

**SUBGENERIC POSITION OF *Aedes dufouri* HAMON WITH NOTES  
ON THE SUBGENUS *LEVUA* STONE AND BOHART  
(DIPTERA: CULICIDAE)**

YIAU-MIN HUANG, WAYNE N. MATHIS, AND RICHARD C. WILKERSON

(YMH) Department of Entomology, P.O. Box 37012, MSC C1109, MRC 534, Smithsonian Institution, Washington, DC 20013-7012, U.S.A. (e-mail: huangy@si.edu); (WNM) Department of Entomology, P.O. Box 37012, MRC 169, Smithsonian Institution, Washington, DC 20013-7012, U.S.A. (e-mail: mathisw@si.edu); (RCW) Walter Reed Biosystematics Unit (WRBU), Smithsonian Institution, Museum Support Center, Suitland, Maryland 20746, U.S.A. (e-mail: wilkersonr@si.edu) and Entomology Branch, Walter Reed Army Institute of Research, Silver Spring, Maryland 20910 U.S.A.

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*Abstract.*—*Aedes dufouri* Hamon, heretofore placed in the subgenus *Levua* Stone and Bohart, is transferred back to the subgenus *Ochlerotatus* Lynch Arribalzaga, where it is placed in a new monotypic lineage, the *dufour* group, based on a morphological assessment of characters of specimens, including the type species, *Aedes (Levua) suvae* Stone and Bohart, 1944, from Suva, Fiji. *Aedes fryeri* (Theobald) was previously removed from the subgenus *Levua* (Huang et al. 2010). Thus, no members of the subgenus *Levua* (genus *Aedes* Meigen) are now known to occur in the Afrotropical Region. The female and the male genitalia of *Ae. dufouri* are redescribed and illustrated, and the *dufour* group is diagnosed. Some morphological characters of adult males and females, as well as larvae, of the subgenera *Ochlerotatus* and *Levua* (genus *Aedes* Meigen) are tabulated.

*Key Words:* *Aedes (Levua) geoskusea* (= *suvae*), Afrotropical Region, characterization, classification, *dufour* group, *Levua*, *Ochlerotatus*, Réunion

DOI: 10.4289/0013-8797.114.2.194

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Hamon (1953: 35) described *Aedes dufouri* from specimens collected on the island of Réunion (21°06'S, 55°36'E) and placed it in the subgenus *Ochlerotatus* Lynch Arribalzaga. Danilov (1981: 86–87) then transferred *Ae. dufouri* from *Ochlerotatus* to the subgenus *Levua* Stone and Bohart, and that precedent has usually been followed in papers to the present.

We have discovered evidence, however, from our detailed study of topotypic specimens of *Ae. dufouri* (males and females) for again placing this species in the subgenus *Ochlerotatus* as a distinct lineage (the *dufour* group) and not in *Levua* or any other subgenus of *Aedes* Meigen. The primary purpose of this paper is to document the basis for our proposed reclassification of *Ae. dufouri*. *Aedes dufouri* is redescribed and illustrated as part of this documentation, which also includes diagnostic characters

\* Edited by Martin Hauser; accepted by Robert R. Kula

for separating *Ae. dufouri* from other *Ochlerotatus*. Type data, distribution, biometrics, medical importance and a taxonomic discussion of this species are also presented. Some morphological characters of adults (male and female) and larvae of the subgenera *Ochlerotatus* and *Levua* of *Aedes* are tabulated.

The specific objectives of this paper are to (1) affirm that *Aedes fryeri* (Theobald) (Huang et al. 2010) and now *Ae. dufouri*, based on morphological characters that are strikingly different from those of *Aedes (Levua) geoskusea* Amos (= *suvae*) (Fig. 1, Table 1, and Huang et al. 2010), should not be placed in the subgenus *Levua* and (2) deal formally with the suggested reclassification of *Ae. dufouri* in the subgenus *Ochlerotatus*.

#### Historical Review

Stone and Bohart (1944: 214) described the subgenus *Levua* (genus *Aedes*) and its type species, *Ae. (Levua) suvae*, from specimens collected by S. T. Helms on Suva, Fiji. The subgenus *Levua* was formerly monobasic (*Ae. geoskusea* Amos = *suvae* Stone and Bohart) and known to occur only on the Fiji Islands, South Pacific area.

Several hypotheses regarding the classification of *Aedes*, including the subgenus *Levua*, have been proposed (Reinert 2000; Reinert et al. 2004, 2006, 2008, 2009). Reinert (2000) divided *Aedes*, then with 43 subgenera, into two genera, *Aedes* and *Ochlerotatus*, and assigned 21 of the subgenera that had been included in *Aedes* to *Ochlerotatus*, keeping the remaining 22 subgenera in his redefined concept of *Aedes*. Reinert (2000) assigned the subgenus *Levua* to the genus *Ochlerotatus*. Thus, in Reinert's (2000) classification, *Aedes (Levua)* became *Ochlerotatus (Levua)*.

Subsequently, Reinert et al. (2004: 289) wrote that "(ii) three small subgenera within the basal polytomy... are undoubtedly

monophyletic, i.e. *Aedes (Huaedes)*, *Ae. (Skusea)* and *Oc. (Levua)*...," and further (2004: 360) that "*Levua* Stone and Bohart, 1944, stat. nov., [be] raised to generic rank [comprising three species] *dufour* (Hamon 1953), comb. nov., *fryeri* (Theobald 1912), comb. nov., [and] *geoskusea* (Amos 1944), comb. nov." Reinert et al. (2006: 93) continued to treat *Levua* as a genus. Reinert et al. (2008: 112) then reverted to including *Levua* as a subgenus of *Ochlerotatus*: "Subgenus *Levua* Stone and Bohart, 1944 stat. rev. *dufour* (Hamon 1953), comb. rev., *fryeri* (Theobald 1912), comb. rev., *geoskusea* (Amos 1944), comb. rev." More recently, *Levua* was again accorded generic status (Reinert et al. 2009).

#### MATERIALS AND METHODS

This study is based primarily on specimens in the Department of Entomology, National Museum of Natural History, Smithsonian Institution (USNM). Other specimens were borrowed from individuals and institutions mentioned in the acknowledgments. The terminology follows Harbach and Knight (1980, 1982) (<http://mosquito-taxonomic-inventory.info/>) with the exception of "tarsal claws," which is retained for "ungues." The wing venation follows Belkin (1962). An asterisk (\*) following the abbreviations M (= male), F (= female), P (= pupa), and L (= larva) indicates that all or some part of that sex or stage is illustrated.

#### RESULTS AND DISCUSSION

##### Classification

Edwards (1932: 130) recognized the following characters as the primary basis for the classification of *Aedes*: (1) form of the phallosome, (2) presence or absence of claspettes, and (3) form of the male palpi. These characters were used extensively in his "Keys to Subgenera" (Edwards 1932: 130–132).

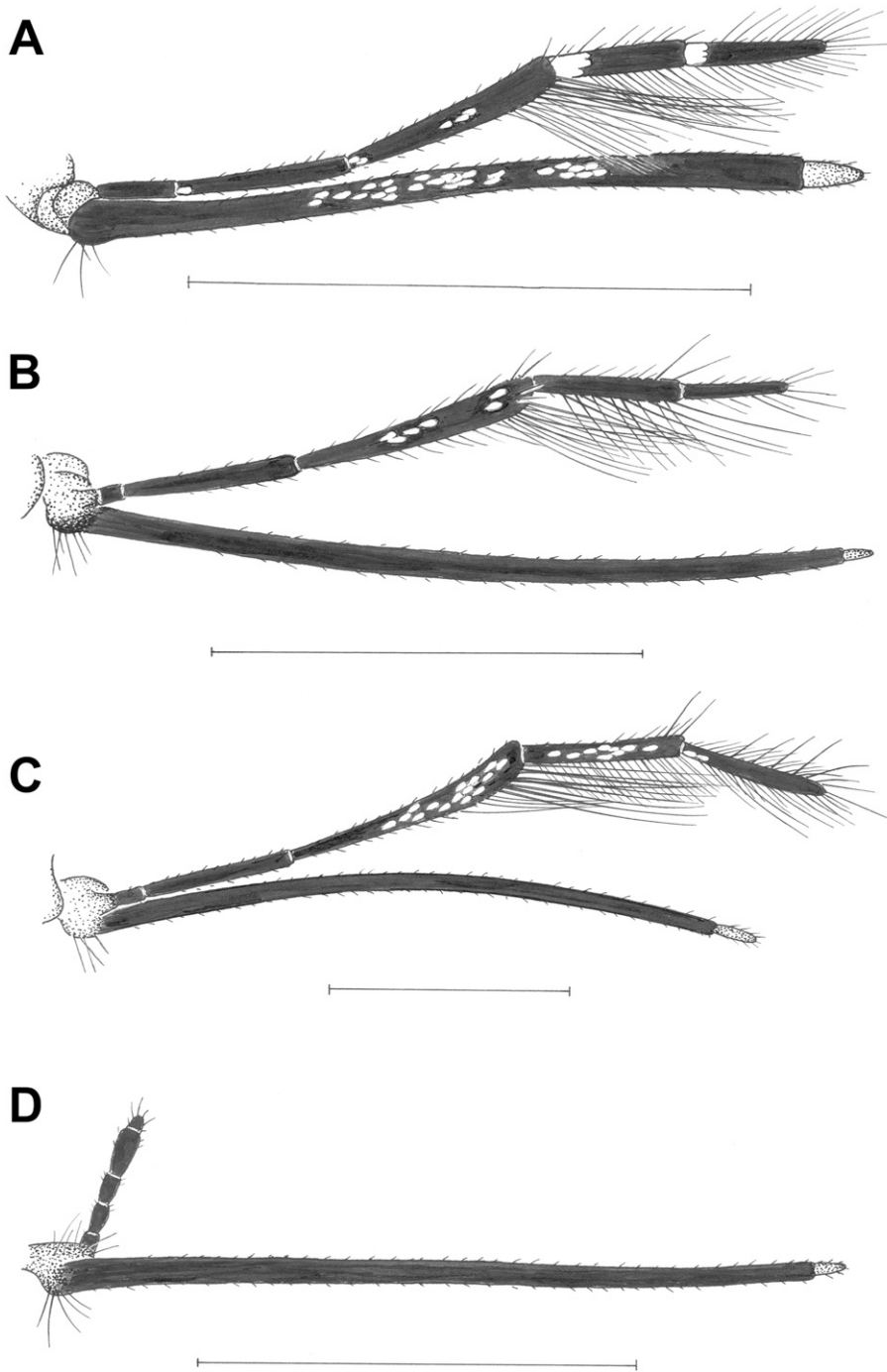


Fig. 1. Maxillary palpus and proboscis of males, lateral view. A, *Aedes (Coetzeemyia) fryeri* (Theobald); B, *Aedes (Ochlerotatus) dufouri* Hamon; C, *Aedes (Ochlerotatus) harrisoni* Muspratt; D, *Aedes (Levua) geoskusea* (Amos). Scale bars = 1.0 mm.

Table 1. Selected morphological characters of *Aedes (Ochlerotatus) dufouri*, *Ae. (Ochlerotatus)* and *Ae. (Levua) geoskusea*.

Structure	Character	Taxa		
		<i>dufourii</i>	<i>Ae. (Ochlerotatus)</i>	<i>geoskusea</i>
Adult Head	Maxillary palpus of male long, slightly shorter, as long as or longer than proboscis length	Yes	Yes	No
	Maxillary palpus of male long, 5-segmented, last two segments subequal in length and hairy	Yes	Yes	No
	Maxillary palpus of male short, 5-segmented, the last segment minute	No	No	Yes
Thorax	Lower prealar scales present	Yes	Yes	No
	Paratergal scales present	Yes	Yes	No
	Subspiracular scales present	No	Yes	No
	Postspiracular scales present	Yes	Yes	No
	Lower mesepimeral setae absent	Yes	Yes/No	Yes
	Scutellum with narrow dark scales on all lobes	Yes	No	Yes
Leg	Femora, tibiae, and tarsi all dark	No	No	Yes
Male genitalia	Gonostylus with a pair of short, very stout, pointed gonostylar claws inserted under a hood (subapically)	Yes	No	Yes
	Aedeagus large, broadened beyond base, rounded apically	No	No	Yes
	Aedeagus long, not broadened in middle, parallel-sided in basal 0.60.	Yes	No	No
	Claspette with a slender, tapered spiniform setal appendage	Yes	No	Yes
	Paraproct with a long apical spine bifid for about half its length, strongly sclerotized and curved	No	No	Yes
	Paraproct with strongly sclerotized apical tooth	Yes	Yes	No
	Tergum IX lobes prominent, strongly developed, rounded, with numerous setae on dorsal and ventral surfaces	No	No	Yes
	Tergum IX with two distinctly protrudent lobes, close together, bearing 10–11 strong setae on dorsal and ventral surfaces	Yes	No	No
Larva abdomen	Comb in very large patch of numerous long scales	No	No	Yes
	Comb scales in 2, 3 irregular rows	Yes	Yes	No

In Edwards’ “*Mosquitoes of the Ethiopian Region*” (1941: 115) under the sub-genus *Ochlerotatus*, he described the

palpus of males as being as long as or longer than the proboscis, with the last two palpomeres being subequal, downturned

and hairy. When Stone and Bohart (1944: 214) described the subgenus *Levua* and its type species, *Ae. (Levua) suvae*, they reported that the male palpus is about 0.20 the length of the proboscis. Belkin (1962: 399–400) reported that *Levua* differs from *Ochlerotatus* primarily by having a short palpus in the male and simple claws in the female. In *Ae. (Levua) suvae*, he further noted that the male palpus is about 0.20–0.25 the length of the proboscis and that it lacks long setae. Edwards (1941: 117) described *Ae. (Ochlerotatus) fryeri* in part as follows: “male palpi scarcely as long as proboscis; last two segments hairy, subequal in length, together two-thirds as long as shaft segment, with white rings at base.” Hamon (1953: 35) described *Ae. (Ochlerotatus) dufouri* from specimens collected on the island of Réunion and noted that the male palpus of this species is about 0.80 the length of the proboscis.

Apparently, Danilov (1981) mistakenly assigned *Ae. fryeri* and *Ae. dufouri* to the subgenus *Levua* since males of both of these species have long maxillary palpi (Fig. 1). In addition, other morphological characters of *Ae. fryeri* and *Ae. dufouri* are strikingly different from those of *Ae. (Levua) geoskusea* (= *suvae*) (Table 1 and Huang et al. 2010), and they therefore should be removed from the subgenus *Levua*. As a result, the subgenus *Levua* is only found in the Pacific Region and is no longer considered to occur in the Afrotropical Region.

Edwards (1932: 135–137) divided the subgenus *Ochlerotatus* (genus *Aedes*) into eight groups with the letter designations A–H, and *Ae. fryeri* was assigned to Group A (*taeniorhynchus* group: *Culicelsa*). Edwards (1932: 136) wrote that “Group A (*taeniorhynchus* group: *Culicelsa*) differs from all the other groups in having no definite apical lobe on the male coxite, and the claspette appendage is

straight and bristle-like, instead of curved and more or less flattened. The lower mesepimeral bristles are usually absent. Tarsi (at least of hind legs) have basal white rings on all segments (except perhaps the fifth). Most of the species in this group breed in brackish coastal swamps, and are found chiefly in America and Australia, one species being East African. The group does not occur in Europe.” Thus, *Ae. dufouri* is also included in Edwards’ Group A. Using Belkin’s (1962: 325–326) classification, *Ae. dufouri*, is placed in Belkin’s Section A, Subsection 4, b. – *Aedes*, subgenera *Mucidus*, *Ochlerotatus*, and *Levua*.

*Aedes dufouri* shows some similarities with species in the subgenera *Ochlerotatus* and *Levua*. It shares more important characters, however, with Afrotropical members of the subgenus *Ochlerotatus* than with the subgenus *Levua* (see Table 1). The male genitalia of *Ae. dufouri* have the gonostylus with a pair of short, pointed gonostylar claws inserted under a hood, which distinguishes it from all the known species in the subgenus *Ochlerotatus*. Because of this we recommend that a distinct lineage be recognized for *Ae. dufouri* as detailed below.

*Aedes (Ochlerotatus) dufouri* Hamon  
(Figs. 1B, 2A–D)

*Aedes (Ochlerotatus) dufouri* Hamon 1953: 40 [M\*, F\*, P\*, L\*].

*Aedes (Levua) dufouri*, Danilov 1981: 87 [subgeneric combination].

*Levua dufouri*, Reinert et al. 2004: 360 [*Levua* Stone and Bohart, 1944, stat. nov., raised to generic rank]; 2006: 93; 2009: in Appendix 2 [same as Reinert et al. 2004].

*Ochlerotatus (Levua) dufouri*, Reinert et al. 2008: 112 [subgenus *Levua* Stone and Bohart, 1944, stat. rev.].

Redescription of adult female of *Ae. dufouri*.—The description below is based

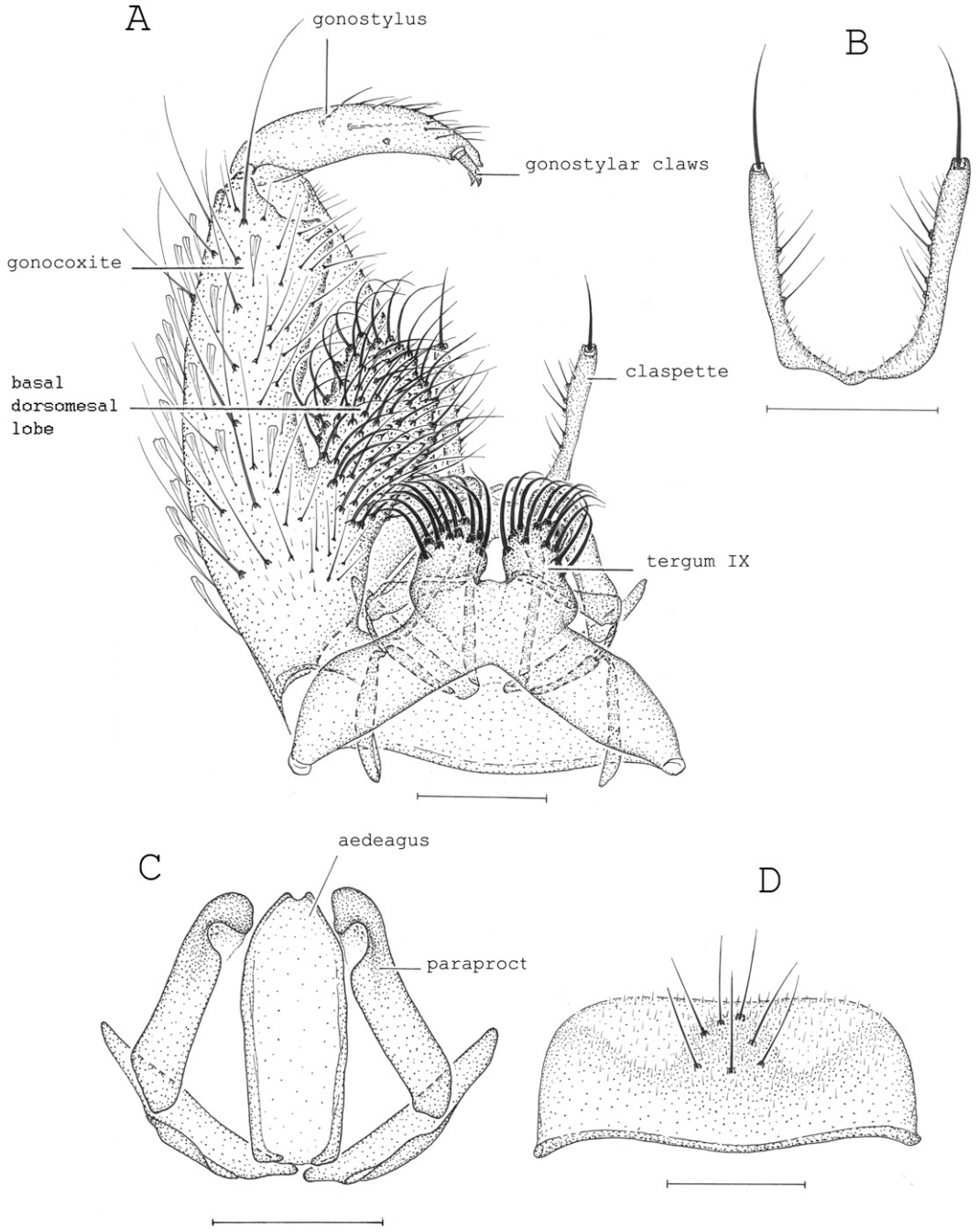


Fig. 2. *Aedes (Ochlerotatus) dufouri* Hamon. A, Tergal aspect of the male genitalia; B, Claspettes; C, Proctiger and aedeagus; D, Sternite IX. Scale bars = 0.1 mm.

on a female from Baril, La Réunion, in the Musée Royal d’Afrique Centrale, Tervuren, Belgium, [MRAC/(CMT)]. Female, with

three labels: “(1) LA REUNION, Baril, 27-4-56, J. Hamon, (2) COLL. MUS. CONGO, ex coll. J. Hamon, and (3) R. DET. 6997, F.”

Female. *Head*: Proboscis dark-scaled, speckled with few pale scales on basal 0.60 of ventral surface, with apical 0.40 all dark, about as long as forefemur; maxillary palpus 0.14–0.16 length of proboscis, dark, with a few pale scales at apex; antennal pedicel with short slender setae and few small broad flat dark scales on mesal surface; flagellomere 1 with few small flat dark scales on mesal surface; clypeus bare; erect forked scales numerous, not restricted to occiput; vertex largely with dark and some white narrow curved scales in middle, with broad dark scales on lateral areas. *Thorax*: Scutum with narrow dark brown scales; acrostichal setae present; dorsocentral setae present, well developed; scutellum with narrow dark scales on all lobes; antepronotum with broad dark scales; postpronotum with broad flat dark scales; paratergite with few broad white scales; prespiracular setae absent; postspiracular setae present; postspiracular area with broad white and dark scales; hypostigmal and subspiracular areas without scales; lower prealar scale-patch present; patches of broad white scales on propleuron, upper and lower areas of mesokatepisternum and mesepimeron; lower mesepimeron without setae; metameron and mesopostnotum bare. *Wing*: With narrow dark scales; wing membrane not clouded on crossveins r-m and m-cu; remigial setae present; upper calypter fringed with hairlike setae; alula with row of fringe scales; vein 1A ending well beyond base of fork of vein Cu; vein  $R_{2+3}$  shorter than vein  $R_2$ . *Halter*: With white scales. *Legs*: Coxae with patches of white scales; femora speckled with few pale scales; tibiae dark-scaled; fore- and midlegs with basal white bands on tarsomeres 1–3; tarsomeres 4 and 5 dark-scaled; hind leg dark-scaled with basal white band on tarsomeres 1–4, ratio length of white bands on dorsal surface to total length of tarsomeres 0.10–0.12, 0.20, 0.25 and

0.16, respectively; tarsomere 5 dark. Fore- and midlegs with tarsal claws equal, both toothed; hind leg with tarsal claws equal, both simple. *Abdomen*: Tergite I with small, median patch of white scales, and with white scales on laterotergite; tergites II–VI each with basal white band and lateral white spots not connecting with basal white band; segment VIII completely retracted; cerci long.

Redescription of male genitalia of *Ae. dufouri*.—The description below is based on a specimen from Baril, La Réunion, in the USNM. Male, with three labels: “(1) LA REUNION, Baril, 27- 4 -56, J. Hamon, (2) *Aedes dufouri* Hamon, J. Hamon, det. 1956 [handwritten], and (3) T 86.35 Term [handwritten].”, with associated genitalia on a slide (86.35 Term).

Male. *Genitalia* (Fig. 2): Gonocoxite short and broad, with large distinct basal dorsomesal lobe, but no apical dorsomesal lobe; basal dorsomesal lobe extends, as in most *Ochlerotatus*, to mesal surface on tergal part of gonocoxite, with numerous setae on expanded part; mesal membrane from base to apex. Claspette present, stem slender, with slender tapered spiniform seta at apex. Gonostylus short and stout, gradually narrowed to apex, with several setae on dorsal and ventral surfaces, with pair of short pointed gonostylar claws inserted under a hood subapically. Aedeagus simple, long, not broadened in middle, parallel-sided in basal 0.60; paraproct with strongly sclerotized curved apical tooth, with cercal setae on each side. Tergite IX with 2 distinctly protrudent, approximate lobes, each bearing 10–11 strong setae on dorsal and ventral surfaces. Sternite IX short, with 7 setae.

Type data.—*Aedes (Ochlerotatus) dufouri* Hamon, holotype male, with four data labels: (1) “24 Avril 1952, Ex pupa B” [handwritten], (2) “Ile de La Réunion, S<sup>TE</sup> Rose Marine” [handwritten], (3) “TYPE” [red rectangular paper, printed],

and (4) “*OCHLEROTATUS dufouri* Hamon TYPE” [handwritten], and paratype female, with four data labels: (1) “20 Avril 1952, Ex pupa A” [handwritten], (2) “S<sup>TE</sup> Rose Marine” [handwritten] (3) “PARATYPE” [red rectangular paper, printed], and (4) “*OCHLEROTATUS dufouri* Hamon, Matériel ayant servi à la description J. H.” [handwritten], are in the Museum National d’Histoire Naturelle, Paris, France [MNHP]; type locality: Ile de La Réunion.

Other material examined.—La Réunion: 1 male (LA REUNION, Baril, 27-4-56, J. Hamon / *Aedes dufouri* Hamon, J. Hamon, det. 1956 [handwritten] / T 86.35 Term), with associated genitalia on a microscope slide (86.35 Term); 1 female genitalia on a microscope slide (T 87.8 Term), with data (LA REUNION, Baril, 27-1956, J. Hamon / *Ae. dufouri*); all in [USNM]. 2 males (Baril, St. Philippe, La Réunion, 27-4-1956 exp. J. HAMON ORSTOM REC. / COLL. MUS. CONGO, ex coll. J. Hamon / *Ochlerotatus dufouri* Hamon, J. HAMON ORSTOM DET.); 2 females (LA REUNION, Baril, 27-4-56, J. HAMON / COLL. MUS. CONGO, ex coll. J. Hamon / R. DET. 6997, F); all in MRAC.

Distribution.—Presently known only from La Réunion (Baril).

Bionomics.—The larval habitat of *Ae. dufouri* is brackish water.

Medical importance.—Unknown.

Taxonomic discussion.—*Aedes dufouri*, formerly placed in the subgenus *Levua* by Danilov (1981), differs significantly from *Ae. (Levua) geoskusea* by the form of the male maxillary palpus (see Fig. 1B and Fig. 1D) and by structures of the male genitalia, i.e., by the absence of a group of short, broadened setae on dorsal surface along mesal margin of the gonocoxite (see Fig. 2A and fig. 3A of Huang et al. 2010); by the form of the paraprocts and the aedeagus (Fig. 2C and fig. 3C of Huang

et al. 2010); and by the development of tergite IX and sternite IX (Figs. 2A, 2D and figs. 3A, 3D of Huang et al. 2010). Therefore, it should be removed from the subgenus *Levua*. *Aedes dufouri* shares more important characters in both adult and immature stages with members of the subgenus *Ochlerotatus* than with *Levua* (Table 1), and it should be transferred back to *Ochlerotatus* (see explanation below).

The adult male and female of *Ae. dufouri* are very similar to those of *Levua* in having the vertex with largely narrow decumbent scales, with numerous erect forked scales, not restricted to occiput, the subspiracular area without scales, and the scutellum with narrow dark scales on all lobes. However, adults of *Ae. dufouri* can be distinguished from those of *Levua* by the presence of the lower prealar scale-patch, the paratergite with a few broad white scales, the postspiracular area with scales, and the femora, tibiae, and tarsi that are not entirely dark-scaled. On the other hand, these characters are also shared with species of the subgenus *Ochlerotatus*.

The male of *Ae. dufouri* is similar to that of *Levua* in having the maxillary palpus of the male with five palpomeres. It can be easily distinguished from *Levua* by the long maxillary palpus, about 0.8 length of the proboscis; palpus with conspicuous, long setae and the distal two palpomeres subequal in length and bearing setae (Fig. 1B). In *Levua*, the maxillary palpus of the male is very short, at most 0.25 length of the proboscis, without conspicuous long setae, and the distal palpomere is minute (Fig. 1D).

The male genitalia of *Ae. dufouri* (Fig. 2A) are very similar to that of *Levua* in having the aedeagus simple, without teeth, and the gonostylus with a pair of short, stout, pointed gonostylar claws inserted under a hood (subapically). They can be easily distinguished from those of *Levua* by the following: the gonocoxite lacks a



group of short broadened setae on the dorsal surface along the mesal margin; the paraproct has a strongly sclerotized apical tooth; the aedeagus is long, not broadened in the middle and parallel-sided on the basal 0.60 (Fig. 2C); tergite IX has two approximate, distinctly protrudent lobes, each bearing 10–11 strong setae on the dorsal and ventral surfaces (Fig. 2A); and sternite IX is short and bears seven setae (Fig. 2D).

In *Levua*, the male genitalia (fig. 3A of Huang et al. 2010) have the gonocoxite with a group of five to seven short, broadened setae on the dorsal surface along the mesal margin at the level of the basal dorsomesal lobe; the basal dorsomesal lobe is well developed and has shifted to the mesal surface but is connected by an indistinct basal sclerotization to the tergal surface; the paraproct has a long apical spine that is bifid for about half of its length, with the apical spine strongly sclerotized and curved; the aedeagus is large, broadened beyond the base, and is rounded apically (fig. 3C of Huang et al. 2010); tergite IX has prominent, strongly developed, rounded lobes with numerous setae on the dorsal and ventral surfaces (fig. 3A of Huang et al. 2010); and sternite IX is long with nine setae (fig. 3D of Huang et al. 2010).

The maxillary palpus of the *Ae. dufouri* males is similar to that of species of the subgenus *Ochlerotatus*. In *Ochlerotatus*, the maxillary palpus of the male is slightly shorter, as long as or longer than the proboscis, and has conspicuous long setae on the distal half. The distal two palpomeres are subequal in length, downturned, and lack white bands at their bases (see Fig. 1C).

Males and females of *Ae. dufouri* can be easily distinguished from all Afro-tropical *Ochlerotatus* species in having the subspiracular area without scales, the scutellum has narrow dark scales on all

lobes, and hind tarsomeres 1–4 have basal white bands, but tarsomere 5 is entirely dark-scaled.

The male genitalia of *Ae. dufouri* (Fig. 2) have the gonostylus with a pair of short, pointed gonostylar claws inserted under a hood, which differs from all the known species in the subgenus *Ochlerotatus* (see the description above of the male genitalia of *Ae. dufouri*). Thus, a distinct lineage (the *dufourii* group) is recognized for this species.

#### *Aedes dufouri* group

Diagnosis.—The *dufourii* group can be distinguished from other *Ochlerotatus* by the following combination of characters: (1) vertex with erect forked scales numerous, not restricted to occiput and decumbent scales largely narrow; (2) acrostichal setae present; (3) scutellum with narrow dark scales on all lobes; (4) antepnotum with broad dark scales; (5) postpronotum with broad flat dark scales; (6) paratergite with a few broad white scales; (7) postspiracular area with broad white and dark scales; (8) subspiracular area without scales; (9) lower prealar scale-patch present; (10) lower mesepimeral setae absent; (11) remigial setae present; and (12) hind tarsus with basal white band on tarsomeres 1–4, tarsomere 5 all dark.

#### Remarks on Reinert's Classification of Aedini

Although Reinert et al. (2004, 2006, 2008, 2009) substantially revised the classification of the tribe Aedini, and some of their conclusions are warranted, we do not accept all of their classification primarily for two reasons. First, their results were based on partial treatments of many groups, and a large number of species remain unplaced in their classification. Second, the selection of exemplars in some cases did not represent the known

complexity and diversity within a group. The subgenus *Levua*, for example, of Reinert et al. (2004, 2006, 2008, 2009) included only one species, *Ae. geoskusea*, for the character data in their study, and the other two known species (*Ae. fryeri* and *Ae. dufouri*) were not represented. Results of the morphological comparisons of *Ae. fryeri* and *Ae. dufouri* carried out in the present study suggest that the subgenus *Levua* is a phylogenetically heterogeneous assemblage of species rather than a monophyletic group. The new reclassification of *Aedes* by Reinert et al. (2004, 2006, 2008, 2009) has considerable preliminary merit since it is based on all generic-level taxa and most informal groups. Much refinement, however, such as some corrections proposed by Huang et al. (2010), is still needed. Thus, for the present, we are using Edwards' (1932) classification of the genus *Aedes*, retaining both *Ochlerotatus* and *Levua* as subgenera of the genus *Aedes*.

#### ACKNOWLEDGMENTS

We express our sincere appreciation and gratitude to the Walter Reed Biosystematics Unit (WRBU) for providing funding for the publication; to Dr. Leopoldo M. Rueda, Walter Reed Biosystematics Unit (WRBU), and Dr. Maria Anice Mureb Sallum, University of São Paulo, São Paulo, Brazil, for critically reviewing this manuscript and for their valuable comments; to Drs. Raymond J. Gagne and Alexander Konstantinov, Research Entomologists, Systematic Entomology Laboratory, U. S. Department of Agriculture, for translating French and Russian.

We are most grateful to Miss Theresa M. Howard, Head of Collections, Department of Entomology, The Natural History Museum, London, England, for the loan of several types and other specimens. We also acknowledge with sincere

appreciation the following: Dr. E. De Coninck and Mr. Stephane Hanot, Entomologie Section, Musee Royal d'Afrique Centrale (MRAC), Tervuren, Belgium, for the loan of *Aedes dufouri* specimens in the [MRAC (formerly CMT)]; Prof. Maureen Coetzee, Director, Malaria Entomology Research Unit, Wit University and the Vector Control Reference Unit, National Institute for Communicable Diseases (NICD), Johannesburg, South Africa, for the loan of several types and other specimens; Dr. Christophe Daugeron, Département Systematique et Evolution, Museum National d'Histoire Naturelle, Paris, France (MNHP), for the loan of the types of *Aedes (Ochlerotatus) dufouri* Hamon.

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

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