



Pictorial keys to the sections, groups, and species of the *Aedes* (*Finlaya*) in the Afrotropical Region (Diptera: Culicidae)

YIAU-MIN HUANG¹ & LEOPOLDO M. RUEDA²

¹Department of Entomology, P.O. Box 37012, MSC C1109, MRC 534, Smithsonian Institution, Washington, D.C. 20013-7012, U.S.A. E-mail: huangy@si.edu

²Walter Reed Biosystematics Unit, Department of Entomology, Museum Support Center (MRC 534), Smithsonian Institution, 4210 Silver Hill Road, Suitland, MD 20746, U.S.A. E-mail: ruedapol@si.edu

Abstract

Eight species of the subgenus *Finlaya* Theobald, genus *Aedes* Meigen, in the Afrotropical Region are treated in pictorial keys based on diagnostic morphological features. Images of the diagnostic morphological structures of the adult thorax, leg and wing are included.

Key words: Culicidae, mosquitoes, identification key, *Aedes*, *Finlaya* Africa

Introduction

In “Mosquitoes of the Ethiopian Region, in the Subgenus *Finlaya* Theobald”, Edwards (1941: 119) noted that the African species of this subgenus belonged to two very distinct groups: the Wellmanii Group without metallic markings, and the Fulgens Group of black species with silvery markings on the thorax and abdomen.

Edwards (1941: 120), in his “Key to Ethiopian Species of *Finlaya*”, included six species from Africa in **Couplet 1b. “No metallic silvery scales on thorax or abdomen”**: (1) *Aedes* (*Finlaya*) *wellmanii* (Theobald) (1905: 103) from Bihe, Angola; (2) *Aedes* (*Finlaya*) *ingrami* Edwards (1930: 296) from Aburi, Ghana (Gold Coast); (3) *Aedes* (*Finlaya*) *embuensis* Edwards (1930: 295) from Embu, Kenya; (4) *Aedes* (*Finlaya*) *nyasae* Edwards (1930: 296) from Fort Johnston, Malawi (Nyasaland); (5) *Aedes* (*Finlaya*) *barnardi* Edwards (1924: 161) from Oudebosch, Cape Province, Republic of South Africa (Union of South Africa); and (6) *Aedes* (*Finlaya*) *pulchrithorax* Edwards (1939: 17) from Nairobi, Kenya. In addition, Robinson (1950: 80) described *Aedes* (*Finlaya*) *luteostriatus* from Ndola, Zambia (Northern Rhodesia); and Van Someren (1962: 21) described *Aedes* (*Finlaya*) *hancocki* from Amani, Tanzania (Tanganyika). Thus, the subgenus *Finlaya* in the Afrotropical Region currently consists of eight species.

To assist entomologists and other field workers in the identification of mosquitoes from Africa, pictorial keys are included as add-ons to the key of Huang (2001). A few additional characters, indicated by double asterisks (**), were added as needed to facilitate identification. Images of the diagnostic morphological structures of the adult thorax, leg, and wing are also included in the supplemental pictorial keys.

Material and methods

This study is based on specimens in the mosquito collection of the Department of Entomology, National Museum of Natural History (USNM), Smithsonian Institution and specimens borrowed from individuals and institutions noted in the Acknowledgments. The terminology follows Harbach and Knight (1980, 1982) with the exception of “tarsal claws,” which is retained as “ungues.” Terminology for wing venation follows Belkin (1962).

Result and discussion

Classification. The African subgenus *Finlaya* can be further divided into two sections, Sections A and B. Section A is characterized by having the subspiracular area with scales, and the hindtibia is all dark, without a white stripe on the ventral surface of the basal area. It is represented by two species-groups: the Wellmanii Group (including *Ae. (Fin.) wellmanii* (Theobald) and *Ae. (Fin.) ingrami* Edwards); and the Barnardi Group (including *Ae. (Fin.) barnardi* Edwards, *Ae. (Fin.) embuensis* Edwards, and *Ae. (Fin.) nyasae* Edwards). Section B is characterized by having the subspiracular area without scales and a white stripe on the ventral surface of the basal area of the hindtibia. It is represented by one species-group, the Pulchrithorax Group (including *Ae. (Fin.) pulchrithorax* Edwards, *Ae. (Fin.) hancocki* Van Someren, and *Ae. (Fin.) luteostriatus* Robinson). Thus, the African Subgenus *Finlaya* currently consists of three species-groups.

Huang (2001) published a key to the *Aedes* mosquitoes of the Afrotropical Region. It is openly available from the website of the Biodiversity Heritage Library (<http://www.biodiversitylibrary.org/>) and Walter Reed Biosystematics Unit (http://wrbu.si.edu/wrbupubs_chron.html).

The present paper includes three pictorial keys for *Aedes (Finlaya)* Sections (Appendix 1), Wellmanii and Barnardi Groups (Appendix 2), and Pulchrithorax Group (Appendix 3) in the Afrotropical Region. These keys are formatted so that they can be merged with the key of Huang (2001). The following steps should be followed when using the key of Huang (2001) to merge the supplemental keys:

(1) Pictorial Key to the Sections of the *Aedes (Finlaya)* in the Afrotropical Region (Diptera: Culicidae) (Appendix 1). From page 34 of the Huang (2001) key, with “**Part 3. Key to Subgenera of *Aedes*”**, ADULTS, follow the key to pages 35, 36, 38, and 39. Then, replace page 39, on the left side—Thorax. Subspiracular area with scales ...SECTION A, and ** Leg. Hindtibia all dark, without a white stripe on ventral surface in basal area, and to page 39A (1st page) of Appendix 2. On the right side—Thorax. Subspiracular area without scales ...SECTION B, and ** Leg. Hindtibia with a white stripe on ventral surface in basal area, and to page 39D (4th page) of Appendix 3.

(2) Pictorial Key to the Species of the *Aedes (Finlaya)* Wellmanii and Barnardi Groups in the Afrotropical Region (Diptera: Culicidae) (Appendix 2). Using Appendix 2, the supplemental key, add pages 39A (1st page), 39B (2nd page), and 39C (3rd page), to key out to five species of *Aedes (Finlaya)* Wellmanii and Barnardi Groups.

(3) Pictorial Key to the Species of the *Aedes (Finlaya)* Pulchrithorax Group in the Afrotropical Region (Diptera: Culicidae) (Appendix 3). Using Appendix 3, the supplemental key, add pages 39D (4th page), 39E (5th page A and 5th page B), and 39F (6th page A and 6th page B), to key out to three species of *Aedes (Finlaya)* Pulchrithorax Group.

Medical Importance and Brief Biology. *Aedes ingrami* is a suspected vector of Uganda S virus (USV) (in the Yellow Fever Virus Subgroup, Flavivirus Group, Flaviviridae), with birds and humans as hosts, in Uganda, Nigeria and Central Africa (Chamberlain 1980). Dick & Haddow (1952) isolated USV from a pool of 47 *Ae. (Zavortinkius) longipalpis* (Grunberg), 17 *Ae. (Finlaya) ingrami*, and one *Ae. (Aedimorphus) natronius* Edwards in Bwamba County, Uganda. However, Haddow (1961) stated that either *Ae. longipalpis* or *Ae. ingrami* was probably the species of the original isolation of USV. Zika virus (ZIKV) (in Flavivirus Group, Flaviviridae), which was first discovered from Zika Forest, Uganda, and was named after that forest (<http://www.cdc.gov/zika/about/index.html>). It has never been isolated from African *Aedes (Finlaya)* species, although ZIKV was found in other subgenera of *Aedes* in Africa and other regions of the world.

Unlike some African *Aedes* mosquitoes, including *Ae. (Aedimorphus) cumminsii* (Theobald), *Ae. (Aedimorphus) domesticus* (Theobald) that actively bite during the day and night, *Ae. ingrami* bites mainly at dusk (Service 1993). Haddow *et al* (1968) recorded the modal periods for onset of biting at dusk by *Ae. ingrami* and six other mosquito species above the forest canopy of Zika Forest, Uganda. Kaddumukasa *et al* (2014) collected *Ae. cumminsii* (n = 12 adults) and *Ae. ingrami* from CO₂- baited light traps (n = 19 adults) and *Ae. ingrami* from human-bait (n = 129 adults) in Zika Forest (2009–2010). In the previous mosquito surveillance in Zika Forest, *Ae. cumminsii* adults were also collected from 1960–1961, while *Ae. ingrami* were found from 1955–1965 (Kaddumukasa *et al* 2014). Furthermore, Clements (1999) described interesting observations on *Ae. ingrami* and *Ae. (Stegomyia) africanus* (Theobald) in a forest. He reported that just before sunset, a female of *Ae. ingrami* would arrive and within a few minutes as darkness descended on the forest, a large swarm of *Ae. ingrami* females were biting. After 15 minutes, when the wave of mosquito attack was nearly over, the first female of *Ae. africanus*

arrived. After about five minutes of overlap when small numbers of both species were present together, *Ae. ingrami* disappeared from the scene and the numbers of *Ae. africanus* built up to a considerable peak. *Aedes ingrami* eggs were collected from debris inside tree holes, together with other *Aedes* species in Nigeria (Lambrecht and Peterson 1977). Except for *Ae. ingrami*, the medical importance and biology of other African *Finlaya* mosquitoes are unknown.

Remarks. Reinert *et al.* (2006) placed three species (*pulchrithorax*, *hancocki* and *luteostriatus*) of the *Aedes* (*Finlaya*) in a new Genus, *Vansomerenis* Reinert, Harbach & Kitching 2006 and Reinert *et al.* (2008) placed five species (*barnardi*, *embuensis*, *nyasae*, *wellmanii* and *ingrami*) of *Aedes* (*Finlaya*) in a new Genus, *Hopkinsius* Reinert, Harbach & Kitching 2008. On the other hand, Wilkerson *et al.* (2015) did their own interpretation of the taxonomic ranks of Reinert *et al.* (2006, 2008) genera by placing *Vansomerenis* and *Hopkinsius* as subgenera of the Genus *Aedes*. Based on the diagnostic morphological characters of the male genitalia, however, we recognize that the above eight African *Aedes* species belong to a single subgenus *Finlaya*, which consists of three species-groups.

In the present paper, we follow Edwards' (1932, 1941) classification of the genus *Aedes*, retaining *Finlaya* as a subgenus of the genus *Aedes* in the Afrotropical Region.

Acknowledgments

We express sincere appreciation and gratitude to Mr. Scott D. Whittaker, Manager SEM Laboratory, National Museum of Natural History, Smithsonian Institution, for access to and assistance with the imaging-digital instrument (Olympus SZX-12 MDU) while conducting this study; to Dr. Wayne N. Mathis, Department of Entomology, Smithsonian Institution, Dr. Richard C. Wilkerson, and Dr. Maysa Motoki, Walter Reed Biosystematics Unit (WRBU), and Prof. Maria Anice Mureb Sallum, University of São Paulo, São Paulo, Brazil, for critically reviewing this manuscript, and for their valuable comments.

We are most grateful to Miss Theresa M. Howard, Head of Entomological Collections, Molecular Collections, and Plants, Department of Life Sciences, The Natural History Museum, London, UK, for the loan of several types and other specimens. We also acknowledge with sincere appreciation Prof. Maureen Coetzee, Vector Control Reference Unit, National Institute for Communicable Diseases (VCRU/NICD), Johannesburg, South Africa, for the loan of types and other specimens from the South African Institute for Medical Research (SAIM).

This research was performed under a Memorandum of Understanding between the Walter Reed Army Institute of Research and the Smithsonian Institution, with institutional support provided by both organizations. The text and graphics published herein reflect the views of the authors and should not be construed to represent those of the Department of the Army or the Department of Defense.

References

- Belkin, J.N. (1962) *The mosquitoes of the South Pacific (Diptera, Culicidae)*. Vol. 1. & 2. University California Press, Berkeley and Los Angeles, 608 pp. & 412 pp.
- Chamberlain, R.W. (1980) Epidemiology of arthropod-borne togaviruses: the role of arthropods as hosts and vectors of natural transmission cycles, In: Schlesinger, W.R., ed., *The Togaviruses: Biology, Structure, Replication*. Academic Press, New York, pp. 175–228.
- Clements, A.N. (1999) *The Biology of Mosquitoes, Vol. 2: Sensory Reception and Behavior*. CABI Publishing, Wallingford, UK, 756 pp.
- Dick, G.W.A. & Haddow, A.J. (1952) Uganda S virus a hitherto unrecorded virus isolated from mosquitoes in Uganda. (1) Isolation and pathogenicity. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 46, 600–618.
- Edwards, F.W. (1924) Some mosquitos from Ovamboland, S. W. Africa, and from the Cape Province. *Annals of the South African Museum*, 19, 159–163.
- Edwards, F.W. (1930) Mosquito notes.—IX. *Bulletin of Entomological Research*, 21, 287–306.
- Edwards, F.W. (1932) *Genera Insectorum. Diptera. Family Culicidae. Fascicle 194*. Desmet-Verteneuil, Brussels, 258 pp.
- Edward, F.W. (1932) *Genera Insectorum. Diptera. Family Culicidae. Fascicle 194*. Desmet-Verteneuil, Brussels, 258 pp.
- Edwards, F.W. (1939) A new East African *Aedes* (Diptera, Culicidae). *Proceedings of the Royal Entomological Society of London (B)*, 8, 17.
- Edwards, F.W. (1941) *Mosquitoes of the Ethiopian region. III. Culicine adults and pupae*. British Museum (Natural History), London, 499 pp.

- Haddow, A.J. (1961) Studies on the biting habits and medical importance of East African mosquitoes in the genus *Aedes*. II.— Subgenera *Mucidus*, *Diceromyia*, *Finlaya* and *Stegomyia*. *Bulletin of Entomological Research*, 52, 317–351.
- Haddow, A.J., Casley, D.J.L., O'sullivan, J.P., Ardoin, P.M.L., Ssenkubuge, Y. & Kitama, A. (1968) Entomological studies from a high steel tower in Zika Forest, Uganda. Part II. The biting activity of mosquitoes above the forest canopy in the hour after sunset. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 120, 212–236.
- Harbach, R.E. & Knight, K.L. (1980) *Taxonomists' glossary of mosquito anatomy*. Plexus Publishing, Inc., Marlton, New Jersey, 415 pp.
- Harbach, R.E. & Knight, K.L. (1982) Corrections and additions to taxonomists' glossary of mosquito anatomy. *Mosquito Systematics* (1981), 13 (2), 201–217.
- Huang, Y.-M. (2001) A Pictorial Key for the Identification of the Subfamilies of Culicidae, Genera of Culicinae, and Subgenera of *Aedes* Mosquitoes of the Afrotropical Region (Diptera: Culicidae). *Proceedings of the Entomological Society of Washington*, 103 (1), 1–53.
- Kaddumukasa, M.A., Mutebi, J.P., Lutwama, J.J., Masembe, C. & Akol, A.M. (2014) Mosquitoes of Zika Forest, Uganda: species composition and relative abundance. *Journal of Medical Entomology*, 51 (1), 104–113. <http://dx.doi.org/10.1603/ME12269>.
- Lambrecht, F.L. & Peterson, R.D. (1977) The hatching of mosquito larvae from material collected in dry tree holes and in dry water storage jars in Anambra State, Nigeria. *World Health Organization (WHO)/Vector Biology & Control (VBC)*, 76.649, 1–6.
- Reinert, J.F., Harbach, R.E. & Kitching, I.J. (2006) Phylogeny and classification of *Finlaya* and allied taxa (Diptera: Culicidae: Aedini) based on morphological data from all life stages. *Zoological Journal of the Linnean Society*, 148 (1), 1–101.
- Reinert, J.F., Harbach, R.E. & Kitching, I.J. (2008) Phylogeny and classification of *Ochlerotatus* and allied taxa (Diptera: Culicidae: Aedini) based on morphological data from all life stages. *Zoological Journal of the Linnean Society*, 153 (1), 29–114.
- Robinson, G.G. (1950) A new species of *Aedes* (*Finlaya*) from Northern Rhodesia. *Journal of the Entomological Society of Southern Africa*, 13, 80–82.
- Service, M.W. (1993) Mosquitoes (Culicidae). In: Lane, R.P. & Crosskey, R.W. (eds), *Medical Insects and Arachnids*. Natural History Museum, Chapman and Hall, London, United Kingdom, pp. 120–240.
- Theobald, F.V. (1905) New Culicidae from the west coast of Africa. *Entomologist*, 38, 101–104, 154–158.
- Van Someren, E.C.C. (1962) Ethiopian Culicidae: Three new *Aedes* from Tanganyika, with a description of the male of *Aedes usambara* Mattingly and the female of *Uranotaenia henrardi* Edwards. *Proceedings of the Royal Entomological Society of London (B)*, 31, 19–26.
- Wilkerson, R.C., Linton Y.M., Fonseca, D.M, Schultz, T.R., Price, D.C. & Strickman, D.A. (2015) Making mosquito taxonomy useful: a stable classification of Tribe Aedini that balances utility with current knowledge of evolutionary relationships (Diptera: Culicidae). *PLOS ONE*, 10 (7), e0133602. <http://dx.doi.org/10.1371/journal.pone.0133602>.

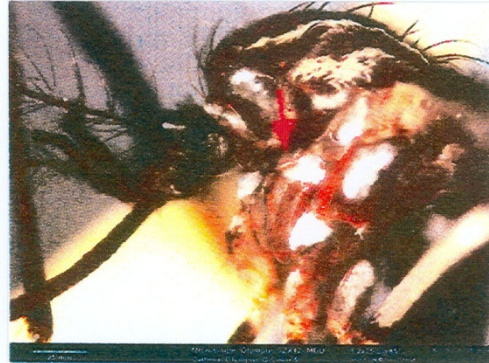
APPENDIX 1. Pictorial Key to the Sections of the *Aedes (Finlaya)* (Diptera: Culicidae) in the Afrotropical Region.

(replace Page 39)

Page 39

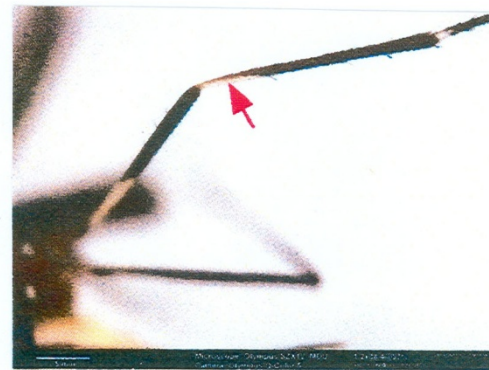
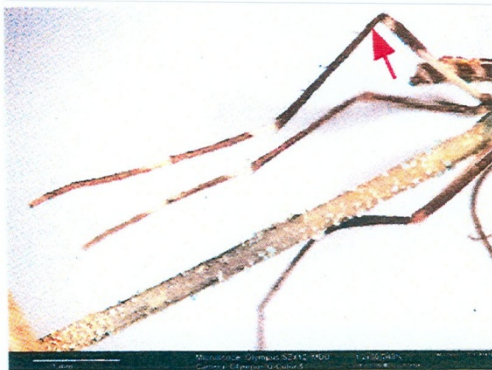
Thorax. Subspiracular area with scales ... SECTION A

Thorax. Subspiracular area without scales ... SECTION B



**
Leg. Hindtibia all dark, without a white stripe on ventral surface in basal area

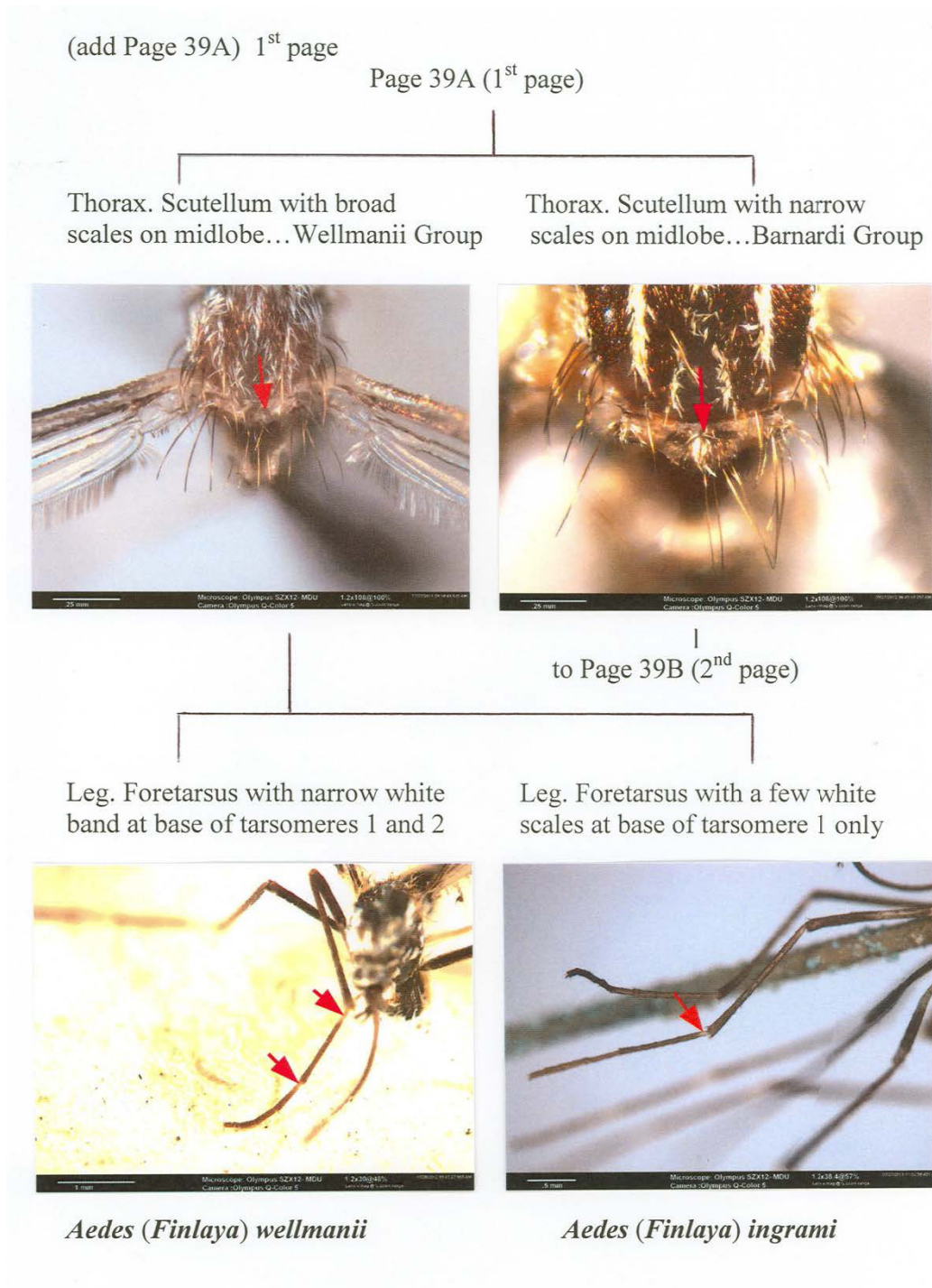
**
Leg. Hindtibia with a white stripe on ventral surface in basal area



to Page 39A (1st page)

to Page 39D (4th page)

APPENDIX 2. Pictorial Key to the Species of the *Aedes* (*Finlaya*) *Wellmanii* and *Barnardi* Groups (Diptera: Culicidae) in the Afrotropical Region.



Thorax. Midlobe of scutellum
with narrow, golden yellow scales



Thorax. Midlobe of scutellum
with narrow scales, some dark
and some light



Wing. With a patch of creamy-white
scales at base of costa



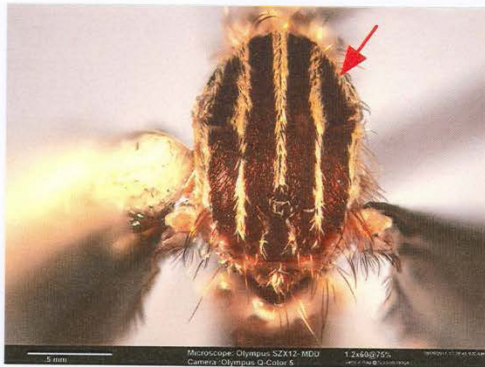
Wing. Without a patch of creamy-white
scales at base of costa



Aedes (Finlaya) embuensis

1
to Page 39C (3rd page)

Thorax. Scutum with white narrow scales forming a narrow border all around and 3 narrow lines extending from anterior margin to scutellum

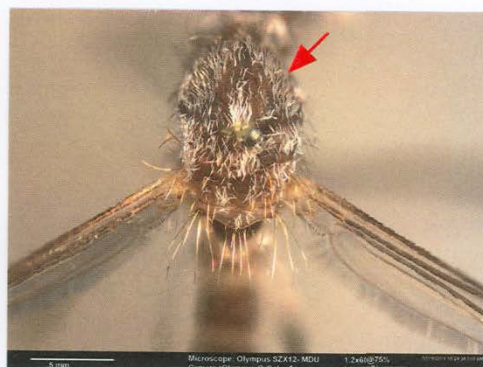


Leg. Hindtarsomere 5 all dark



Aedes (Finlaya) barnardi

Thorax. Scutum without white narrow scales forming a narrow border all around



Leg. Hindtarsomere 5 all white, or sometimes dark on one side



Aedes (Finlaya) nyasae

APPENDIX 3. Pictorial Key to the Species of the *Aedes* (*Finlaya*) Pulchrithorax Group (Diptera: Culicidae) in the Afrotropical Region.

(add Page 39D) (4th page)

Page 39D (4th page)

↓
Thorax. Scutellum with narrow
scales on midlobe...Pulchrithorax
Group

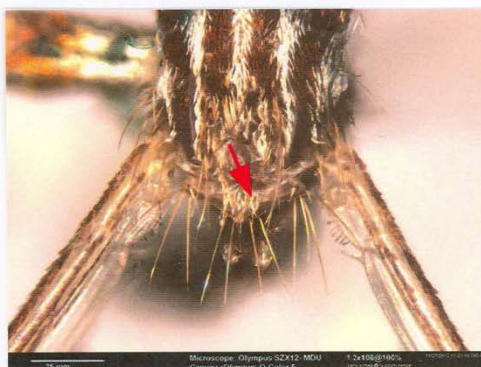


↓
Thorax. Midlobe of scutellum with
a small area of narrow, yellowish
scales, bordered by a few narrow,
dark scales



↓
to Page 39E (5th page A)

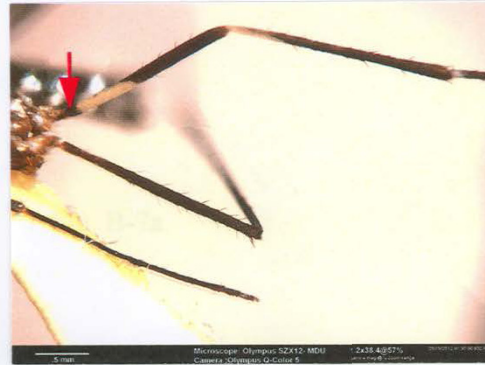
↓
Thorax. Midlobe of scutellum with
a small patch of narrow, yellow
scales,
or with some narrow, pale scales



↓
to Page 39E (5th page B)

Thorax. Scutum with 3 narrow straight lines of narrow, yellowish-white scales, the median line running whole length and forking just in front of scutellum, the 2 lateral lines are at most, very slightly wider than the median line

**
Leg. Hindfemur with a narrow, dark, basal band

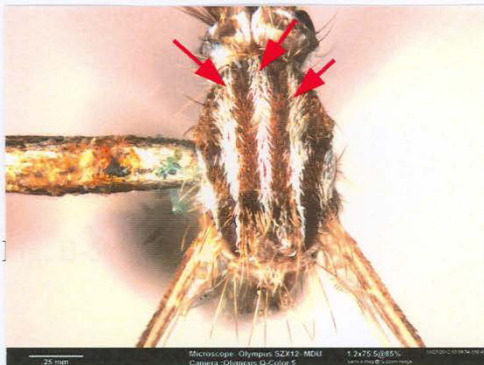


Aedes (Finlaya) pulchrithorax

(5th page B)

Thorax. Scutum with 3 yellow lines running full length of the scutum, the 2 lateral lines much wider in front than behind, with greatest breadth 0.5-2.0 times width of the median line

Thorax. Scutum with a double median stripe of narrow, yellow scales extending from the bare space to the front of the scutum, the 2 lateral lines extending about halfway forward

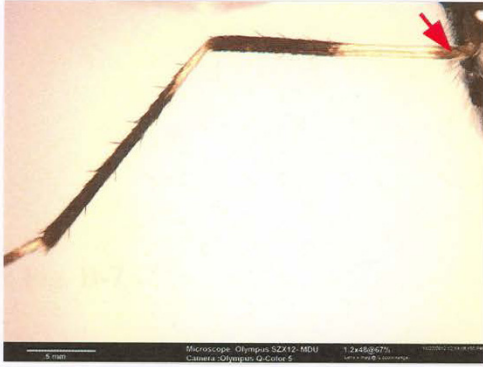


to Page 39F (6th page A)

to Page 39F (6th page B)

(6th page A)

Leg. Hindfemur with a narrow,
dark, basal band



Aedes (Finlaya) hancocki

(6th page B)

Leg. Hindfemur with all white scales
on basal half and without a narrow,
dark, basal band



Aedes (Finlaya) luteostriatus