green, with the exception of tympana of fore legs that are brown and one black spot between tympana. Stridulatory area brownish. Black spots at the base of tegmina.

Description. Males. Head and antennae. Fastigium of vertex narrow, sulcate above, not contiguous with fastigium of frons. Eyes rounded, well projecting. Legs. Fore coxae armed with a fine spine. Fore tibiae furrowed on upper margin, distinctly widening above tympanum, conchate on inner, open on outer side. Fore femora armed on inner ventral side with 4 small spines, fore tibiae with 2 spines + 1 spur on inner ventral side and 1 spine + 1 spur on outer ventral side, mid femora unarmed, mid tibiae with 2 outer and 2 inner ventral spines, inner ventral spur of mid tibiae long, up-curved, exceeding ¾ of the first tarsal article; its length is about 10% the length of tibia. On the outer ventral margin of mid tibiae, three close short spines are present (Fig. 30). Hind femora armed with 3 small spines on outer and 3 on inner ventral sides, hind tibiae with many spines on ventral and dorsal sides + 3 spurs on each side. Thorax. Pronotum narrowing at the level of the humeral sinus, flat above, lateral margins rounded, anterior margin straight, posterior rounded, humeral sinus well developed, lobes of pronotum rounded. Tegmina narrow with rounded apices (Figs 4, 12, measurements in Table 1), wings longer than tegmina. Stridulatory area of the left tegmen raised (Fig. 12). Mirror of the right tegmen smaller than in *M. hamuligera* (Fig. 12). Pattern of costal area of tegmina with a net of small cells; stridulatory file 1.8 mm long, arched and composed of ca. 100 teeth; the distal teeth of the stridulatory file are more widely spaced than the proximal ones, that are also more densely set together (Fig. 22). Cerci club-shaped with an apical spine, the inner part is concave, the outer rounded. Subgenital plate with a small apical concavity in ventral view with tips straight in lateral view (Figs 39, 40).

Diagnosis. *M. lehmannorum* sp. n. is characterised by narrow tegmina (Table 1), club-shaped cerci, a long and up-curved spur on the mid tibia, the stridulatory area brown, the costal area of tegmina with a net of small cells and the stridulatory file that is 1.8 mm long, arched and composed of ca. 100 teeth, the distal teeth are more widely, the proximal ones more closed set. Differences to other species of the genus are summarised in Table 2.



Figures 19–22. Stridulatory file of the left tegmen in the male of *Morgenia rubricornis* **(19)**, *M. hamuligera* **(20)**, *M. plurimaculata* sp. n. **(21)** and *M. lehmannorum* sp. n. **(22)**.

Etymology. We have the pleasure to dedicate this species to the German orthopterologists Arne and Gerlind Lehmann, who collected the only known specimen.

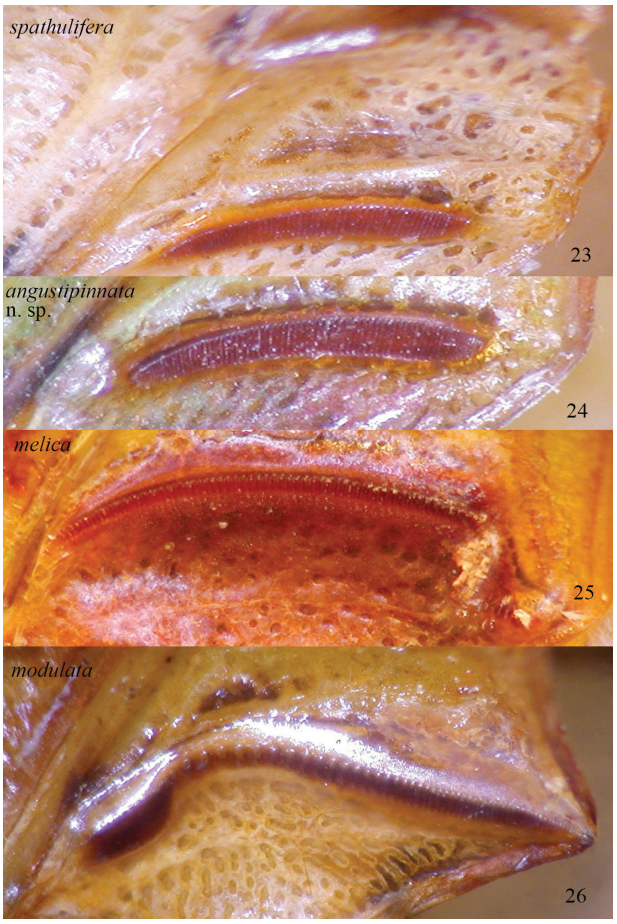
Morgenia angustipinnata Massa, sp. n.

http://zoobank.org/254C7B6A-00DD-4663-B44B-B0008D2587AF
Figs 6, 16, 24, 31, 45, 46

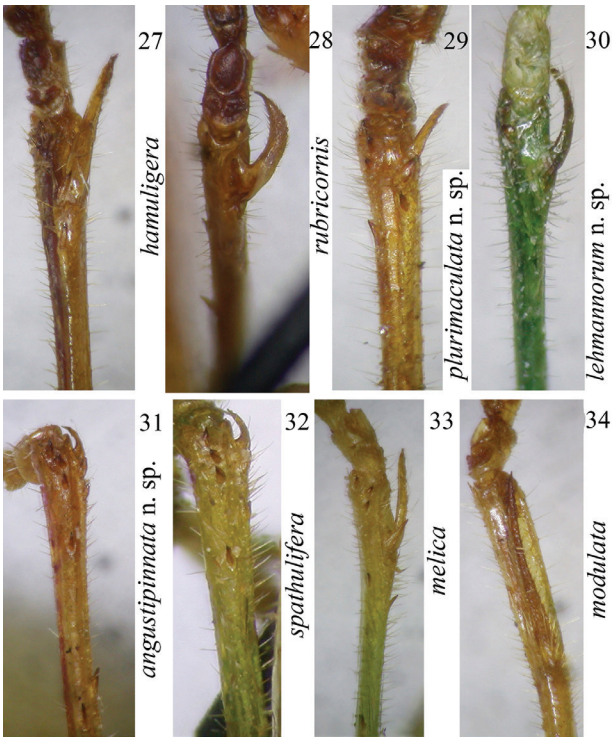
Material examined. Central African Republic, Dzanga-Ndoki National Park, Mboki (5°18'31"N, 25°57'16"E), 24.I.2012 (light), Sangha2012 team (1♂ holotype, MSNG); Dzanga-Sangha Special Reserve at 35m on canopy of *Terminalia superba* (02°20'03.0"N, 16°08'11.2"E, 375m) 9.II.2005, P. Annoyer (1♂ paratype, BMPC); same locality 13–23.II.2012 (light), Sangha2012 team (2♂ paratypes, BMPC).

Distribution. At the present time, known only from the type locality, Dzanga-Ndoki National Park (Central African Republic).

Colour. Head and pronotum yellow-green, antennae yellowish, abdomen yellow-brown, cerci yellow, tegmina



Figures 23–26. Stridulatory file of the left tegmen in the male of *Morgenia spathulifera* **(23)**, *M. angustipinnata* sp. n. **(24)**, *M. melica* **(25)** and *M. modulata* **(26)**.



Figures 27–34. Mid tibia showing the inner spur in the male of *Morgenia hamuligera* **(27)**, *M. rubricornis* **(28)**, *M. plurimaculata* sp. n. **(29)**, *M. lehmannorum* sp. n. **(30)**, *M. angustipinnata* sp. n. **(31)**, *M. spathulifera* **(32)**, *M. melica* **(33)** and *M. modulata* **(34)**.

with a black line at base, green with brownish stridulatory area. One black spot between tympana of fore tibiae.

Description. Males. Head and antennae. Fastigium of vertex narrow, sulcate above, not contiguous with fastigium of frons. Eyes rounded, well projecting. Antennae longer than body. Legs. Fore coxae armed with a small spine. Fore tibiae furrowed on upper margin, distinctly widening above tympanum, conchate on inner, open on outer side. Fore femora armed on inner ventral side with 3–4 small spines, fore tibiae with 3 spines + 1 spur on inner side and 3 spines + 1 spur on outer ventral side, mid femora with 4–5 spines on outer ventral side, mid tibiae with 6–7 spines on outer and 3–4 on inner ventral sides. The inner ventral spur of mid tibiae is more apically located, short, up-curved and does not exceed the base of the first tarsal article; its length is about 2.5–3.0% the length of tibia. On the outer ventral margin of mid tibiae, three close short spines are present (Fig. 31). Hind femora armed with 3–4 small spines on outer and on inner ventral sides, hind tibiae with many spines on ventral and dorsal sides + 3 spurs on each side. Thorax. Pronotum narrowing at the level of the humeral sinus, flat above, lateral margins rounded, anterior margin incurved, posterior margin rounded, humeral sinus well developed, lobes of pronotum rounded. Tegmina very narrow with rounded apices (Figs 6, 16, measurements in Table 1), wings longer than tegmina. Stridulatory area of the left tegmen raised and stout. Mirror of the right tegmen smaller than in *M. hamuligera* (Fig. 14). Costal area of tegmina with a net of small cells (Fig. 16); stridulatory file 1.7 mm long, arched, composed of ca. 70 widely spaced teeth (Fig. 24). Cerci club-shaped with an apical spine, the inner part is concave, the outer rounded. Subgenital plate long and narrow, with a small concavity, interior margins undulate in ventral view with tips rather straight in lateral view (Figs 45, 46).

Diagnosis. Tegmina of *M. angustipinnata* sp. n. are very narrow (Table 1); their costal area has a net of small cells. The stridulatory file is 1.7 mm long, arched, composed of ca. 70 widely spaced teeth and the spur of the mid tibia is very short. Differences to other species of the genus are summarised in Table 2.

Etymology. From Latin *angusta* = narrow, and *pinnata* = winged.

Morgenia melica Karsch, 1893

Figs 7, 17, 25, 33, 47, 48

Karsch, 1893. Entom. Nachricht. 19 (13): 196.

Type locality: Victoria (Cameroon) (MfN, Berlin).

Material examined. Cameroon, Victoria (holotype ♂) (MfN); **Gabon**, Lope National Park Res. Station, Ogooue-Ivindo 28.III.2014, (1♂, BOLD LopeORT14-618)

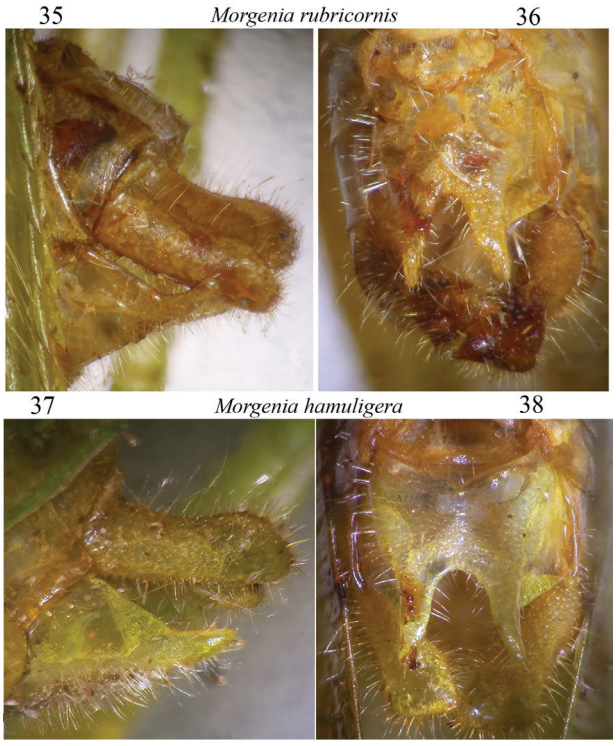
Table 2. Main characters that allow the separation of males of the eight species of the genus *Morgenia*.

	Spot on stridulatory area	Costal area of tegmina	Stridulatory file	Cerci	Subgenital plate (ventral)	Subgenital plate (lateral)	Spur of mid tibia
Morgenia hamuligera	Blackish, rectangular (Figs 9, 54)	Spaced crossveins (Fig. 13)	3.5 mm long (80 dense + 70 widely spaced teeth) (Fig. 20)	Club-shaped (Fig. 37)	Widely concave (Fig. 37)	Rather straight (Fig. 38)	Long and pointed (Fig. 27)
Morgenia rubricornis	Blackish, triangular (Figs 10, 14)	Spaced crossveins (Fig. 10)	2.2 mm long (60 dense + 50 widely spaced teeth) (Fig. 20)	Club-shaped (Fig. 35)	Widely concave (Fig. 35)	Tips up-curved (Fig. 36)	Long and more or less up-curved (Fig. 28)
Morgenia spathulifera	Very few small spots on tegmina (Fig. 11)	Net of small cells (Fig. 11)	1.2 mm long (60 densely spaced teeth) (Fig. 23)	Club-shaped (Fig. 43)	Concave, interior margins undulate (Fig. 43)	Rather straight (Fig. 44)	Very short and up-curved (Fig. 32)
Morgenia plurimaculata sp. n.	Few scattered spots on tegmina in most specimens (Figs 15, 55)	Net of small cells (Fig. 15)	2.8 mm long (90 widely spaced teeth) (Fig. 21)	Club-shaped (Fig. 41)	Widely concave (Fig. 41)	Tips down-curved (Fig. 42)	Short and pointed (Fig. 29)
Morgenia lehmannorum sp. n.	Very few (Figs 12, 56)	Net of small cells (Fig. 12)	1.8 mm long (ca. 100 teeth, distal more widely spaced than proximal) (Fig. 22)	Club-shaped (Fig. 39)	Small apical concavity (Fig. 39)	Rather straight (Fig. 40)	Long and up-curved (Fig. 30)
Morgenia angustipinnata sp. n.	Very few, brownish (Fig. 16)	Net of small cells (Fig. 16)	1.7 mm long (70 widely spaced teeth) (Fig. 24)	Club-shaped (Fig. 45)	Long and narrow, small concavity, interior margins undulate (Fig. 45)	Rather straight (Fig. 46)	Very short and up-curved (Fig. 31)
Morgenia melica	Blackish, more or less square (Fig. 17)	Spaced crossveins (Fig. 17)	2.3 mm long (70 widely spaced teeth) (Fig. 25)	Slender, apically flattened (Fig. 47)	Widely concave, tips divergent (Fig. 47)	Tips up-curved (Fig. 48)	Long and pointed (Fig. 33)
Morgenia modulata	Very few, nearly absent (Fig. 18)	Spaced crossveins (Fig. 18)	3.0 mm long (100 dense, + ca. 20 widely and ca. 30 evenly spaced) (Fig. 26)	Slender, apically flattened (Fig. 49)	Widely concave with right base (Fig. 49)	Tips gently up-curved (Fig. 50)	Long but enclosed inside the tibia (Fig. 34)

(light), ecotrop 2014 team; **Central African Republic**, Dzanga-Ndoki National Park, 31.I.–29.II.2012 (light) (19♂), Sangha2012 team; Mboki 24.I.2012 (1♂), Sangha2012 team; **Ivory Coast**, Täi National Park, Res. Station 16–20. III.2017 (light) (3♂, 1♀), B. Massa; 22.III-4.IV.2017 (light) (26♂), P. Moretto (BMPC); **Democratic Republic of the Congo**, Hombo 22.XII.1970, T. De Stefani (1♂) (MRT).

Distribution. *M. melica* is known from Cameroon, Democratic Republic of the Congo, Central African Republic, Uganda, Gabon and Ivory Coast (Karsch 1893, Massa 2013, Holstein 2015, present paper).

Remarks. The left tegmen of *M. melica* has a small brown spot covering only the stridulatory area, costal area of tegmina has regularly spaced crossveins (Fig. 17) and cerci are slender, apically flattened and end with a small inner spine (Figs 47, 48). The mirror of the right tegmen is as wide as in *M. hamuligera* (Fig. 17). The stridulatory file is 2.3 mm long, arched and composed of ca. 70 widely spaced teeth (Fig. 25). The inner ventral spur of mid tibiae is long and does not exceed the first tarsal article; its length is about 12–12.5% the length of the tibia. On the outer ventral margin of mid tibiae, three close short spines are present (Fig. 33).



Figures 35–38. Cerci and subgenital plate of male of *Morgenia rubricornis* (**35** lateral, **36** ventral) and *M. hamuligera* (**37** lateral, **38** ventral).

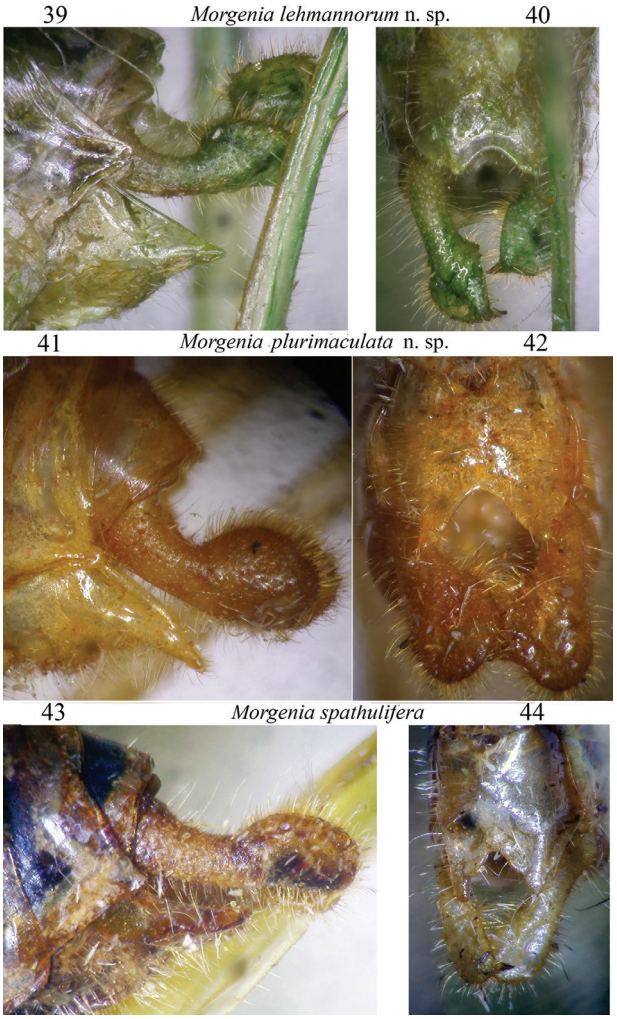
Morgenia modulata Karsch, 1896

Figs 8, 18, 26, 34, 49, 50

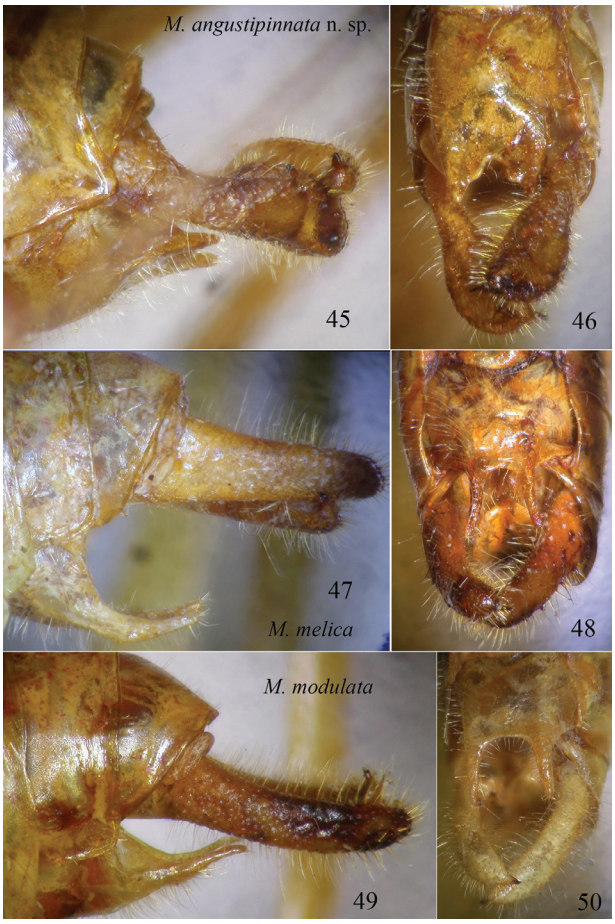
Karsch, 1896. Stett. Entomol. Z. 57: 340.

Type locality: Lolodorf (Cameroon) (MfN, Berlin).

Material examined. Cameroon, Lolodorf, L. Conradt (♂, ♀ syntypes, labeled as *Morgenia maculata*); Johann Albrechtshöhe, L. Conradt (♂, labeled as *M. maculata*) (MfN); **Central African Republic**, Sangha Special Reserve, Epiphyte 2008 Expedition, Camp 2, 22.X.2008 (light) (1♂), P. Annoyer; Dzanga-Ndoki National Park,



Figures 39–44. Cerci and subgenital plate of male of *Morgenia lehmannorum* sp. n. (**39** lateral, **40** ventral), *M. plurimaculata* sp. n. (**41** lateral, **42** ventral) and *M. spathulifera* (**43** lateral, **44** ventral).



Figures 45–50. Cerci and subgenital plate of male of *Morgenia angustipinnata* sp. n. (**45** lateral, **46** ventral), *M. melica* (**47** lateral, **48** ventral) and *M. modulata* (**49** lateral, **50** ventral).

Ndoki 26.I.–23.II.2012 (light) (28♂); Mboki 24.I.2012 (5♂), Sangha2012 team; **Gabon**, Lope National Park Res. Station, 22.III.2012 (light) (1♂) (GAB12-05), Ecotrop2012 team; **Ivory Coast**, Täi National Park, Res. Station 16–18.III.2017 (light) (2♂), B. Massa; 22.III-4.IV.2017 (light) (2♂), P. Moretto; **Togo**, Fazao Hotel 4.VIII.2013 (light), P. Moretto (1♂) (BMPC). Some specimens here listed were erroneously identified by Massa (2013) as *M. melica*.

Distribution. *M. modulata* is known from Gabon, Cameroon, Central African Republic, Ivory Coast and Togo (Karsch, 1896, Leroy 1970[1], present paper).

Remarks. Karsch (1896) described *M. modulata* very briefly, only highlighting its affinity with *M. melica*. Later Griffini (1908) also pointed out that the cerci of this species are not club-shaped, but similar to those of *M. melica*. Actually, the syntypes of *M. modulata* are labelled as *Morgenia maculata* (J. Deckert, pers. comm.), which probably was the first name that Karsch wished to use. This name very probably derived from the high number of scattered brown spots on the body of most specimens of this species. The stridulatory area of the left tegmen is protruding below its posterior margin (Figs 18, 26), the mirror of the right tegmen is rather wide (Fig. 18). *M. modulata* is also characterised by the costal area of the tegmina that has regularly spaced crossveins (Fig. 18) and by a very atypical stridulatory file that is 3.0 mm long, strongly arched and composed of two parts, the proximal part that is composed of at least 100 dense and evenly spaced teeth, followed by the distal part, composed of ca. 50 teeth, the first 20–22 widely spaced, the others closely set (Fig. 26). The spur of the mid tibiae is very long and straight, its insertion is at about ¼ the length of the tibia from the tip (its length is ca. 22.5–23.0% the length of the tibia), which has a hollow underneath where the spur remains hidden; the spur does not exceed the apex of the tibia. On the outer ventral margin of the mid tibiae, three close short spines are present (Fig. 34).

[1] Leroy (1970) cited *M. melica*, but the photograph of the stridulatory file reported by her corresponds to that of *M. modulata*.

Identification of females of the genus *Morgenia*

We know very little about morphological differences of the females of species of the genus *Morgenia*. However, according to Griffini (1908), the female of *M. hamuligera* has

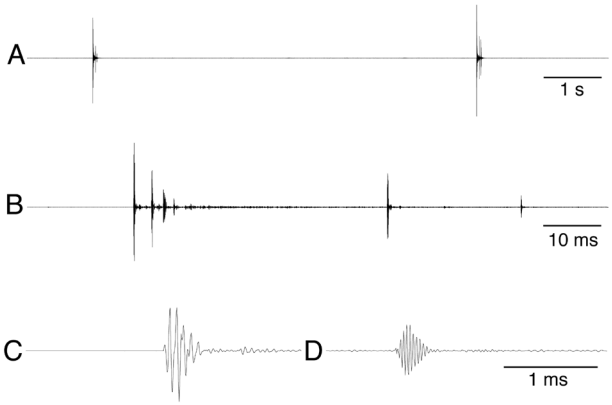


Figure 51. Oscillogram of the calling song of *Morgenia lehmannorum* sp. n. at different time scales. **A** two syllables with an unusually short inter-syllable interval **B** complete syllable **C** first impulse of syllable **D** pulse-like middle element.

a black spot between the tympana of the fore tibiae and we can confirm this character. In all other species, we were unable to find this black spot. In addition, females of *M. rubricornis*, *M. hamuligera*, *M. plurimaculata* sp. n., *M. spathulifera* and *M. melica* have regularly spaced crossveins in the costal area of the tegmina, while females of *M. modulata* have a net of cells in the costal area. No female specimens were available for *M. angustipinnata* sp. n. and *M. lehmannorum* sp. n. The subgenital plates of the examined females have more or less the same shape, triangular and apically rounded. However, the female of *M. plurimaculata* sp. n. has a more pointed subgenital plate. The females of *M. spathulifera*, *M. plurimaculata* sp. n. and *M. modulata* have brown spots scattered on the tegmina.

Generally, females are rarely collected; however, it may be the method of collecting these insects (by artificial light during the night) that attracts mainly males and only rarely some females are captured. Overall, both by means of studying material preserved in museums or by collecting in the field, males are always much more numerous than females.

The spur in the mid tibia of males

The presence of a spur on the mid tibia of males is already known in other genera of Phaneropterinae (in tropical Africa genera *Atlasacris* Rehn, 1914, *Monticolaria* Sjöstedt, 1909, *Odonturoides* Ragge, 1980 and *Meruterrana* Sjöstedt, 1912; in tropical America *Centrofera bimaculata* Brunner von Wattenwyl, 1878). Its origin could be a modified apical spur and probably it appeared several times independently. In the genus *Morgenia*, the spur may be an apical, very short and up-curved spur in *M. angustipinnata* sp. n. and *M. spathulifera* or a sub-apical spur, long and pointed or up-curved in *M. hamuligera*, *M. melica*, *M. rubricornis* and *M. lehmannorum* sp. n., and short and pointed in *M. plurimaculata* sp. n.; only in the case of *M. modulata,* it is very long, not sub-apical or apical located, but enclosed inside the mid tibia. The remarkable difference, evolving in *M. modulata*, has not been previously noticed.

Where spurs are present on the forelegs of insects, these are generally used to clean antennal segments. Zagatti and Castel (1987) have also noticed a sexual role for the spurs; they have highlighted the presence of male spurs on hind legs of a Lepidoptera Tortricidae (*Thaumatotibia leucotreta*) and that the insect places these spurs on the female's head during the courtship in such a way that the spurs fit the base of the female antennal segments. It is possible that the original role of spurs was to clean antennae, but secondary adaptations may have changed the original role and involved it during courtship and mating. In most species, it disappeared or never appeared, in others it remained only in the mid or hind legs. Thus, this peculiar structure of mid-leg in *Morgenia*, present only in males, possibly is used during the mating. It may be a case of a Darwinian sexual selection, a structure evolved by sexual factors.

A possible relation between the colour of the stridulatory area and the shape of the spur has been observed: four species with a blackish stridulatory area (*M. hamuligera*, *M. rubricornis*, *M. melica*, *M. plurimaculata* sp. n.) and only one with a less coloured stridulatory area (*M. lehmannorum* sp. n.) have a more or less long and pointed or up-curved, sub-apical spur, while the two species with less coloured stridulatory areas (*M. angustipinnata* sp. n., *M. spathulifera*) have a short and up-curved apical spur; the sole species with a nearly colourless stridulatory area (*M. modulata*) has a very modified spur at the mid tibiae. Within the tribe Poreuomenini, other genera may have a blackish coloured stridulatory area (e.g. *Cestromoecha* Karsch, 1893, *Poreuomena* Brunner von Wattenwyl, 1878); thus, we can consider that this pattern could be ancestral, even if it appeared independently at different times. If this interpretation is correct, the long and pointed spur at the mid tibiae in *Morgenia* species could be the ancestral character, while the short and up-curved spur could be a more recent adaptation, a sort of reduction of the character. The very singular shape of the spur in *M. modulata* remains seemingly inexplicable. It does not seem an adaptation; it changed very probably the original apical position of a modified spur and moved lower down into a new position, where probably it has maintained its function. We were unable to find this kind of modified spur in other genera of Phaneropterinae.

Bioacoustics of *Morgenia lehmannorum* Heller & Massa, sp. n.

The calling song of the male was recorded only during daytime, from 6 a.m. to 5 p.m. It consisted of isolated, very short syllables (less than 100 ms: 71±6 ms; n=12) which were produced at intervals of about 10 s or longer (Fig. 51A). A syllable (ca. 150 recorded) starts with a short (3 to 5) series of impulses with mean intervals between of 2–4.5 ms (2.65±0.7 ms; n=12) and decrescending in amplitude (Figs 51B, 51C). After a longer interval (37±2 ms; n=12),

two (rarely one or three) sound elements follow which are pulse-like in structure (Fig. 51D) separated by an interval of 23±7 ms (n=12). Interestingly, the carrier frequency of the impulses and the pulse-like sounds always distinctly differed. The impulses had a peak frequency of about 14±1.5 kHz, while the pulses were around 28.6±1.3 kHz (first pulse; in the second 28.5±1.4 kHz; n=12) (Fig. 52).

Comparing the syllable structure with the stridulatory file (Fig. 22), it seems plausible that the impulse series (or at least the first sounds) is produced by contact of the scraper with the large teeth at the distal end of the file. The stridulatory movement would thus have similarities to that of *Ectadia fulva* (see Heller et al. 2015). The high frequency pulses may be produced by using the dense basal part of the file. Different carrier frequencies within one syllable are quite rare amongst tettigoniids (see discussion in Heller and Hemp 2017). It will be very interesting to study the song of other species of the genus to see if this characteristic is more widespread.

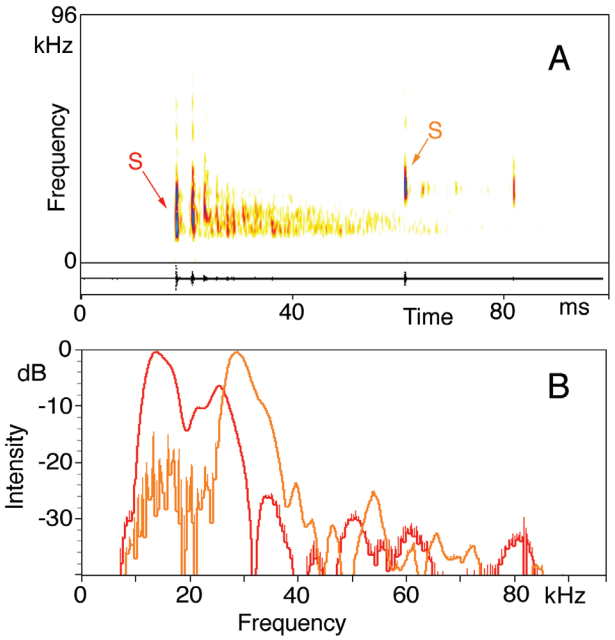


Figure 52. Sonogram of a syllable (**A**) and power spectra of song elements (**B**; see markings in **A**) in the calling song of *Morgenia lehmannorum* sp. n. (different colours mark the different sound elements; red: impulse, orange: pulse-like sound).

Cytogenetics of *Morgenia lehmannorum* Heller & Massa, sp. n.

Analysis of the standard karyotype of *Morgenia lehmannorum* Heller & Massa sp. n. revealed a diploid chromosome number (2n) of 25 for the male with the X0 sex determination system. Study of the mitotic metaphase showed one large and one small biarmed submetacentric pairs, four medium and six small acrocentric pairs; the X chromosome is metacentric and the largest element in the set. So, the FN (Fundamental Number, the number of chromosome arms including of the X chromosome) of this species = 30. The C-heterochromatin was characterised by paracentromeric C-bands of similar size (Figs 53a, 53b). Staining with $AgNO_3$ revealed the presence of one active NOR in the interstitial region of the large bivalent (Fig. 53c), probably in the secondary constriction region in the largest arm of the biarmed chromosome (Fig. 53b).

The modal karyotype of Phaneropterinae consists in the male of 31 acrocentric chromosomes, with the X0 sex determination system probably plesiomorphic for the whole Tettigoniidae (e.g. Warchałowska-Śliwa 1998). Most hitherto African genera investigated up to now – *Altihoratosphaga*, *Horatosphaga*, *Monticolaria* (Hemp et al. 2010a), *Lunidia* (Hemp et al. 2010b), *Parapyrrhicia* (Hemp et al. 2017) *Tropidonotacris* (Hemp et al. 2014) possess this karyotype as well. The ancestral chromosome number is reduced to 29 chromosomes (X0) in the African genera *Eurycorypha*, *Plangia* and *Gonatoxia* (Hemp et al. 2013, 2015, 2016), implying a more derived condition. In *Morgenia*, presented in this paper, the chromosome set is reduced to 2n = 25 (FN = 30). The patterns of the chromosome evolution in this species are interesting and differ from ancestral karyotypes in terms of chromosome number and morphology. Such a karyotype is probably the result of two Robertsonian fusions between the autosomes

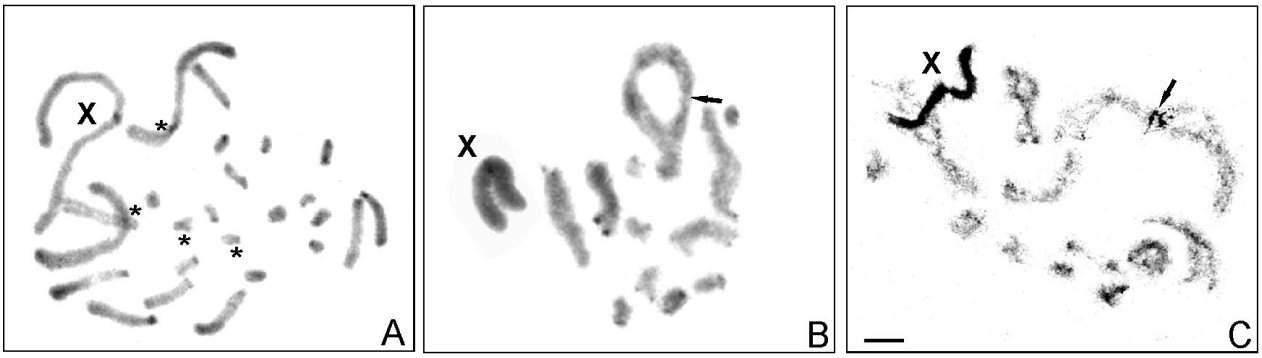
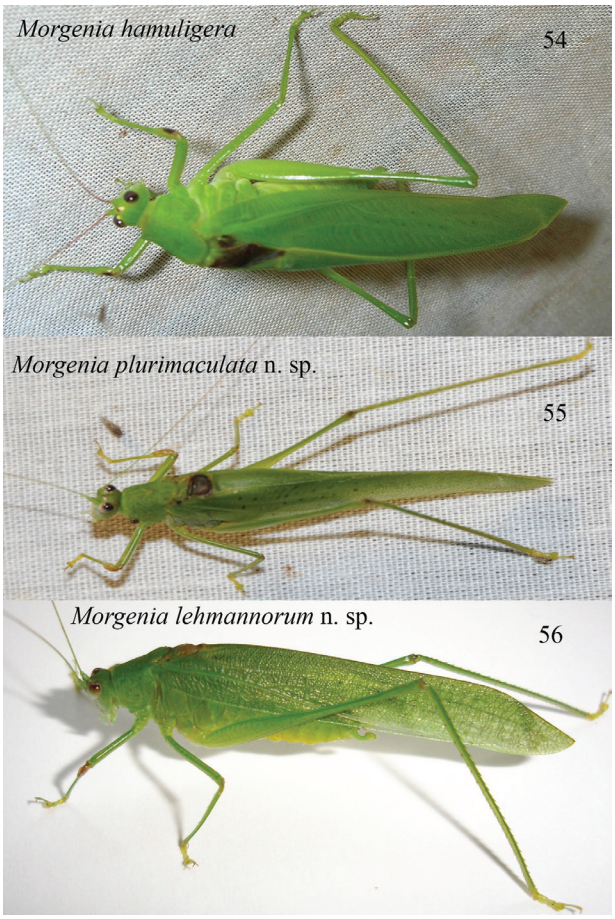


Figure 53. Chromosomes of *Morgenia lehmannorum* sp. n.; C-banded mitotic metaphase (**A**) and diakinesis (**B**) as well as silver nitrate staining of diakinesis (**C**) of male complement. Arrows indicate secondary construction region in the largest arm of biarmed chromosome (**b**) which correspond to the presence of one active NOR (**c**). An asterisk indicates biarmed medium and small pairs. X, sex chromosome. Scale bars = 10 µm.



Figures 54–56. Living specimens of *Morgenia hamuligera* from Central African Republic, Dzanga-Ndoki National Park (**54**; photo by P. Annoyer), *M. plurimaculata* sp. n. from Central African Republic, Dzanga-Ndoki National Park (**55**; photo by S. Danflous) and *M. lehmannorum* sp. n. from Uganda, Semliki Forest National Park (**56**; photo by K-G Heller).

(leading to the formation of biarmed chromosomes) and one tandem fusion. Pericentric inversion modified the position of the centromere and changed the morphology of the ancestral acrocentric to the metacentric X chromosome in this species. Both pericentric inversion and tandem fusion constitute the common mode of karyotype evolution within Phaneropterinae; however, Robertsonian fusion is not typical for this subfamily (e.g. Warchałowska-Śliwa 1998, Warchałowska-Śliwa et al. 2011). The great majority of cytotaxonomic analyses in African phaneropterids are based on the conventional cytogenetic (C-banding, NOR Ag-staining) methods, which were established for a better understanding of chromosome organisation and evolution.

DNA barcoding

Barcoding diagnoses separate species from gabonese specimens. The male of *M. rubricornis* (LopeORT14-617) with BIN: BOLD: ACO0217 has a sequence different from the male of *M. melica* (LopeORT14-618) with BIN: BOLD: ACN9970. Sequencing of a specimen, LopeORT14-673 did not work but was identified as *M. rubricornis* by one of the authors (BM). There is not enough data in BOLD or public data for the sequences of *Morgenia* to be compared with each other. The construction of a neighbour-joining tree of DNA barcodes (COI) was not possible.

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