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A NEW RECORD OF ZORAPTERA (INSECTA) FROM KENYA, WITH REMARKS ON THEIR HABITAT

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ABSTRACT

We hereby record a zorapteran insect from Kenya. The species is easily distinguishable from other described African species of Zoraptera because of its distinct sexual dimorphism and male characteristics. Males have a hairy patch on the head and an asymmetric hairy patch with different types of setae on the last sternite, whereas females have no hairy patch. These conspicuous characteristics have not been described for any known African species described to date. The African fauna of Zoraptera were investigated until the 1970s and have not been thoroughly studied since that time. To accumulate knowledge on this enigmatic order and stimulate more research in Africa, we describe the habitat where we found this species in Kenya.

Keywords: Angel insects; field work; ground lice; Kakamega National Park; sexual dimorphism

INTRODUCTION

The insect order Zoraptera is a lineage typically classified among the Polyneoptera, but its phylogenetic position remains challenging to determine and is of continued investigation (*e.g.* Wang, Y.H. *et al.*, 2013, 2016; Ma *et al.*, 2014; Mashimo *et al.*, 2014; Misof *et al.*, 2014). Although Silvestri (1913) established the order slightly more than a century ago, it is still one of the smallest and least understood of insect lineages (Beutel *et al.*, 2014; Engel, 2014; Mashimo *et al.*, 2014). Up to the present, 41 extant species have been described (Wang, J. *et al.*, 2016), which is amazingly few compared to other insect orders. Species are relatively

small (*ca*. 2–3 mm) and live in cryptic habitats, *e.g*. under bark of rotting trees or in fermented sawdust (Choe, 1992; Costa, 2006; Engel, 2009, 2014; Mashimo *et al*., 2014). Because of their homogenous appearance, all extant species have been classified into a single family, Zorotypidae, with two genera, one of which is extinct (Engel & Grimaldi, 2000, 2002). The general appearance of zorapterans is rather simple and the group as a whole can be recognized by their dimorphic life stages, with apterous and blind dominant form and fully winged and eyed dispersive forms, as well as unique wing venation, enlarged metafemora with ventral spination and metatibial depressors greatly developed, dimerous tarsi, unsegmented cerci and absence of an ovipositor (Engel & Grimaldi, 2000; Engel, 2009, 2014; Beutel *et al*., 2014; Mashimo *et al*., 2014). In contrast to their outer appearance, there is a wide diversity in reproductive morphology and mating behaviour among the few species that have been studied in sufficient detail (Gurney, 1938; Choe, 1997; Mashimo *et al*., 2014; Dallai *et al*., 2015). This diversity almost corresponds to that of Hexapoda in terms of the symmetry/asymmetry of genitalia, elongation of the penis, two intromittent organs, correlation of spermatozoon and spermathecal duct lengths, nuptial gifts, dominant hierarchy in males, and external sperm transfer (*e.g*. Mashimo *et al*., 2014; Matsumura *et al*., 2014; Dallai *et al*., 2015). Because they are relatively easy to rear in a laboratory (Gurney, 1938; Shetlar, 1978; Mashimo *et al*., 2011, 2015), these insects have the potential to be used for evolutionary studies of sexual selection (*e.g*. Choe, 1994a, b, 1995).

Many new records and species have been reported recently from South America, Asia, and Oceania (Chao & Chen, 2000; New, 2000; Engel, 2000, 2001; Rafael & Engel, 2006; Engel, 2007; Engel & Falin, 2008; Rafael *et al*., 2008; Terry & Whiting, 2012; Mashimo *et al*., 2013; Engel & Gimmel, 2014; Yin *et al*., 2015; Wang, J. *et al*., 2016). However, no records have been reported from Africa since 1971 (Ryn-Tournel, 1971), aside from a single species occurring in the Seychelles (Zompro, 2005). Investigation of Zoraptera from Africa was carried out in the early 20th century, and until now, it has been completely ignored on the mainland. To reduce the bias of research among continents and as a preliminary step, we carried out an intensive field survey in Kenya, where zorapterans were not yet known. Based on our field survey, we report an undescribed species of zorapteran from western forests and provide important habitat information to assist researchers who intend to study Zoraptera in Africa.

MATERIAL AND METHODS

We carried out an intensive field study in the Kakamega National Park (00°14'N, 34°52'E)(figure 1), Kakamega County, Kenya from 28 May to 2 June 2016. We explored the forest with a local guide and checked almost all of the fallen trees encountered, as well as their surroundings, using a hatchet and a buccal aspirator (*e.g*. figure 8). Zorapterans were kept in plastic bags with pieces of same bark according to locality, occasionally in plastic boxes, to observe their general behaviour for one week, after which they were fixed in 99.5% ethanol or 2.5% glutaraldehyde for further investigation. Voucher specimens were deposited in the National Museum of Kenya, Nairobi (NMK).

One male fixed with 2.5% glutaraldehyde was rinsed in phosphate-buffered saline (PBS; Carl Roth GmbH & Co. KG, Karlsruhe, Germany), dehydrated with a graded series of ethanol up to 100%, and then dried with a critical point dryer (CPDA/Quorum Technologies LTD, Kent, UK). The dried individual was sputter-coated with gold palladium (*ca*. 10 nm)

using a Leica EM SCD 500 High Vacuum Sputter Coater (Leica Microscopy GmbH, Wetzlar, Germany). The surface structures were observed using a scanning electron microscope Hitachi S3000 (Hitachi High-Tech Corp., Tokyo, Japan) at an accelerating voltage of ca. 15 kV.

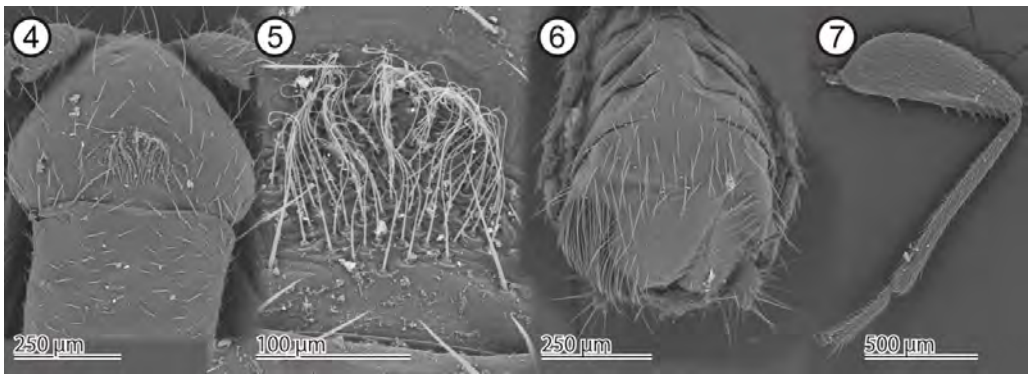
Figure 1 Location of the Kakamega Forest National Park in Kenya.

RESULTS AND DISCUSSION

During our field survey, we successfully collected 145 adults (eight sex-unidentified individuals deposited in NMK, 38 males and 99 females which are under further investigation and will be deposited at a later date) and 28 juveniles (under morphological investigation), from 15 different locations within Kakamega Forest. All individuals belonged to one species, and both morphs (*i.e.* winged and wingless) were observed (figures 2 and 3). They showed marked sexual dimorphism in their outer structures, as is true for other species of Zoraptera, particularly those from Africa (*e.g.* Delamare-Deboutteville, 1951). The females were rather simple, similar to other zorapteran species, while males had a dense setal patch on the dorsal surface of the head (figures 4 and 5) and an asymmetric region with different types of setae on their last sternite (figure 6). A loose setal patch is present in the same region on the vertex of males of *Zorotypus congensis* Ryn-Tournel, 1971, and in this species and some others there is a central fontanelle present. Unlike *Z. congensis*, the present species from Kenya lacks a distinct fontanelle within this setal patch, and the combination of characters similarly differs from other African species—*Z. delamarei* Paulian, 1949, *Z. vinsoni* Paulian, 1951, and *Z. guineensis* Silvestri, 1913. Like, many of the African taxa, the Kenyan species has rather fine, short, and comparatively simple metafemoral spines (figure 7). Among the known African species, the Kenyan species most closely resembles *Z. congensis*, but appears to represent an unnamed species and will be treated in taxonomic detail elsewhere.

Figure 2. Zorotypus *sp. in the field. Wingless male. Courtesy of Takashi Komatsu (Kyushu Uni. Japan).*

Figure 3. Zorotypus *sp. in the field. Dealate female. Courtesy of Takashi Komatsu (Kyushu Uni. Japan).*



Figures 4–7. Scanning electron microscopy images of Zorotypus *sp. 4. Dorsal view of head of apterous male. 5. Details of the dense setal patch on the head of the image 4. 6. Ventral view of post-abdomen of same male. 7. Ventral view of left hind leg of same male.*

Our field analysis was not carried out statistically. However, to collect certain insect groups, which are associated with specific environments, some tips based on experience are quite useful. Therefore, we documented their habits, including our subjective view of the environments that the zorapterans in the forest seemed to prefer. In Kakamega Forest, the insects were found only in areas of relatively high humidity. As generally known for Zoraptera, the insects were found under the bark of fallen dead trees at certain stages of decomposition (Choe, 1992; Mashimo *et al.*, 2014), widely referred to as the "zorapteran stage" (Wilson, 1959). We never found the insects in dry trees or trees filled with mud (figure 9). They were also not found in trees that had no decomposed material under the bark. The environment observed by Y.M. was in complete contrast to zorapterans in Malaysia, Ecuador, and Brazil, where undecomposed trees were the most preferred habitat. In Kakamega Forest, zorapterans were found under bark containing a great deal of decomposed and fluffy material (figure 10) or, occasionally, in areas with probable osoriine beetles (figure 11). Moreover, zorapterans were found under small chunks of wood (figures 12–14) located in relatively sunny and hot areas during the daytime (figure 15). No zorapterans were found in litter close to the wood. Another important observation was that most zorapterans were not found in clusters; however, nymphs were often observed together. To collect zorapterans it is necessary to destroy the logs in which they were found and we therefore had to make our observations under unnatural conditions. They might have a gregarious habit, as discussed by Shetlar (1978) and Costa (2006), but from our field and laboratory observations, we were unable to observe gregarious habits. One noteworthy observation we made under laboratory conditions was necrophagic cannibalism, whereby individuals ate the corpses of conspecifics (figure 16). What we could not confirm from our study was whether there were any interactions among individuals. However, in the same habitat, we often found osoriine beetles, dermapterans, and collembolans, while logs harbouring termites and ants were never colonised by zorapterans.

Mating of zorapterans is relatively easy to observe in some species (*e.g.* Choe, 1994a, b, 1995; Dallai *et al.*, 2013, Matsumura *et al.*, 2014), but we did not observe mating during this survey. In the Central American species *Z. barberi* Gurney, 1938 a similar setal patch on the head of males is used to secrete liquids as a nuptial gift to females (Choe, 1995, 1997). The structure found in the current species might be related to this type of mating behaviour and could be homologous. Unfortunately, there is presently no information on the mating behaviour of the African species, and this should therefore be investigated in future studies.

Figures 8–15. Habitats of the Zorotypus *sp. in the Kakamega forest. 8. Collecting* Zorotypus *sp. on log using hatchet and buccal aspirator. 9. Mud rich habitat where no zorapterans were observed. 10. Typical decomposed and fluffy soil on log. 11. One of the places where we found several individuals of the* Zorotypus *sp. The gallery is mined by beetle larvae. 12. A relatively sunny area where* Zorotypus *were found. 13. The place where we collected the* Zorotypus *sp. under small log. The hatchet (*ca. *25 cm in length) we used are located as a scale. 14. Close-up view of image 13, where the* Zorotypus *sp. were observed. 15. A typical sun exposed zorapteran habitat in Kakamega forest.*

Figure 16. Necrophagous cannibalism of conspecifics.

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