*Zootaxa* 4044 (4): 556–566
www.mapress.com/zootaxa/

**Article**

ISSN 1175-5326 (print edition)
**ZOOTAXA**
ISSN 1175-5334 (online edition)

http://dx.doi.org/10.11646/zootaxa.4044.4.5
http://zoobank.org/urn:lsid:zoobank.org:pub:A586866F-D65E-4058-815B-13D7CA0D781F

# A new species of *Alhajarmyia* Stuckenberg (Diptera: Vermileonidae), the first wormlion fly described from East Africa and its biogeographical implications

VAUGHN R. SWART[1], ASHLEY H. KIRK-SPRIGGS[2] & ROBERT S. COPELAND[3]

[1]*Department of Zoology and Entomology, University of the Free State, P.O. Box 339, Bloemfontein 9300, South Africa.*
*E-mail: SwartVR@ufs.ac.za*
[2]*Department of Entomology, National Museum, P.O. Box 266, Bloemfontein 9300, South Africa.*
*E-mail: ashley.kirk-spriggs@nasmus.co.za*
[3]*International Centre of Insect Physiology and Ecology, P.O. Box 30772, Nairobi and Research Affiliate, National Museums of Kenya, P.O. Box 40658, Nairobi 00100, Kenya. E-mail: rcopeland@icipe.org*

## Abstract

A second species of the genus *Alhajarmyia* Stuckenberg (*A. stuckenbergi* Swart, Kirk-Spriggs & Copeland, **sp. n.**), is described and figured, from the Eastern Arc Mountains of Kenya (Kasigau Mountain and Taita Hills), being the first vermileonid recorded from East Africa. The species is shown to differ from its congener, *A. umbraticola* (Stuckenberg & Fisher), described from Oman in the Arabian Peninsula, based on external characters including male and female terminalia. An identification key is provided together with distribution maps for the two species, and biogeographical aspects are discussed.

**Key words**: Afrotropical, allopatric speciation, ancient relicts, biogeography, Eastern Arc Mountains, Kenya, identification key, Oman, Taita Hills, Tabanomorpha

## Introduction

Vermileonidae is a family comprising *ca*. 60 described species in eleven genera globally, with greatest species diversity in xeric areas of the southern Palaearctic and Afrotropical Regions (Marshall 2012: 196). The larval stages, or “wormlions”, of Vermileonidae construct conical pits, usually in dusty rock-overhangs like those made by species of Myrmeleontidae (Neuroptera), and in which they capture prey in a similar fashion (*e.g*., Marshall 2012: 196; Wheeler 1930; Woodley 2009: 482). Adults are not commonly collected and most taxonomic studies are based on specimens reared from collected larvae (Woodley 2009: 482).

The phylogenetic placement of the family remains contentious, but it appears that Vermileonidae is an early-diverging lineage in the Tabanomorpha (*e.g*., Sinclair *et al*. 1994; Woodley *et al*. 2009: 84). Eight genera are currently recognised as occurring in the Afrotropical Region; *Isalomyia* Stuckenberg, *Lampromyia* Macquart, *Leptynoma* Westwood, *Perianthomyia* Stuckenberg, *Namaquamyia* Stuckenberg, *Vermileo* Macquart, *Vermilynx* Stuckenberg and *Vermipardus* Stuckenberg. The family Vermileonidae has not been recorded previously from East Africa, although Stuckenberg (2003) suggested that dispersal from an East African ancestor may have produced the *Alhajarmyia* Stuckenberg lineage in the Arabian Peninsula.

In 1999, Stuckenberg & Fisher described *Lampromyia umbraticola* from the Al Hajar Mountains of northern Oman, the first recorded species of the family Vermileonidae from the Arabian Peninsula. Later, in 2003, Stuckenberg erected the new monotypic genus *Alhajarmyia* to contain it. Stuckenberg suggested that *Alhajarmyia* and the endemic, monotypic Malagasy genus *Isalomyia* represent sister-groups and discussed possible means of dispersal of the two genera. He predicted that undescribed species of *Alhajarmyia* may occur in the mountains of Yemen and the Somali Peninsula.

In 2011, one of the authors (RSC) sampled six specimens of a vermileonid using Malaise traps in two localities in Kenya. Examination of this material confirms its placement within the heretofore monotypic genus *Alhajarmyia* and a new species is described and figured herein.

*Accepted by C. Lamas: 29 Oct. 2015; published: 20 Nov. 2015*

## Material and methods

**Material. Dissection.** Abdomens were removed with watchmaker's forceps and macerated in 10% potassium hydroxide (KOH) in a heated block. Once macerated, these were transferred to 70% ethanol with a few drops of glacial acetic acid in an excavated glass block. Following dissection, abdomens and terminalia were stored in a micro-vial containing glycerol. The micro-vial was then pinned beneath each specimen.

**Figures.** Photographic images of the mesonotum, head, wings and female terminalia (Figs 1–8, 21, 22), were captured using a Leica EZ4HD stereo microscope, with build-in digital camera. Images were captured at a range of focal planes and were digitised using Combine ZP Image Stacking Software (http://www.hadleyweb.pwp.blueyonder.co.uk). Wings (Figs 5–8) were detached and placed between two glass slides. Male and female terminalia were mounted laterally or dorsally, in a drop of heated and set glycerine jelly. Photographic images (Figs 9, 11, 13, 15, 17 and 19) were captured with Nikon DS-L3 camera system mounted on a Nikon SMZ800 stereomicroscope and were digitised using the same software. Diagrammatical figures of the male terminalia (Figs 10, 12, 14, 16, 18, 20), were re-drawn digitally from the original photographs, using the program CoralDraw 12. The distribution map (Fig. 24) was prepared by converting the geographic coordinates indicating the point location of specimen records into a spatial data layer in ArcMap 9.3. The specimen location layer was overlaid on topography and state boundaries in order to assist with the interpretation and location of records. The layers political boundaries and the shaded relief were derived from Hearn *et al*. (2000).

**Labels.** Type label data are quoted exactly as they appear. A division slash (/) denotes the commencement of a new line, two division slashes (//) data on a further label. All labels are printed on white card, unless otherwise stated.

**International codens.** The type material examined in this study is deposited in the following institutions:

| | |
|---|---|
| NMKE | National Museums of Kenya, Nairobi, Kenya. |
| NMSA | KwaZulu-Natal Museum, Pietermaritzburg, South Africa. |

Abbreviations used in the text

Wing vein, cell and crossvein terms applied here use the revised terminology system adopted in the forthcoming *Manual of Afrotropical Diptera*, which largely follows Wootton & Ennos (1989) and Saigusa (2006).

aed—aedeagus; *bm*—basal medial cell; *br*—basal radial cell; cerc—cercus; *CuA*—anterior branch of cubital vein; *cua*—anterior cubital cell; *CuP*—posterior branch of cubital vein; *cup*—posterior cubital cell; *d*—discal cell; d brg—dorsal bridge; goncx—gonocoxite; gonst—gonostylus; HT—holotype; $M_1$—first branch of media; $m_1$—first medial cell; $M_2$—second branch of media; $m_2$—second medial cell; $M_3$—third branch of media; $m_3$—third medial cell; $M_4$—fourth branch of media; $m_4$—fourth medial cell; PT—paratype; $R_1$—anterior branch of radius; $r_1$—first radial cell; $R_{2+3}$—second branch of radius; $r_{2+3}$—second + third radial cell; $r_4$—fourth radial cell; $R_4$—upper branch of third branch of radius; $r_5$—fifth radial cell; $R_5$—lower branch of third branch of radius; *r–m*—radial–medial crossvein; *Sc*—subcostal vein; *stm vn*—stem vein; synst—synsternite; tg—tergite; v ap—ventral aperture.

## Taxonomy

### Genus *Alhajarmyia* Stuckenberg

*Alhajarmyia*: Stuckenberg, 2003: 197. Type species: *Lampromyia umbraticola* Stuckenberg & Fisher, 1999: 129, by monotypy.

**Diagnosis.** The genus *Alhajarmyia* is characterised as follows: proboscis elongate and slender; clypeus protruding; palpus slender, clavate and straight, with apical sensory pit; aedeagus comprising sclerotised tube, formed by fusion of paraphyses; ejaculatory apodeme in form of slender, irregularly curved rod, situated within aedeagal tube (Stuckenberg 2003).

## Key to species of the genus *Alhajarmyia* Stuckenberg

1. Antennal stylus short, < 1/4 length of postpedicel (Fig. 3). Male wing with vein $R_4$ irregularly rounded basally, with short projecting stem vein (*stm vn*) in cell $r_{2+3}$; veins $M_3$ and $M_4$ slightly convergent at wing margin; *r–m* crossvein situated at 1/5 length of discal cell (*d*) (Fig. 5). Female wing with vein $R_4$ irregularly rounded basally; veins *CuP* and *CuA* and veins $M_3$ and $M_4$ strongly convergent and closely approximated at wing margin (Fig. 6). Male terminalia with synsternite laterally expanded in apical 2/3 (Figs 9, 10, 13, 14); tergite 9 short, laterally expanded (Figs 17, 18). Female terminalia with cercus weakly projecting, shallowly notched medially (Fig. 21). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *umbraticola* (Stuckenberg & Fisher)

– Antennal stylus very long, subequal in length to postpedicel (Fig. 4). Male wing with vein $R_4$ evenly rounded basally, without stem vein in cell $r_{2+3}$; veins $M_3$ and $M_4$ sub-parallel; *r–m* crossvein situated at 2/5 length of discal cell (*d*) (Fig. 7). Female wing with vein $R_4$ evenly rounded basally; veins *CuP* and *CuA* weakly convergent not closely approximated at wing margin and veins $M_3$ and $M_4$ subparallel to wing margin (Fig. 8). Male terminalia with synsternite sub-parallel-sided (Figs 11, 12, 15, 16); tergite 9 sub-elliptical, not laterally expanded (Figs 19, 20); Female terminalia with cercus strongly projecting, deeply notched medially (Fig. 22) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *stuckenbergi* Swart, Kirk-Spriggs & Copeland, **sp. n.**

## ***Alhajarmyia stuckenbergi*** Swart, Kirk-Spriggs & Copeland, sp. n.

Figs 2, 4, 7, 8, 11, 12, 15, 16, 19, 20, 22, 24, 25.

**Etymology.** The species is named in honour of the late Brian Roy Stuckenberg (1930–2009), in recognition of his major contributions to Afrotropical dipterology and the study of Vermileonidae specifically.

**Differential diagnosis.** *Alhajarmyia stuckenbergi* **sp. n.** differs from its congenor, *A. umbraticola* mainly in the length of the antennal stylus, wing and terminalia characters and can be separated using the above key.

**Description.** *Male* (primarily based on ex spirit-preserved HT).

*Measurements* ($n = 5$): proboscis length: 4.9–5.3 mm; mesonotum length: 1.4–1.5 mm; wing length (measured from humeral crossvein to apex): 5.5–6.8 mm.

*Head:* with frons sub-rectangular, concave at lateral margins, width (at widest point) *ca.* 1/6 width of head. Antenna (Fig. 4) with scape elongate, slightly expanded apically, *ca.* 3 × as long as deep; postpedicel elongate, 1.5 × length of scape; stylus long, subequal in length to postpedicel, basal stylomere (segment 9) less than 1/3 length of apical stylomere (length ratio: 5 : 16). Face similar to *A. umbraticola*, except proboscis *ca.* 2.6 × mesonotal length and lacking whitish section in basal 1/4.

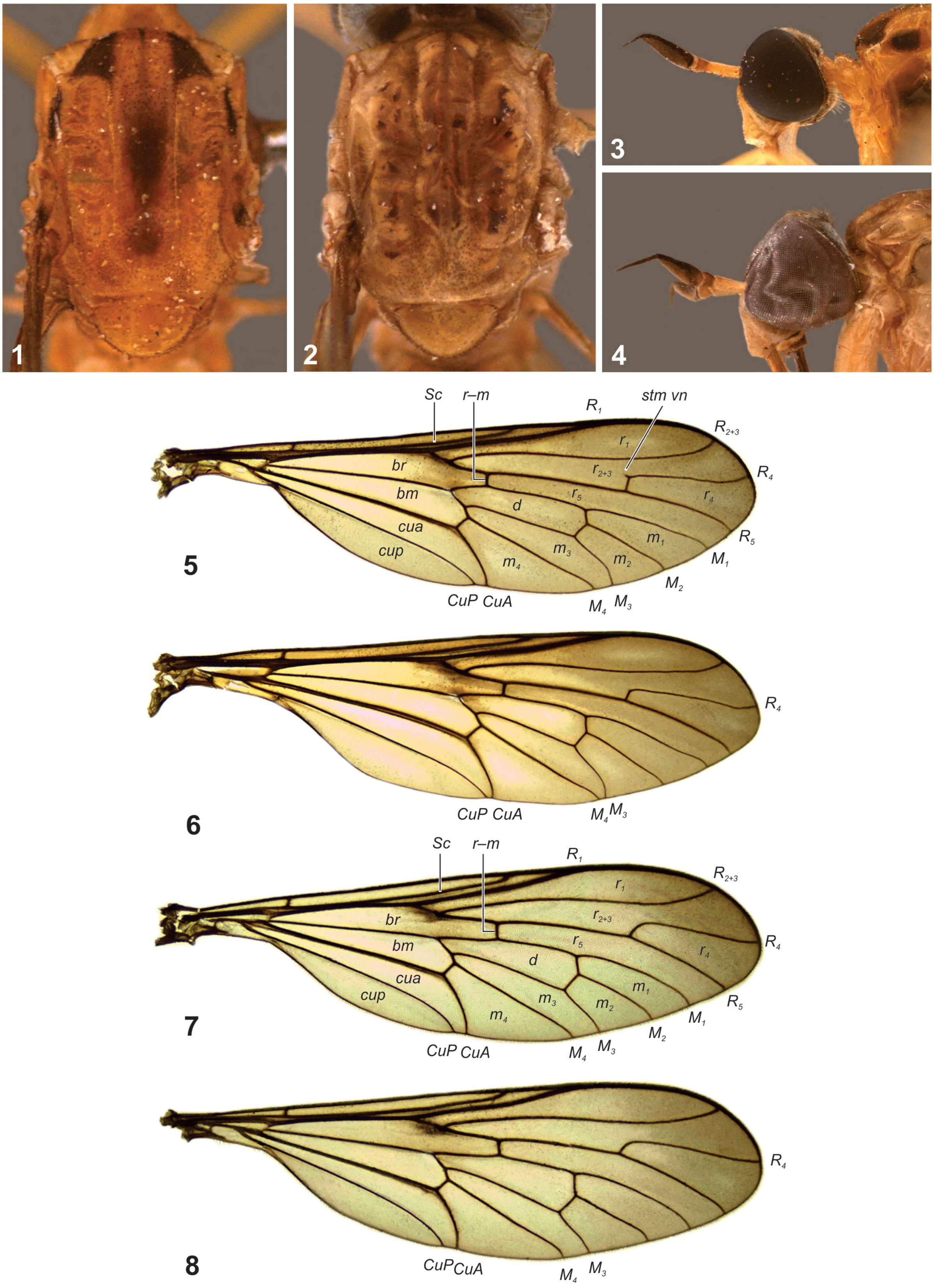
*Thorax*: with mesonotum (Fig. 2) as described for *A. umbraticola*, but apparently less distinctly marked in holotype (paratypes with dark median vitta rounded posteriorly, terminating between wing bases, anteriorly this vitta narrowing abruptly into slender midline marking, extending to anterior margin; with conspicuous, subtriangular, blackish markings laterally, between humeral callus and raised median area over which vitta lies, extended laterally on either side up to posterior end of vitta; notopleural area unmarked). Scutellum flat, unmarked. Legs: with femur darkened in apical 1/4; tibia as described for *A. umbraticola*; fore and mid tarsi as described in *A. umbraticola*, metatarsus darkening in apical 1/2, remaining tarsomeres as described in *A. umbraticola*.

Wing (Fig. 7): with membrane mostly pale smoky-grey, darker toward apex and in region of basal radial cell (*br*), basic wing vein configuration as described for *A. umbraticola*, but differing as follows: length of vein $R_5$ *ca.* 86% length of $R_{4+5}$ measured from *r–m* intersection; vein $R_4$ evenly rounded basally (without stem vein in cell $r_{2+3}$); veins $M_3$ and $M_4$ sub-parallel; *r–m* crossvein situated at 2/5 length of discal cell (*d*) (Fig. 7); discal cell (*d*) expanded in apical 1/2 (not parallel-sided).

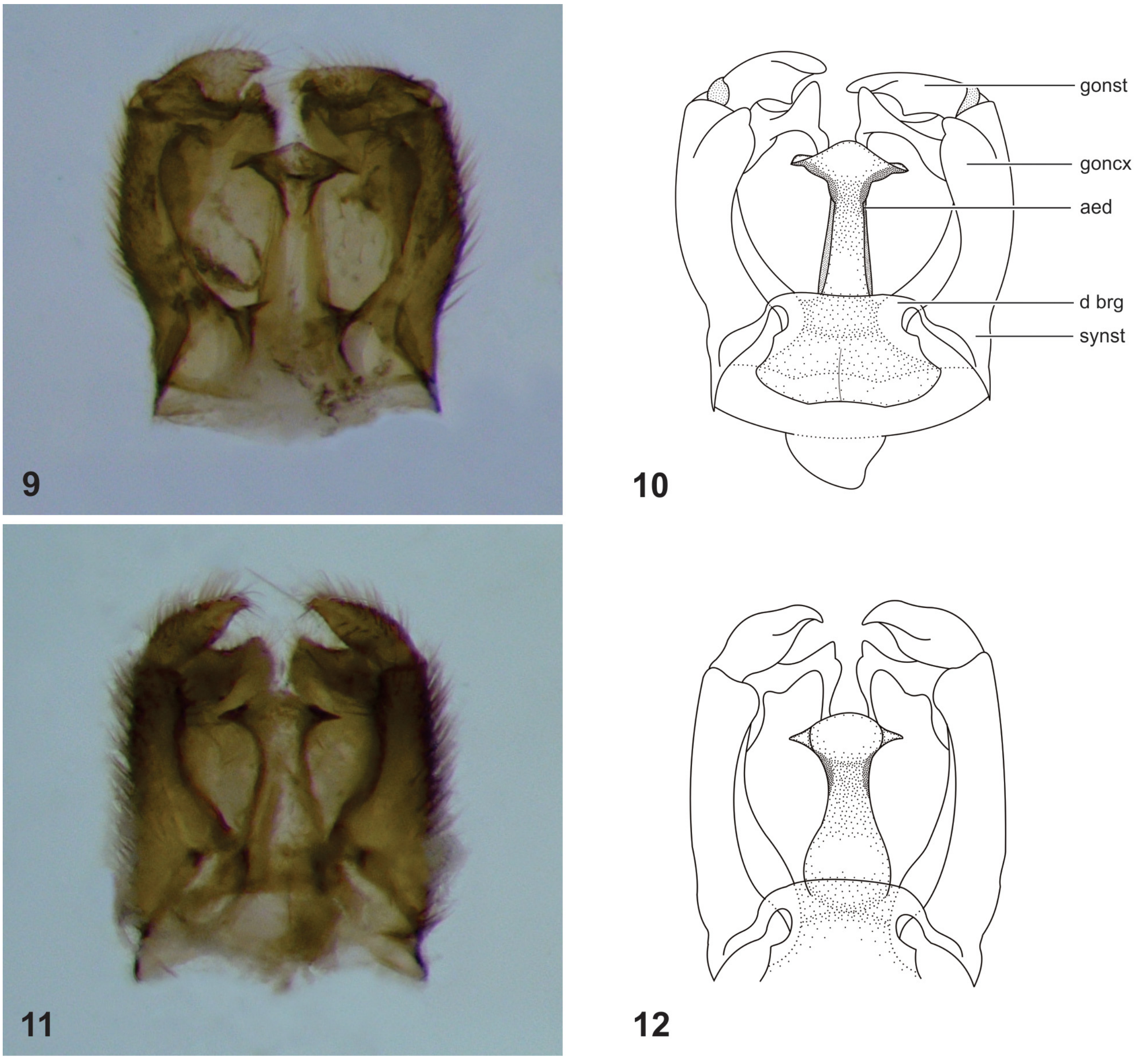
*Abdomen:* with tergites yellow banded in apical 2/3 (as described for *A. umbraticola*). Hypopygium with tergite 8, as described for *A. umbraticola*; tergite 9 (Figs 19, 20) sub-quadrate (not laterally expanded); cercus short and broad, medially expanded; synsternite (Figs 15, 16) parallel-sided; clothed in long, dense setation, with long, narrow, sub-rectangular ventral aperture, dorsal margin evenly curved (not markedly undulate); gonostylus (Fig 11, 12) claw-like, narrowed basally; gonocoxite (Figs 11, 12) slightly curved, with apical part squarely rounded (lacking lobular process apically); aedeagus (Figs 11, 12) broad basally, with rounded ventrobasal keel, constricted sub-apically, strongly upcurved over apical section which is transversely flattened and broadened, with lateral processes sub-triangular; dorsal bridge (Figs 11, 12) as described for *A. umbraticola*.

*Female* (similar to male; differing in the following aspects):

*Measurements* ($n = 1$): proboscis length: 5.8 mm; mesonotum length: 1.5 mm; wing length: 7.5 mm.



**FIGURES 1–8.** External features of *Alhajarmyia* spp. **1**. Mesonotum of *A*. *umbraticola* (Stuckenberg & Fisher), dorsal view (HT, Oman, NMSA). **2**. Same, *A*. *stuckenbergi* **sp. n.** (HT, Kenya, NMKE). **3**. Head and antenna of *A*. *umbraticola*, lateral view (HT, Oman, NMSA). **4**. Same, *A*. *stuckenbergi* **sp. n.** (HT, Kenya, NMKE). **5**. Male wing of *A*. *umbraticola*, dorsal view (HT, Oman, NMSA). **6**. Same, female (PT, Oman, NMSA). **7**. Male wing of *A*. *stuckenbergi* **sp. n.** (HT, Kenya, NMKE). **8**. Same, female (PT, Kenya, NMKE). Not to scale.



**FIGURES 9–12.** Male terminalia of *Alhajarmyia* spp. **9**. Synsternite of *A. umbraticola* (Stuckenberg & Fisher), dorsal view (HT, Oman, NMSA). **10**. Same, diagrammatic. **11**. Synsternite of *A. stuckenbergi* **sp. n.** dorsal view (HT, Kenya, NMKE). **12**. Same, diagrammatic. Not to scale.

Head as described for ♂ Thorax virtually unmarked (may be a remnant of alcohol preservation). Legs as described for ♂ (hind legs missing). Wing as described for ♂ , but vein $R_4$ evenly rounded basally; veins *CuP* and *CuA* weakly convergent not closely approximated at wing margin and veins $M_3$ and $M_4$ subparallel to wing margin (Fig. 8). Spermathecae as described for *A. umbraticola*

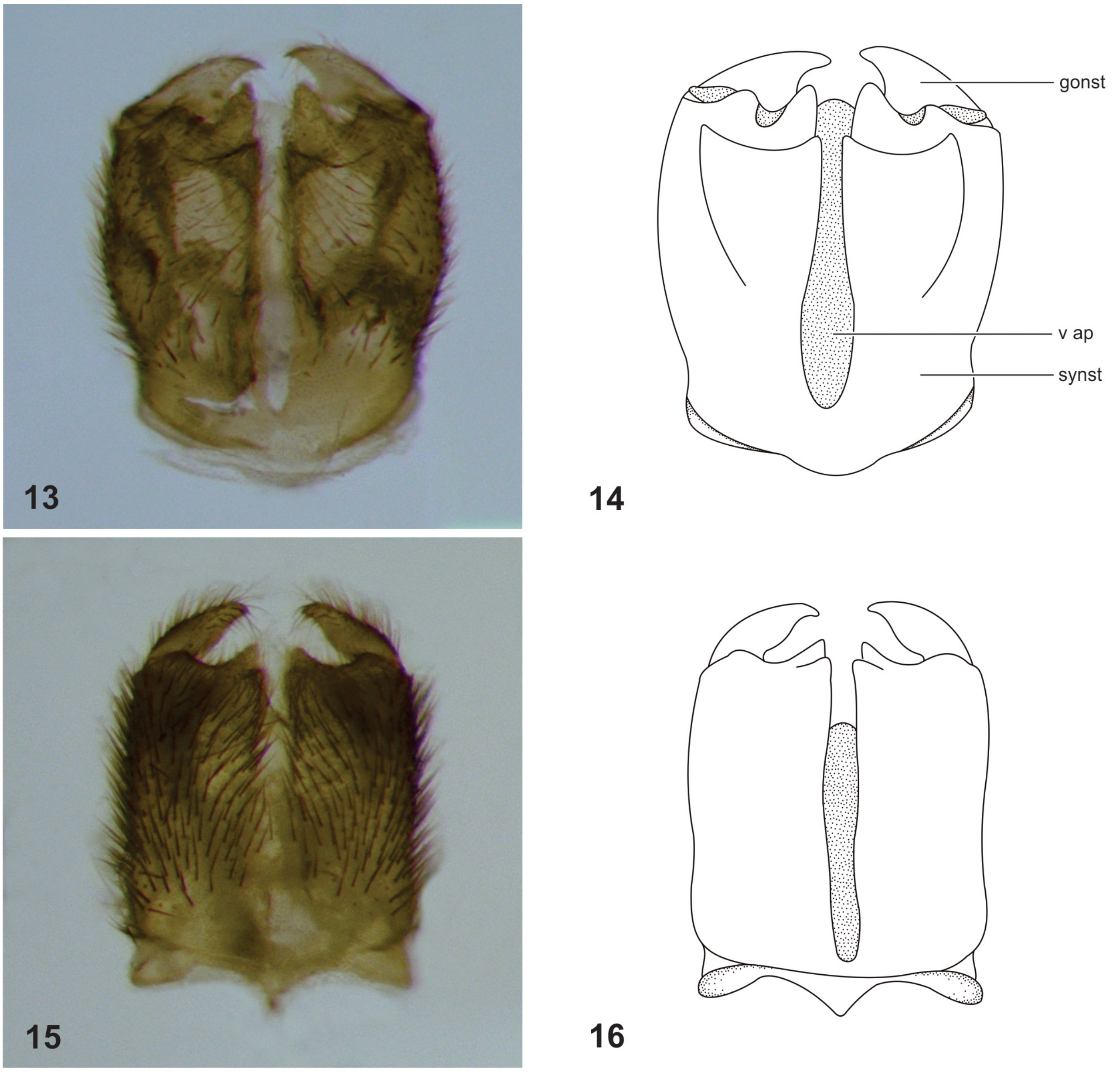
**Type material.** Holotype: ♂, "KENYA Coast Prov / Kasigau Mtn / indigenous forest, 1065 m, / 3.82700°S, 38.64875°E // Malaise trap, next to / campsite in forest / 14-28 Dec 2011 / R. Copeland // P1 // IBOL 19700VermA1 // HOLOTYPE / *Alhajarmyia* ♂ / *stuckenbergi* **sp. n.** / Swart, Kirk-Spriggs & / Copeland 2014 //" [printed; red card] (NMKE). Micro-pinned and staged; in fair condition (ex alcohol); left mid leg missing; right mid leg glued to card; dissected, terminalia and abdomen in micro-vial pinned beneath specimen; right wing detached and glued to card.

Paratypes: 1♂, "KENYA Coast Prov / Kasigau Mtn / indigenous forest, 1117 m, / 3.82667°S, 38.64982°E // Malaise trap, next to / spring in forest / 2-16 JUN 2011 / R. Copeland // P2 // IBOL 19700VernA2 // 14482-*Lampromyia* F8 // PARATYPE / *Alhajarmyia* ♂ / *stuckenbergi* **sp. n.** / Swart, Kirk-Spriggs & / Copeland 2014 //" [printed; blue card] (NMKE); 1♂, same labels, except: "Malaise trap, next to / spring in forest / 2-16 JUN 2011 / R.

Copeland // P3 // IBOL 19700VermA3"; 1♀, same labels, except: "Malaise trap, next to / spring in forest / 19 MAY-2 JUN 2011 / R. Copeland // P4 // IBOL 19700VermA4 // 14482-*Lampromyia* F7" (NMKE). Dissected; abdomen in micro-vial pinned beneath specimen; both wings detached and glued to cards; 1♂ , "KENYA Coast Prov / Taita Hills, Chawia / Forest, 3.47908°S, / 38.34162°[E] 1614 m // Malaise trap, next / to small forest pond / 12-26 DEC 2011 / R. Copeland // P5 // IBOL 19700VermA5" (NMKE). Dissected, terminalia and abdomen in micro-vial pinned beneath specimen; 1♂, same labels, except: "P6 // IBOL 19700VermA6" (NMKE).

**Distribution.** Apparently confined to Kasigau Mountain and the Taita Hills of Kenya.

**Bionomics.** Unknown.

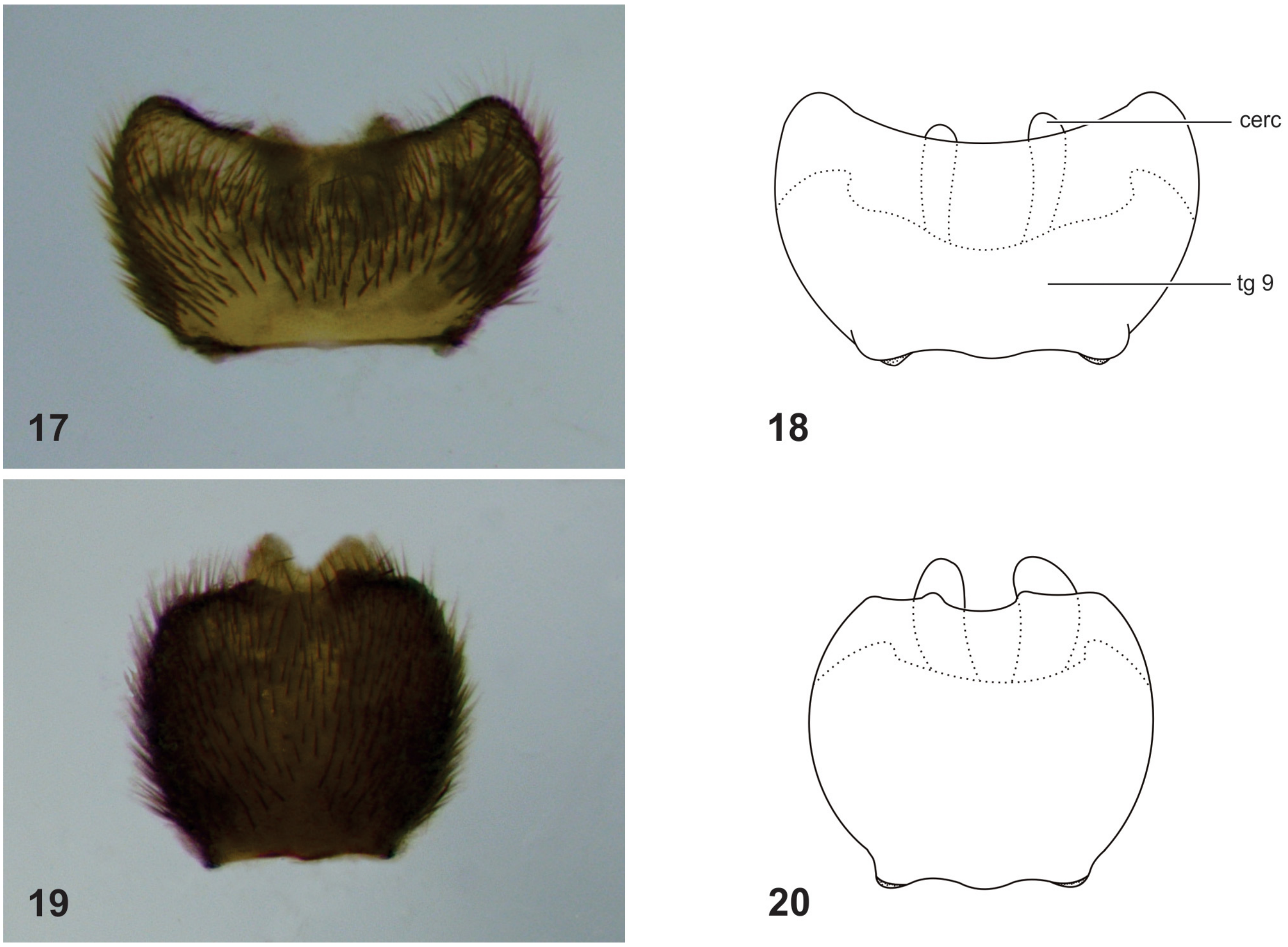


**FIGURES 13–16.** Male terminalia of *Alhajarmyia* spp. **13**. Synsternite of *A*. *umbraticola* (Stuckenberg & Fisher), ventral view (HT, Oman, NMSA). **14**. Same, diagrammatic. **15**. Synsternite of *A*. *stuckenbergi* **sp. n.** ventral view (HT, Kenya, NMKE). **16**. Same, diagrammatic. Not to scale.

### *Alhajarmyia umbraticola* (Stuckenberg & Fisher) (*Lampromyia*)

Figs 1, 3, 5, 6, 9, 10, 13, 14, 17, 18, 21, 24.

*Lampromyia umbraticola* Stuckenberg & Fisher, 1999: 129.
*Alhajarmyia umbraticola* Stuckenberg & Fisher, 1999: 129, by designation of Stuckenberg (2003: 197).



**FIGURES 17–20.** Male terminalia of *Alhajarmyia* spp. **17**. Tergite 9 of *A. umbraticola* (Stuckenberg & Fisher), dorsal view (HT, Oman, NMSA). **18**. Same, diagrammatic. **19**. Tergite 9 of *A. stuckenbergi* **sp. n.** dorsal view (HT, Kenya, NMKE). **20**. Same, diagrammatic. Not to scale.

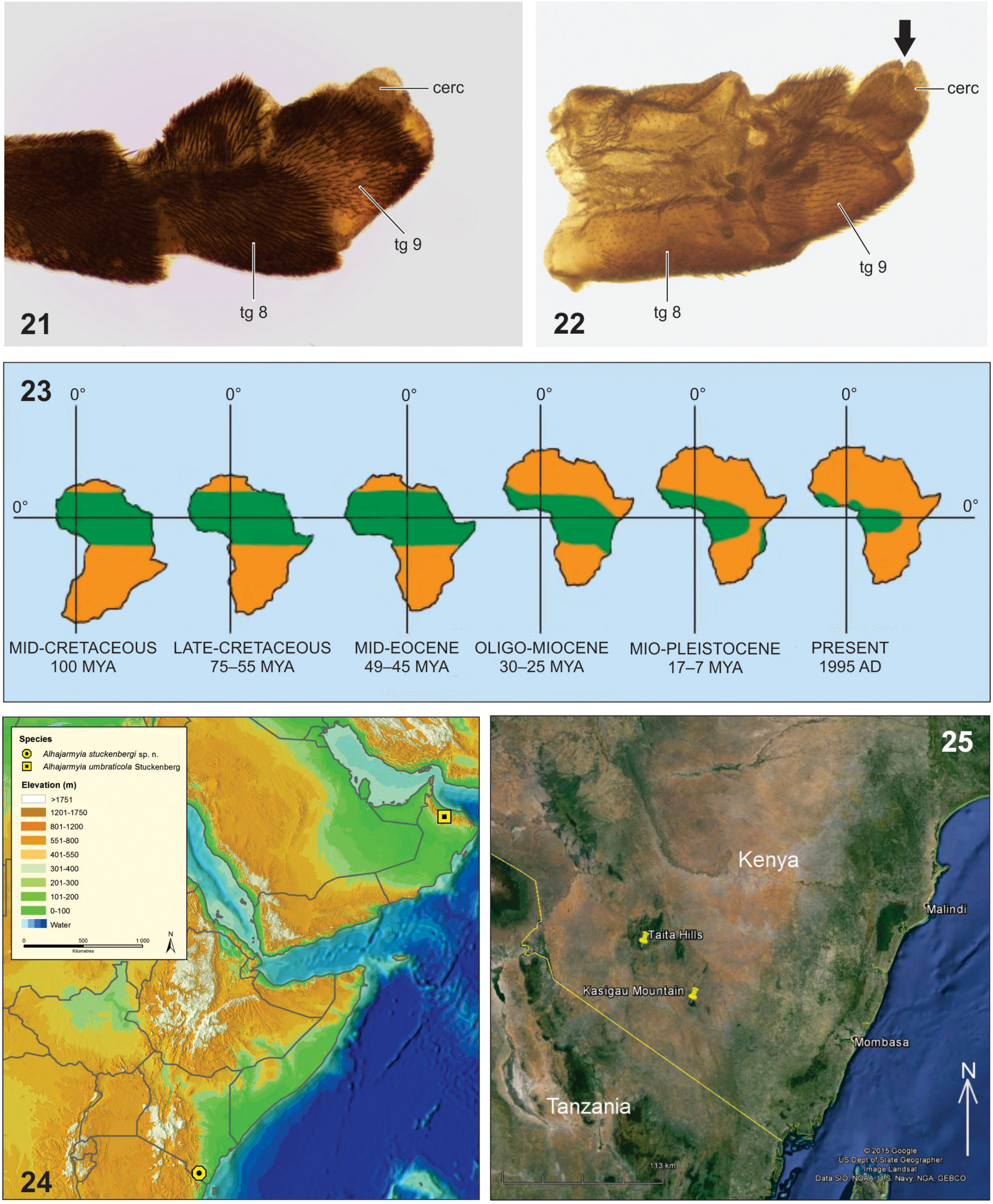
**Type material examined.** Holotype ♂, "ARABIA: Oman #45 / Hajar Mountains 2400m / 23°14.0'N: 57°14.9'E / Date: 21.iv.1998 / Collector: M. Fisher / Slopes of Jebel Shams // Collected as larva / Reared at Merrivale / By B. R. Stuckenberg / Fly emerged on / Date: 17.XII.98 // HOLOTYPE / *Lampromyia* / *umbraticola* / Stuckenberg & / Fisher [printed and handwritten, red border] // NMSA-DIP / 66339" (NMSA). Direct-pinned; dissected abdomen in micro-vial pinned beneath specimen; right wing detached and glued to card. Paratype ♀, same labels as holotype, except "Collected as larva / Reared at Merrivale / By B. R. Stuckenberg / Fly emerged on / Date: 23.XII.98 // PARATYPE / *Lampromyia* / *umbraticola* / Stuckenberg & / Fisher [printed and handwritten, yellow border] // NMSA-DIP / 66341" (NMSA). Direct-pinned; dissected abdomen in micro-vial pinned beneath specimen. Paratype ♀, same data, except: "Fly emerged on / Date: 6.I.99 // NMSA-DIP / 66340" (NMSA). Direct-pinned; right wing detached and glued to card.

**Distribution.** Apparently confined to the Hajar Mountains of Oman in the Arabian Peninsula.

**Bionomics.** Stuckenberg & Fischer (1999) provide a habitat description.

## Discussion

The discovery of the relict species *A. stuckenbergi* **sp. n.** in the Eastern Arc Mountains of Kenya and its close relationship with the Arabian Peninsula species *A. umbraticola* and the Malagasy genus *Isalomyia*, was expected and concurs with Stuckenberg's (2003) prediction of undiscovered species of *Alhajarmyia* in East Africa.



**FIGURES 21–25.** Female terminalia and distribution of *Alhajarmyia* spp. **21**. Terminalia of *A. umbraticola* (Stuckenberg & Fisher), lateral view (PT, Oman, NMSA). **22**. Same, *A. stuckenbergi* **sp. n.** (PT, Kenya, NMKE). **23**. Inferred changes to the extent and distribution of forest cover in Africa since the mid-Cretaceous. Shoreline changes are not represented. Changes in the position and orientation of the African continent are due to continental drift (after Clarke 2000). **24**. Distribution of *A. umbraticola* and *A. stuckenbergi* **sp. n.** in Africa and the Arabian Peninsula. **25**. Collecting localities of *A. stuckenbergi* **sp. n.** in the Eastern Arc Mountains of Kenya (Copyright 2015 Google, Data SIO, NOAA, US Navy NGA GEBCO, image Landsat). Figs 21–23 not to scale.

The Al Hajar Mountains are the highest mountains in the eastern Arabian Peninsula, at an elevation exceeding 3000 m a.s.l. and run parallel to the coast of the Gulf of Oman for a distance of more than 600 km (Fig. 24). Geologically, the Al Hajar are comprised predominantly of the ophiolite complex (Cretaceous limestone of Oligocene and Miocene age) (Rollinson *et al.* 2014). Due to their higher elevation, these mountains receive 150–350 mm annual precipitation (Fisher & Membery 1998), considerably greater than the arid peneplain that surrounds them. As a result of elevation and increased precipitation, these mountains provide an important refuge for endemic and relict species of fauna and flora (Ghazanfar 1998). At the elevation at which the holotype was collected, vegetation consists of woodland, which occurs from 1100–2500 m a.s.l., where this is characterised by olive trees and hop bush. The uppermost zone, from 2100–3000 m a.s.l., occupies the summit area, where large junipers form open woodland (Ghazanfar 1998; Mandaville 1977).

In their current formations the Hajar Mountains are the result of deformation in the late Oligocene and Early Miocene (Kusky *et al*. 2005), followed by uplift and erosion under generally arid or semi-arid conditions, continuing to the present day. This deformation and uplift is presumed to be related to the slow motion collision (*i.e*., tectonic convergence) of the NE margin of the Afro-Arabian lithospheric plate with the Eurasian plate and other marginal plates, together with the opening of the Red Sea (Pickford *et al.* 2006). This was then followed by aridification of the Arabian Peninsula at the beginning of the Miocene with further aridification during the Pliocene and Quaternary.

Geological evidence suggests that due to sea-level changes the Arabian Peninsula lay predominantly beneath the Tethys Sea during the Eocene (Cranston 2005). Isostatic uplift raised the Hajar Mountain area above sea level, possibly with considerable relief, but these were rapidly eroded in a wet tropical climate (Nolan *et al.* 1990). Shallow-water sediments from the latest Cretaceous and Early Tertiary drape the western flank of today's mountains, indicating that some if not all of the region was again submerged at that time.

*Alhajarmyia stuckenbergi* **sp. n.** is recorded exclusively from high- to medium-elevation Afromontane forests associated with the Eastern Arc Mountain group of Kenya. The Eastern Arc comprises a chain of mountains that begin in southern Kenya and stretch in a south-east direction toward the Indian Ocean before curving to follow a south-westward line through Tanzania. These represent ancient crystalline Precambrian basement mountains, that were uplifted at least 30 MYA and which fall under the direct climatic influence of the Indian Ocean (Lovett *et al.* 2004). The Eastern Arc Mountains are renowned for high concentrations of endemic species of animals and plants (Burgess *et al.* 2007) and have been recognised as part of the Eastern Afromontane biodiversity hotspot by the Critical Ecosystem Partnership Fund (CEPF 2015).

Located in south-eastern Kenya (Fig. 24), the Taita Hills (including Kasigau Mountain) are the northernmost of the 13 separate mountain blocks that comprise the Eastern Arc Mountains. With an afforested area of only 3 km² the Taita Hills offer small, isolated refugia (Burgess *et al.* 2007) and are, therefore, important habitats for a number of species that inhabit its confined forested areas. The Eastern Arc Mountains are conspicuous for having a stable recent climate and this stability has persisted over the long term.

The origins and history of the vegetation in East Africa have had a profound impact on the modern distribution of the flora and fauna of the region. According to Clarke (2000), during lower and basal Middle Miocene times, northern Africa was covered in tropical forest and woodland (Fig. 23). The Neogene and Quaternary were marked by a succession of changes which affected the climate and played an important role in modifying African flora and fauna. This led to the sequential retraction and expansion of tropical forests. The East African expansion of grasslands began in the Upper Miocene, and expanded during the Late Pliocene replacing moist lowland forests. At high elevations in the Eastern Arc these upland forest remnants retained local populations that became isolated, but remained morphologically similar. During the last glacial maxima (18 000 BP), the temperature of the Atlantic Ocean dropped 4–5°C, whereas that of the Indian Ocean in the area of Kenya was similar to present-day temperatures. This implies that during the last glacial maxima the climate of Kenya was similar to that of today.

Due to the fact that both the Eastern Arc and the Al Hajar Mountains were isolated similarly through aridification and changes in vegetation, these two areas are effectively "islands" and speciation has probably taken place allopatrically.

## Conclusion

*Alhajarmyia stuckenbergi* **sp. n.** is geographically isolated within pockets of cloud forest and represents a relict species. This study supports Stuckenberg's (2003) prediction that dispersal from an East African ancestor may also have produced the *Alhajarmyia* lineage in the Arabian Peninsula. There is a strong probability that new species of *Alhajarmyia* may occur in the Ethiopian highlands, Yemen and Somali Peninsula, as a result of the range extension of species, with many lineages now known to stretch from the Afrotropical Region as far north as Yemen (Kirk-Spriggs & Stuckenberg 2009; Stuckenberg & Fischer 1999). It is evident that both *Alhajarmyia* spp. represent ancient relicts that have become isolated (through island speciation), due to climatic changes and aridification. Interestingly, all of the Malaise traps in which *A. stuckenbergi* was collected were set in relatively wet, evergreen forest, and the typical rocky overhang/dry soil microhabitat usually associated with the Vermileonidae was not seen in the surrounding environment.

## Acknowledgements

We thank B. Muller (KwaZulu-Natal Museum, Pietermaritzburg) for the loan of type material of *Alhajarmyia umbraticola*; T. Smit (University of the Free State, Bloemfontein), for digital preparation of Figs 10, 12, 14, 16, 18 and 20; and G. McGregor (Rhodes University, Grahamstown), for preparation of Fig. 24. This contribution is based on a paper presented at the 8th International Congress of Dipterology (Potsdam, Germany, 2014). AHK-S acknowledges the National Research Foundation, South Africa, for Incentive Funding for Rated Researchers. The authors are grateful to the government of Finland for partial funding of our research through a grant to ICIPE (the CHIESA Project; Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa). Thanks also to the director Kenya Forest Service (Nairobi), for permission to sample in the forests of Taita Hills. Juliet Muriuki and Caroli Mwadime Mjomba were excellent field workers.

## References

Burgess, N.D., Butynski, T.M., Cordeiro, N.J., Doggart, N.H., Fjeldså, J., Howell, K.M., Kilahama, F.B., Loader, S.P., Lovett, J.C., Mbilinyi, B., Menegon, M., Moyer, D.C., Nashanda, E., Perkin, A., Rovero, F., Stanley, W.T. & Stuart, S.N. (2007) The biological importance of the Eastern Arc Mountains of Tanzania and Kenya. *Biological Conservation*, 134, 209–231. http://dx.doi.org/10.1016/j.biocon.2006.08.015

CEPF (2015) http://www.cepf.net/resources/hotspots/africa/Pages/Eastern-Afromontane.aspx (accessed 1 July 2015)

Clarke, G.P. (2000) Climate and climatic history. *In*: Burgess, N.D. & Clarke, G.P. (Eds.), *Coastal forests of eastern Africa*. IUCN, Gland, and Cambridge, pp. 47–67.

Cranston, P.S. (2005) Chapter 10. Biogeographical patterns in the evolution of Diptera. *In*: Yeates, D.K. & Wiegmann, B.M. (Eds.), *The evolutionary biology of flies.* Columbia University Press, New York, pp. 274–311.

Fisher, M. & Membery, D.A. (1998) Climate. *In*: Ghazanfar, S.A. & Fisher, M. (Eds), *Vegetation of the Arabian Peninsula*. Kluwer Academic, Dordrecht, pp. 5–38.

Ghazanfar, S.A. (1998) Status of the flora and plant conservation in the Sultanate of Oman. *Biological Conservation*, 85, 287–295.
http://dx.doi.org/10.1016/S0006-3207(97)00162-6

Hearn, P., Hare, T., Shruben, P., Sherrill, D., La Mar, C. & Tsushima, P. (2000) *Global GIS Database: Digital Atlas of Africa*. US Geological Survey Digital Data Series DDS-62-B, Interior Department. [CDRom]

Kirk-Spriggs, A.H. & Stuckenberg, B.R. (2009) Afrotropical Diptera—rich savannas, poor rainforests. *In*: Bickel, D., Pape, T. & Meier, R. (Eds.), *Diptera diversity: status, challenges and tools*. Brill Academic Publishers, Leiden, pp. 155–196.

Kusky, T., Robinson, C. & El-Baz, F. (2005) Tertiary–Quaternary faulting and uplift in the northern Oman Hajar Mountains. *Journal of the Geological Society*, 162, 871–888.
http://dx.doi.org/10.1144/0016-764904-122

Lovett, J.C., Marchant, R., Taplin, J. & Küper, W. (2004) 9. The oldest rainforests in Africa: stability or resilience for survival and diversity? *In*: Purvis, A., Gittleman, J.L. & Brooks, T.M. (Eds.), *Phylogeny and conservation*. Cambridge University Press, Cambridge, pp. 198–229.

Mandaville, J.P. (1977) Plants. *In*: Harrison, D.L. (Ed.), *The scientific results of the Oman flora and fauna survey 1975. Journal of Oman Studies Special Report No.1*. Office of the Adviser for Conservation of the Environment, Muscat, Sultanate of Oman, pp. 229–267.

Marshall, S.A. (2012) *Flies: The natural history and diversity of Diptera*. Firefly Books, Buffalo, NY, 616 pp.

Nolan, S.C., Skelton, P.W., Clissold, B.P. & Smewing, J.D. (1990) Maastrichtian to early Tertiary stratigraphy and palaeogeography of the central and northern Oman mountains. *In*: Robertson, A.H.F., Searle, M.P. & Ries, A.C., (Eds.), *The geology and tectonics of the Oman region. London Geological Society Special Publication*, No. 49, pp. 495–520.

Pickford, M., Wanas, H. & Soliman, H. (2006) Indications for a humid climate in the Western Desert of Egypt 11–10 Mya ago: evidence for Galagidae (Primates, Mammalia). *Comptes Rendus Palevol*, 5, 935–943.
http://dx.doi.org/10.1016/j.crpv.2006.09.001

Rollinson, H.R., Searle, M.P., Abbasi, I.A., Al-Lazki, A.I. & Al Kindi, M.H. (2014) Tectonic evolution of the Oman Mountains: an introduction. *Geological Society, London, Special Publications*, 392, 1–7.
http://dx.doi.org/10.1144/SP392.1

Saigusa, T. (2006) *Homology of wing venation of Diptera*. Privately published, Fukuoka. [unkown pagination]

Sinclair, B.J., Cumming, J.M. & Wood, D.M. (1994) Homology and phylogenetic implications of male genitalia in Diptera—Lower Brachycera. *Entomologica scandinavica*, 24, 407–432.
http://dx.doi.org/10.1163/187631293X00190

Stuckenberg, B.R. & Fisher, M. (1999) A new species of *Lampromyia* Macquart, from Oman: the first record of Vermileonidae (Diptera) from the Arabian Peninsula. *Annals of the Natal Museum*, 40, 127–136.

Stuckenberg, B.R. (2003) A redescription of *Isalomyia irwini* Stuckenberg, the wormlion fly of Madagascar, related to an Arabian species for which the new genus *Alhajarmyia* is erected (Diptera: Vermileonidae). *African Invertebrates*, 44, 191–201.

Wheeler, W.M. (1930) *Demons of the dust*. W.W. Norton & Company Inc., New York, 378 pp.

Woodley, N.E. (2009) 31. Vermileonidae (worm-lions). *In*: Brown, B.V., Borkent, A., Cumming, J.M., Wood, D.M., Woodley, N.E. & Zumbado, M.A., (Eds.), *Manual of Central American Diptera. Vol. 1*. NRC Research Press, Ottawa, pp. 481–483.

Woodley, N.E., Borkent, A. & Wheeler, T.A. (2009) 5. Phylogeny of the Diptera. *In*: Brown, B.V., Borkent, A., Cumming, J.M., Wood, D.M., Woodley, N.E. & Zumbado, M.A., (Eds.), *Manual of Central American Diptera. Vol. 1*. NRC Research Press, Ottawa, pp. 79–94.

Wootton, R.J. & Ennos, A.R. (1989) The implications of function on the origin and homologies of the dipterous wing. *Systematic Entomology*, 14, 507–520.
http://dx.doi.org/10.1111/j.1365-3113.1989.tb00300.x