

Redescription of the Adult and First Descriptions of the Larva  
and Pupa of *Anopheles (Cellia) sulawesi* Waktoedi, a Species of  
the Leucosphyrus Group from Sulawesi, Indonesia  
(Diptera: Culicidae)<sup>1</sup>

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**ABSTRACT.** *Anopheles (Cellia) sulawesi*, a member of the Leucosphyrus Group from Indonesia is redescribed in the adult stage and descriptions and illustrations of the larva and pupa are presented for the first time, based on newly collected material from the Bone-Dumoga forest reserve, north Sulawesi. A complete synonymy is given. Comparisons are made with other named species of the Leucosphyrus Group recorded from Indonesia and Malaysia. *Anopheles (Cel.) balabacensis introlatus*, and *An. (Cel.) riparis macarthuri* are elevated to species status.

**INTRODUCTION.** During a study of anopheline and culicine mosquitoes in the Bone-Dumoga forest reserve, north Sulawesi, larval collections were made of *An. (Cel.) sulawesi* Waktoedi, a hitherto incompletely described species of the Leucosphyrus Group. One of the earliest references to the occurrence of a member of the Leucosphyrus Group on Sulawesi (then known as Celebes) is Swellengrebel and Swellengrebel De Graaf (1920), who listed it in a table of distribution as *Neomyzomyia leucosphyra*. Since only one species of the group is known from Sulawesi, their record is probably what is treated here as *sulawesi*. This reference appeared a few months ahead of the published description of *An. leucosphyrus* var. *hackeri* Edwards (1921) from Malaya, which became only the third named species or variety for the Leucosphyrus Group. Many subsequent references to the species from the Celebes were either as *leucosphyrus* var. *hackeri* or as var. *hackeri* "Celebes form". Some references discussed morphological differences between the adults of *hackeri* and the Celebes form and even suggested the strong possibility of their being distinct species or subspecies (Colless 1948, 1956; Reid 1949), while Bonne-Wepster and Swellengrebel (1953) stated clearly, "This form is distinct from *hackeri*" and included a brief diagnosis, detailed

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drawing of the adult wing and hindtibia, yet each of these authors failed to assign a name to the form. Other references (Colless 1956, Reid 1968) repeated the same diagnostic characters without presenting a full description. The immature stages were not known to these authors. Consequently, this species has remained incompletely described.

Although the name *sulawesi* is now credited to Waktoedi (1954) it was either overlooked or not readily accepted as valid for several years. There are no known type specimens and there is no evidence to suggest any ever existed. We believe that Waktoedi did not realize that he was formally describing a new species when he listed characters in his key to distinguish "*leucosphyrus* var. *Sulawesi*" from "*leucosphyrus* var. *hackeri*". The adult characters used were the same ones cited by Reid (1949) and Waktoedi on page 7 improperly credits Reid (1949) with the name. It is quite likely that Waktoedi did not have specimens of the variety before him, hence no type designation. This hypothesis is supported by the fact that his discussions and keys treated the five, then recognized, *leucosphyrus* varieties as follows: var. *balabacensis* Baisas, *elegans* (James), *hackeri* Edwards, *pujutensis* Colless and *riparis* King and Baisas (first letter for each in lower case). In the key on page 63 he listed "*leucosphyrus* var. *Sulawesi*" (first letter in upper case as in the island Sulawesi) and in the key on page 93 he listed it as: "*leucosphyrus* var. (*Sulawesi*)" again as in the place name. We think it mere coincidence that "*Sulawesi*" has the appearance and spelling of a latinized scientific name and appears to stand as a geographic noun in the genitive case, as defined in Appendix D.IV.22(b) of the *International Code of Zoological Nomenclature* (ICZN) (1985), but it is doubtful Waktoedi intended this. We think it much more likely that since the article was written in the Indonesian language, he intended to refer to a Sulawesi variety or form in the same informal sense as Reid (1949) but used the Indonesian name, Sulawesi, in preference to the "Celebes" which had been used by all others. Nevertheless, the characters presented in the keys of Waktoedi (1954) in association with the name var. *Sulawesi*, appear to satisfy the requirements of articles 11 and 13 of the ICZN (1985) for an indication and therefore validate the name.

An argument based on the above could possibly have been made to reject the name *sulawesi* Waktoedi prior to Reid (1968). Colless (1956) in his review of the *Leucosphyrus* Group presented a brief description of the adult and stated that he was quite certain it was a distinct species but he continued to call it the "*A. leucosphyrus* Celebes form" due to insufficient material. In this paper it is quite apparent that Colless was unaware of Waktoedi (1954). Reid (1968: 303), functioning as the "first reviser" as defined in article 24 and particularly recommendation 24A, of the ICZN (1985), stabilized the name *sulawesi* Waktoedi by the following: "In addition to *hackeri* and the next species *pujutensis*, there are two other species, not occurring in Malaya or Borneo, which have short palps and a long proboscis. These are *elegans* James, 1903, found in southwestern India and Ceylon, and *sulawesi* Waktoedi 1954, found in Celebes. The latter, referred to by Waktoedi as *leucosphyrus* var. *sulawesi* and Colless (1956b) as "*leucosphyrus* Celebes form", is treated here as a distinct species in conformity with Colless's views." We are in full agreement with Reid (1968) on the validation of species *sulawesi* Waktoedi and present here formal descriptions and illustrations of the adult, larva and pupa of this species. It should be pointed out that there has been some confusion concerning the surname of the author of *sulawesi*. We believe the name Waktoedi as used by Stone et al. (1959) and Reid (1968) is correct and not

Koesoemawinangoen as used in Knight and Stone (1977). We have consulted with a number of people on the name Waktoedi, with differing results. Dr. Khian Liem, currently of the South Cook County Mosquito Abatement District, Harvey, Illinois, was a close family friend and co-worker of Waktoedi for approximately five years and is of the opinion the name Waktoedi should be used in view of the Indonesian customs for name usage.

In table 1, selected adult morphological characters are presented for ready comparisons among *sulawesi* and other currently recognized species of the *Leucosphyrus* Group reported from Indonesia and Malaysia. Recent comprehensive taxonomic studies on the *Leucosphyrus* Group by one of us (ELP), has led to the reevaluation of the taxonomic status of some of the included species and subspecies and much of these findings will be published elsewhere. However, so that we may present the names used here in accordance with these latest views and to avoid further confusion in the inconsistent use of some names, we take this opportunity to address two of these issues here. We believe the available morphological and zoogeographic evidence is sufficient to justify the elevation of *An. balabacensis introlatus* Colless and *An. riparis macarthuri* Colless to species status and we formally propose here to designate them as separate and distinct species.

**METHODS.** Collections of immature stages were made along shady freshwater streams radiating from the banks of Tumpah and Toraut rivers, Bone-Dumoga ( $0^{\circ} 35' N. 123^{\circ} 54' E$ ). Wild-caught larvae were individually reared at the Project Wallace base camp laboratory. The larval and pupal pelts which were correlated with the emerging adult, were mounted on the same glass slide in Euparal after dehydration in alcohol. Setal counts followed the system of Belkin (1962). Measurements of the adults were taken using an ocular micrometer on an Olympus stereo microscope at X40 magnification. In the synonymy below, the abbreviations A and F indicate that the publication deals with at least some part of the adult or female; an asterisk following the abbreviation indicates that at least some portion of the stage was illustrated.

*Anopheles (Cellia) sulawesi* Waktoedi

(Figs. 1-3)

*Anopheles (Neomyzomyia) leucosphyrus* var. *hackeri* of Swellengrebel and Rodenwaldt 1932: 195 (F, in part, Celebes records and probably Sangihe and Talaud islands).

*Anopheles (Myzomyia) leucosphyrus* var. *hackeri* of Colless 1948: 104 (A, taxonomy); Van Hell 1952: 45 (distribution, biology).

*Anopheles (Myzomyia) leucosphyrus* var. *hackeri*, Celebes form of Reid 1949: 45 (A, taxonomy).

*Anopheles (Myzomyia) leucosphyrus* var. *hackeri* (Celebes form) of Bonne-Wepster and Swellengrebel 1953: 297 (A\*, taxonomy).

*Anopheles (Myzomyia) leucosphyrus* var. *Sulawesi* Waktoedi 1954: 63 (F, key).

*Anopheles leucosphyrus*, Celebes form of Colless 1956: 81 (F\*, taxonomy).

*Anopheles (Cellia) leucosphyrus* var. *sulawesi* of Stone, Knight and Starcke 1959: 46 (catalog).

*Anopheles (Cellia) sulawesi* of Reid 1968: 303 (F\*, to species status); Knight and Stone 1977: 54 (catalog).

**FEMALE.** (Fig. 1). **Head.** Proboscis with a narrow ring or dorsal patch of pale scales sometimes present at apex, basal to the labella (9/22), length 2.13-3.00 mm, ratio to forefemur 1.23-1.30; palpus 1.60-2.30 mm ( $\bar{x}$ =1.94), ratio to proboscis 0.71-0.84 ( $\bar{x}$ =0.78), palpomeres 2-4 with narrow apical white bands, 5 with an apical white band varying from 0.00-0.27 ( $\bar{x}$ =0.13) length of the preapical dark band, apical white band on palpomere 4, 0.15-0.27 ( $\bar{x}$ =0.19) length of preapical dark band of 5. **Thorax.** Propleural setae 2:2-4:4, most commonly 3:3 (11/23). **Wing.** (Fig. 1, with 3 examples of variations in wing spotting on costa (C), subcosta (Sc) and radius (R)). Light and dark spots of veins M, Cu and 1-A variable in number, length and placement, spots on C, Sc and R less variable; with exception of prehumeral (PHP) and humeral (HP), pale spots usually prominent, occasionally absent, presector pale (PSP) spot of C usually prominent; presector dark (PSD) spot of R usually extending basally beyond PSP of C into level of HD of C on both wings (20/26), seldom beyond 0.5 of HD (4/26) on one or both wings and rarely not reaching HD of C (1/26) on both wings, with 1-4 pale interruptions, rarely (3/26) with 1 on one wing; with the exception of 1 specimen all 26 had C without accessory sector pale (ASP) spot, Sc with ASP (4/26), ASP always present on R, usually small; dark spot on R basal to ASP 0.55-2.70 length of ASP, usually 0.75 or more, rarely with small pale interruption on 1 wing (4/19); sector dark (SD) spot on R distal to ASP with 1-4 small pale spots, usually 2; preapical dark (PD) spot on R1 with 2-4 small pale spots; subcostal pale (SCP) spot on C, 0.50-1.00 length of preapical pale spot (PP), usually shorter than PP on both wings (25/26), or (26/26) on at least one wing; vein 1A with 4-6 pale spots: ratio of length of cell R2 to R2+3 1.60-2.37, ratio of length of cell R2 to cell M2+3 1.07-1.25. **Legs.** Femora, tibiae and tarsomeres 1 speckled with pale spots, tarsomeres 2 usually with 1-4 pale spots on at least one of each pair of legs; tarsomere 3 usually with broad apical and basal pale bands separated by a middle dark band; foretarsomeres 1-4 with broad apical pale bands, tarsomeres 2-4 with basal pale bands, bands more or less complete but less distinct on ventral surface, dorsum of tarsomeres 2 seldom completely pale; tarsomeres 3,4 occasionally predominantly pale dorsally; hindtibia with a narrow ventral extension of dark scales into basal 0.4 of apical white band and usually a separate distal dark spot (Fig. 1); hindtarsomeres 1-4 with narrow apical pale bands, basal pale band on hindtarsomere 4 usually absent (23/26), basal pale bands on hindtarsomeres 2,3 weak or absent, tarsomere 5 without any basal pale band, apex usually pale white or beige. **Abdomen.** Tergum VI very rarely covered with few inconspicuous narrow dark scales on caudal margin, VII occasionally with few dark scales on caudal margin, VIII covered with narrow golden scales, occasionally with few basal dark scales and caudomedian white scales; sternum VI usually bare, rarely with few scattered narrow dark scales on caudal margin, VII with dense caudomedian patch of semi-erect dark scales, VIII with small lateral patches of creamy golden scales.

**MALE.** (Fig. 1). Essentially as in female except for sexual characters. Wing as compared to that of female generally paler with reduced scaling, costal spots highly variable and pale spots usually much longer. Proboscis as in female, 1.92-2.56 mm, ratio to forefemur 1.37-1.62; palpomere 2 variable, usually with dorsal patch of pale scales, apex of palpomere 2 bare, giving the appearance of pale band at the joint of palpomeres 2,3, palpomere 3 usually with long dorsal patch of pale scales at middle, apex usually with broad pale band, dorsal surface of palpomere 4,5 pale except each with dark basal band, ventral surface of 4,5 pale except each with dark basal band and narrow ventrolateral line of dark scales usually extending from base to near apex of each. **Thorax.** Propleural setae 1:1-4:4, usually 3:3. **Wing.** PSD spot on vein R with 1-3 pale interruptions, usually 1,2, ASP usually present on C (14/19), Sc always with distinct ASP spot; SCP and PP of costa variable in length, usually longer than in female, PP longer than SCP (17/19), ratio of length of PP to SCP 0.81-2.15; PD of R1 with 1-3 pale spots, usually 2. **Legs.** Ventral dark stripe on apical pale band of hindtibia often divided, usually with a distal dark dot (14/19) or basal uninterrupted stripe (5/19). Foretarsomeres 1-4 usually with apical bands only, 4,5 occasionally entirely pale dorsally, basal pale bands on hindtarsomere 4 usually absent or weakly developed (16/19) or present (3/19). **Abdomen.** As compared to female caudomedian dark brown scales on sternum VII more numerous: scales on sternum VII more numerous than on sternum VI, rarely with few white scales (2/17) interspersed with brown scales, sternum VIII and sternal and lateral surfaces of basimeres of genitalia profusely clothed with creamy white scales, basimeres with a few dark brown scales basolaterally.

**PUPA** (Fig. 2). Modal condition of chaetotaxy as figured. **Cephalothorax:** setae 1-3-CT about equal in length, 2,3 branches; 4-CT, 2-4 branches; 5-CT, 4-6 branches; 6-CT, 2,3 branches; 7-CT, 3-5 branches; 8-CT, 2,3 branches; 9-CT, 2-4 branches; 10-CT, 2-5 branches; 11, 12-CT, 2-4 branches. **Abdomen.** Seta 2-I, 5-12 branches; 3-I, single, long; 4-I, 4-8 branches; 5-I, 3-5 branches; 6-I, 1-3 branches; 7-I, 2-6 branches; 9-I, single, short; 0-II, 1,2 branches; 1-II, 15-32 branches; 2-II, 4-7 branches; 3-II, 3-5 branches; 4-II, 4-6 branches; 5-II, 2-4 branches; 6-II, 1-4 branches; 7-II, 2-6 branches; 9-II, minute stub; 0-III, 1,2 branches; 1-III, 4-9 branches; 2-III, 4-8 branches; 3-III, 2-5 branches; 4-III, 4-6 branches; 5-III, 5-8 branches; 6-III, 1-3 branches; 7-III, 3-7 branches; 8-III, 2-4 branches; 9-III, short and stubby, length 0.018-0.030 mm ( $\bar{x}$ =0.022); 10-III, 2-4 branches; 11-III, single; 0-IV, simple; 1,2-IV, 3-7 branches; 3-IV, 4-9 branches; 4-IV, 3-6 branches; 5-IV, 5-9 branches; 6-IV, 1,2 branches, usually 1; 7-IV, 2-6 branches; 8-IV, 2-4 branches; 9-IV, twice as long as 9-III, length 0.027-0.099 mm ( $\bar{x}$ =0.042); ratio of length of seta 9-IV/III 1.25-3.30 ( $\bar{x}$ =1.86); 10-IV, 1-3 branches; 11-IV, 1,2 branches, usually 1; 0-V, simple; 1-V, 2,3 branches; 2-V, 2-4 branches; 3-V, 2-5 branches; 4-V, 4-6 branches; 5-V, 2-8 branches; 6-V, 1,2 branches; 7-V, 2-4 branches; 8-V, 1,2 branches; 9-V, long, length 0.078-0.120 mm ( $\bar{x}$ =0.102), usually with few lateral spicules, ratio of length of seta 9, IV/V 0.284-0.557 ( $\bar{x}$ =0.420); 10-V, 1-3 branches; 11-V, single; 0-VI, single; 1,2-VI, 1-3 branches; 3,4-VI, 2-4 branches; 5-VI, 4-7 branches; 6,7-VI, 1,2 branches; 8-VI, 2,3 branches; 9-VI, single, long; 10-VI, 1-3 branches; 11-VI, single; 0-VII, single; 1-VII, 1,2 branches; 2-VII, 2-4 branches; 3-VII, 3-6 branches; 4-VII, 1,2 branches; 5-VII, 3-8 branches; 6-VII, 1-3 branches; 7-VII, 1,2 branches; 8-VII, 2-4 branches; 9-VII, single, usually with few lateral spicules; 10-VII, 2-5 branches; 11-VII, 1,2 branches; 0-VIII, single; 4-VIII, 2 branches; 9-VIII, 9-21 branches. **Paddle.** Seta 1-P, single; 2-P, 1-3 branches.

**LARVA** (Fig. 3). Modal condition of chaetotaxy as figured. **Head.** Seta 1-A, single; 4-A, 2,3 branches; setae 2-4-C long, single; 4-C posterolaterad of 2-C, single to bifid, usually single, rarely bifid; distance between insertions of 2-C and 4-C (measured from mounted exuviae) wide, 0.075-0.102 mm ( $\bar{x}$ =0.091); length of 4-C, 0.111-0.150 mm ( $\bar{x}$ =0.128), reaching forward beyond base of 2-C to as far as 0.46 length of 2-C from its base; 5-C, 8-16 branches; 6-C, 10-16 branches; 7-C, 10-17 branches; 8-C 1-3 branches; 9-C, 1-4 branches; 10-C, 1,2 branches; 11-C, plumose, 29-36 branches; 12-C, 2,3 branches; 13-C, 4-9 branches; 15-C, 6-13 branches; dorsomentum with 4 teeth on each side. **Thorax.** Seta 0-P, minute, single; 1-P, 14-22 branches, stem strong, flattened and shorter than stem of 2-P, basal sclerotized tubercles of setae 1-P and 2-P large, fused basally, each with strong, pointed or rounded apical tooth projecting forward over base; 2-P, 10-18 branches; 3-P, single; 4-P, 13-19 branches; 5-P, 31-39 branches brush tipped; 6, 9-12-P, long, single; 7-P, 23-31 branches; 8-P, 26-33 branches; 13-P, 4-6 branches; 14-P, 5-9 branches; 1-M, 31-37 branches; 2-M, 2,3 branches; 3, 5-M, long, single; 4-M, 2,3 branches; 6-M, 2-5 branches; 7-M, 2-4 branches; 8-M, 23-35 branches; 9-12-M, single; 13-M, 4-8 branches; 14-M, 6-8 branches; 1,2-T, simple; 3-T, 3-6 weak, narrow lanceolate leaflets; 4-T, 2-5 branches; 5-T, 31-38 branches; 6-T, 2,3 branches; 7-T, 23-44 branches; 8-T, 20-38 branches; 9-11-T, single 12-T, 2-4 branches; 13-T, 3 branches. **Abdomen.** Seta 1-I only slightly developed with 3-7 undifferentiated rigid branches; 2-I, 2,3 branches; 3-I, 1-3 branches; 4-I, 3,4 branches; 5-I, 5-7 branches; 6-I, 18-23 branches; 7-I, 15-19 branches; 9-I, 4-6 branches; 10-I, single; 11-I, 3,4 branches; 12-I, 3-5 branches; 13-I, 4-6 branches; 0-II, single; 1-II, moderately developed with 8-15 very narrow, lanceolate leaflets; 2-II, 6-8 branches; 3-II, single; 4-II, 4-7 branches; 5-II, 3-6 branches; 6-II, 17-30 branches; 7-II, 17-29 branches; 8-II, 2,3 branches; 9-II, 4-9 branches; 10-II, 2,3 branches; 11, 12-II single; 13-II, 4-6 branches; 0-III, single; 1-III, fully developed 15-22, lanceolate leaflets; 2-III, 5-7 branches; 3-III, single; 4, 5-III, 3,4 branches; 6-III, 15-20 branches; 7-III, 4,5 branches; 8-III, 1,2 branches; 9-III, 7-11 branches; 10-III, single; 11, 12-III, 2,3 branches; 13-III, 4-7 branches; 0-IV, simple; 1-IV, fully developed, 13-21 lanceolate leaflets; 2-IV, 3-5 branches; 3-IV, 2,3 branches; 4-IV, 2-4 branches; 5-IV, 3,4 branches; 6-IV, 2,3 branches; 7-IV, 3-6 branches; 8-IV, 2,3 branches; 9-IV, 6-11 branches; 10-IV, single; 11, 12-IV, 2,3 branches; 13-IV, 3,4 branches; 0-V single; 1-V, fully developed 15-20 lanceolate leaflets; 2-V, 3-5 branches; 3-V, simple; 4-V, 2-4 branches; 5-V, 3,4 branches; 6-V, 2,3 branches; 7-V, 3-5 branches; 8-V, 2,3 branches; 9-V, 6-9 branches; 10-V, single; 11-V, 2,3 branches; 12-V, 2,3 branches; 13-V, 3 branches; 0-VI, single; 1-VI, fully developed 13-21 lanceolate leaflets; most leaflets of setae 1-III-VI with few apicolateral serrations, with filament and blade equally pigmented; 2-VI, 4-6 branches; 3, 4-VI, single; 5-VI, 3-5 branches; 6-8-VI, 2-4 branches; 9-VI, 5-9 branches; 10-VI, 3-5 branches; 11-VI, 2,3 branches; 12-VI, single; 13-VI, 5-8 branches; 0-VII, single; 1-VII smaller than 1-VI with 12-17 lanceolate leaflets; 2-VII, 4-7 branches; 3-VII, 3,4 branches; 4-VII, single; 5-VII, 3-5 branches; 6-VII, 4-6 branches; 7-VII, 3-5 branches; 8-VII, 4-7 branches; 9-VII, 4-6 branches; 10-VII, 6-8 branches; 11-VII, 2 branches; 12-VII, single; 13-VII, 3,4 branches; 0-VIII, single; 1, 4-VIII, single; 2-VIII, 6-10 branches; 3-VIII, 4-7 branches; 5-VIII, 3-6 branches; 1-S, 4-6 branches; 2-S, 5-8 branches; 6-S, 2,3 branches; 8, 9-S, 2-4 branches; 1-X, single; 2-X, 16-24 branches; 3-X, 10-18 branches.

**EGG.** Unknown.

**DISTRIBUTION.** *Anopheles sulawesi* is known to occur only in Sulawesi (Celebes) and neighboring islands, Indonesia. The collection of specimens for this study was confined to a forested area of a natural reserve in the Bone-Dumoga National Park. The park, situated below 1° north of the equator, occupies an area of 280,000 ha and extends 110 km from Kotamobagu in the east to Gorontalo in the west. It is landlocked and varies in altitude from 200 to 2,000 m.

The distribution of *sulawesi* is most closely associated with foothills and mountainous regions in northern Sulawesi. This is probably also true for other parts of the island but little information on the environment is available for the earlier reported collections. Based on published accounts of var. *hackeri* Celebes form (= *sulawesi*) by Swellengrebel and Rodenwaldt (1932), Reid (1949), Van Hell (1952) and Bonne-Wepster and Swellengrebel (1953) it appears that the species occurs throughout Sulawesi and at least on some of the immediately adjacent islands (Fig. 2). The exact localities as listed in each reference, with the original spelling, which in many cases has since changed, are as follows: "Swellengrebel and Rodenwaldt (1932); Madjene; Mamoedjoe; Paleleh; Posso and the islands of Sangihe and Talaud. Reid (1949); Aalo; Lindoe Meer and the islands of Boeton and Kabaena. Van Hell (1952); Bone-Bone; Kalaena; Kolaka; Lamassi; Lamuru; Luwuk region; Madjene; Malili; Mamuju; Palopo; Pamalaan; Rantepao; Tjenrana and Watanlamuru (Torakala). Bonne-Wepster and Swellengrebel (1953); Lindoe-Lake; Paleleh; Palu and the islands of Buton and Kabaena". In Fig. 2, we have attempted, as best we can, to plot the approximate positions of most of the published localities along with our few specimen-based-localities using maps and the *Official Names Gazetteer of the United States Board on Geographic Names*, prepared by the Defense Mapping Agency Topographic Center and the U.S. Department of the Interior.

In addition to our newly collected material from Bone-Dumoga forest reserve, we have seen 4 females and 7 males of the original Bonne-Wepster and Swellengrebel collections on loan to the Walter Reed Biosystematics Unit (WRBU), Smithsonian Institution, from the Rijksmuseum, Leiden, Netherlands. Three of the males are with unknown localities and even though the WRBU has copies of seven field notebooks of Bonne-Wepster for collections from Indonesia and various other regions of the world, we cannot find entries for these. The remaining specimens are from Paloe [Palu] and Lindoe Meer. The WRBU also has in its collections, three blood-engorged females with label data from Madjene and Buton [Butung] island. Entries in the Bonne-Wepster field notes for Celebes collections made in 1937 by Brug and by Arug and Tesch correspond to the information on the specimens in the Institute for Tropical Hygiene (ITH), Amsterdam which were examined and reported by Reid (1949).

Specimens examined: Toraut, Bone-Dumoga forest reserve, north Sulawesi, 19 males, 19 females, 17 p, 12 l; Paloe 3 females, 2 males; Lindoe Meer, 1 female, 2 males; Wonco, Buton, Tenggara, 2 females; Pasiluang, Majene, Selatan, 1 female; Unknown localities, Sulawesi, 3 males. Localities are as appear on the labels affixed to the specimens.

**BIONOMICS.** Due to the apparently restricted distribution of *An. sulawesi* to Sulawesi and adjacent islands, this species has not received much attention. Our field observa-

tions on the bionomics of *sulawesi* suggests habitats typical of most members of the *Leucosphyrus* Group elsewhere in southeast Asia. The favored immature habitats appear to be shaded rock pools, stream pools and pools in drying stream beds at the margin of Tumpah River in the Bone-Dumoga area. Such pools are approximately 8-15 cm in depth and are partially shaded by low overhanging vegetation, such as bamboo leaves. They usually have a bottom of decaying vegetation or black muddy soil. Abundant material was also collected from an artificial bamboo platform 1.0 X 1.0 X 0.3 m raised 0.2 m above a rocky stream (near "The Waterfall"). This platform was covered by a plastic polythene sheet which held rainwater and leaf litter collections.

Surprisingly, the females of this species did not bite man during three nights of outdoors man-biting collections (1800-2300 h) and using a bednet trap (1800-0600 h). The collecting sites were situated 3-5 m from known larval habitats. After emergence in the laboratory several 2-3 day old females of *sulawesi* refused to feed on the author's (JLKH) arm. The two blood-engorged females in the WRBU collections from Majene [Madjene] are labeled "Man-bite" and "Man-bite-net". The other blood-engorged female from Buton is labeled "Indoor-resting".

Reid (1949) cites 1 female examined in the ITH, Amsterdam, collected by Arug and Tesch 1937, from Lindoe Meer at 1000 m. This collection is recorded in one of the field notebooks of Bonne-Wepster with the additional notation, "Plas in open Terrein" which we interpret as, "ground pool in the open". McArthur (1951) cites a personal communication from Overbeek in 1941, in which natural infections [malaria] were recorded in 4 out of 13 *A. leucosphyrus* var. *hackeri* in the "Colonization Boenta" area but did not state whether these were gland or gut infections.

Van Hell (1952) is the only other known source of information on the bionomics of this species. Since it is the most significant published information to date, we quote most of it here. "*A. (M) leucosphyrus hackeri* has been found in 13 localities in South Celebes, but more often as larva than as adult. The breeding places were in marshy fields, stopped-up gutters and ditches, pools and small wells containing stagnant water. Though this type of species prefers shadow, the variety *hackeri* was often found breeding in sunlight. It was most frequently caught in the Luwuk region. In Lamuru it was found with *A. (M) maculatus* and *A. (M) minimus* var. *flaviostris*, in the tributaries of the River Walanae, close to the breeding places of *A. (M) ludlowi* var. *torakala*. It was a house mosquito in Tjenrana in 1937, the breeding places being in the slow-running basins (with growth of algae) of the Sunabak river. Our archives show that it was found infected only once in Malili (1941), when one gut out of 21 showed cysts (natural infection index 5 per cent), the 73 body fluid preparations all being negative. It's part was secondary, as five other species were also found infected during the investigation. This anopheline needs further study, especially when it is caught in houses..."

**DISCUSSION.** Although all of the presently recognized species of the *Leucosphyrus* Group are extremely similar in all stages, *sulawesi* is quite easily distinguished morphologically from other species of the group in the adult stage. It shows greatest affinity to *hackeri*, *elegans* and *pujutensis*. These four species all have a proboscis which is distinctly longer than the forefemur (ratio about 1.25) and often considerably longer than the palps, in contrast to a shorter proboscis approximately equal to or shorter than the forefemur (ratio 0.85-1.15) and at most only slightly longer than palps for all of the



other known species of the group. Only *hackeri*, *pujutensis* and *sulawesi* are currently described from Indonesia and Malaysia; *elegans* being known only from southwestern India and Sri Lanka. The immature stages of *elegans* were only recently described by Mendis et al. (1983). While *sulawesi*, for many years was either confused with or consistently associated with *hackeri*, the two species differ strikingly in the adult and larval stage and each is easily identified. In addition to the very long proboscis and short palps which serve to readily separate the adult from all but *hackeri* and *pujutensis* in the Indonesia-Malaysia region, the following also serve to readily separate it from these two species. The most readily noticeable difference is the presence or absence of pale spots on the PSD spot on the radial vein (R) of the wing. There are 1-4 pale spots on the PSD of R in *sulawesi*, there are none in the other two species. The apical pale band on female palpomere 5 is usually exceptionally short in *sulawesi* and *hackeri* but long in *pujutensis*. The expression of a distal oval dark spot in the broad apical pale band of hindtibia of *sulawesi* (Fig. 1) is characteristic and differs from the continuous, uninterrupted longitudinal dark stripe into the hindtibial pale band on *hackeri* and the absence of either on *pujutensis* (see Table 1 for other differences).

The pupa of *sulawesi* is not readily distinguished from other described pupae of the Leucosphyrus Group. The chief characteristics are: seta 1-II brush-like with 15-32 branches; 9-IV is short, ratios of 9-IV/III 1.25-3.30 ( $\bar{x}$ =1.85) and 9-IV/V 0.28-0.56 ( $\bar{x}$ =0.42). The mean ratios of 9-IV/III and 9-IV/V in *hackeri* are (1.58) and (0.17), respectively.

The larva of *sulawesi* is distinctive in the length and placement of seta 4-C. Seta 4-C is long, having a mean length of 0.128 mm and reaches forward beyond the base of 2-C to as far as 0.46 the length of 2-C from its base. Seta 1-II is moderately developed with narrow lanceolate leaflets and this readily distinguishes it from the larva of *hackeri* which has seta 1-II fully developed with clearly differentiated filaments.

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## REFERENCES

- Belkin, J.N. 1962. The mosquitoes of the South Pacific (Diptera: Culicidae). Univ Calif. Press, Berkeley and Los Angeles. 2 vol., 608 and 412 p.
- Bonne-Wepster, J. and N.H. Swellengrebel. 1953. The anopheline mosquitoes of the Indo-Australian region. J.H. de Bussy, Amsterdam. 504 p.
- Colless, D.H. 1948. The anopheline mosquitoes of North-West Borneo. Proc. Linn. Soc. N.S.W. 76: 71-119.
- Colless, D.H. 1956. The *Anopheles leucosphyrus* group. Tran. R. Entomol. Soc. Lond. 108: 37-116.
- Edwards, F.M. 1921. Mosquito notes. - II. Bull. Entomol. Res. 12: 69-80.
- International Code of Zoological Nomenclature (1985) Third Edition. Univ. Calif. Press, Berkeley and Los Angeles. 338 p.
- Knight, K.L. and A. Stone. 1977. A catalog of the mosquitoes of the world (Diptera: Culicidae) 2nd Edition. Thomas Say Found., Entomol. Soc. Am. 6: 1-611.
- McArthur, I. 1951. The importance of *Anopheles leucosphyrus*. Trans. R. Soc. Trop. Med. Hyg. 44: 683-694.
- Mendis, K.M., R.L. Ihalamulla, E.L. Peyton and S. Nanayakkara. 1983. Biology and descriptions of the larva and pupa of *Anopheles (Cellia) elegans* James (1903). Mosq. Syst. 15: 318-324.
- Reid, J.A. 1949. A preliminary account of the forms of *Anopheles leucosphyrus* Dönitz (Diptera: Culicidae). Proc. R. Entomol. Soc. Lond. Series B 18: 42-53.
- Reid, J.A. 1968. Anopheline mosquitoes of Malaya and Borneo. Stud. Inst. Med. Res. Malaya 31: 1-520.
- Stone, A., K.L. Knight and H. Starcke. 1959. A synoptic catalog of the mosquitoes of the world. Thomas Say Found., Entomol. Soc. Am. 6: 1-358.
- Swellengrebel, N.H. and E. Rodenwaldt. 1932. Die Anophelen von Niederlandish-Ostindien. Gustav Fischer, Jena. 242 p.
- Swellengrebel, N.H. and J.M.H. Swellengrebel De Graaf. 1920. List of the anophelines of the Malay Archipelago with special reference to adults and larvae of new or incompletely described species or varieties. Bull. Entomol. Res. 11: 77-92.
- Van Hell, J.C. 1952. The anopheline fauna and malaria vectors in South Celebes. Doc. Med. Geogr. Trop. 4: 45-56.
- Waktoedi, K.R. 1954. Anophelini di Indonesia. Djilid I. Djakarta. 191 p.

Table 1. Comparison of selected adult morphological characters of currently recognized species of the *Leucosphyrus* Group reported from Indonesia and Malaysia (+ = present, 0 = absent).

Character	<i>balabacensis</i>	<i>hackeri</i>	<i>introlatus</i>	<i>leucosphyrus</i>	<i>macarthurii</i>	<i>pujutensis</i>	<i>sulawesi</i>
1. Proboscis distinctly longer than forefemur (ratio 1.16-1.42) and palps usually much shorter than proboscis (ratio 0.72-0.87)	0	+	0	0	0	+	+
2. Proboscis usually with a very narrow pale ring or patch at apex basal to the labella.	0	+	0	0	0	+	+ or 0
3. Palps with very narrow pale bands, that at apex of palpomere 5 usually less than 0.3 the length of preapical dark band.	0	+	0	0	0	0	+
4. Presector dark spot (PSD) on vein R with 1 or more pale spots at least on one wing.	+	0	+	+	0	0	+
5. Presector dark spot on vein R usually extending basally to level of costal humeral dark spot (HD) or beyond (85% or more).	0	0	0	+	0	0	+
6. Accessory sector pale spot (ASP) usually present on costa at least on one wing (60% or more).	+	0	+	+	0	+	0
7. Broad apical pale band on hindtibia with a narrow dark linear extension into basal 0.4 or more on ventral aspect (continuous or divided with distal dot).	0	+	0	0	+	0	+
8. Hindtarsomere 4 with a conspicuous basal pale band or dorsal patch (90% or more).	+	+	0	0	0	0	0

\* This table, although useful for identification purposes, is not intended as a definitive key as it does not account for 2 unnamed geographic forms of *An. balabacensis* and *An. dirus* Peyton and Harrison reported from Peninsular Malaysia.

Fig. 1

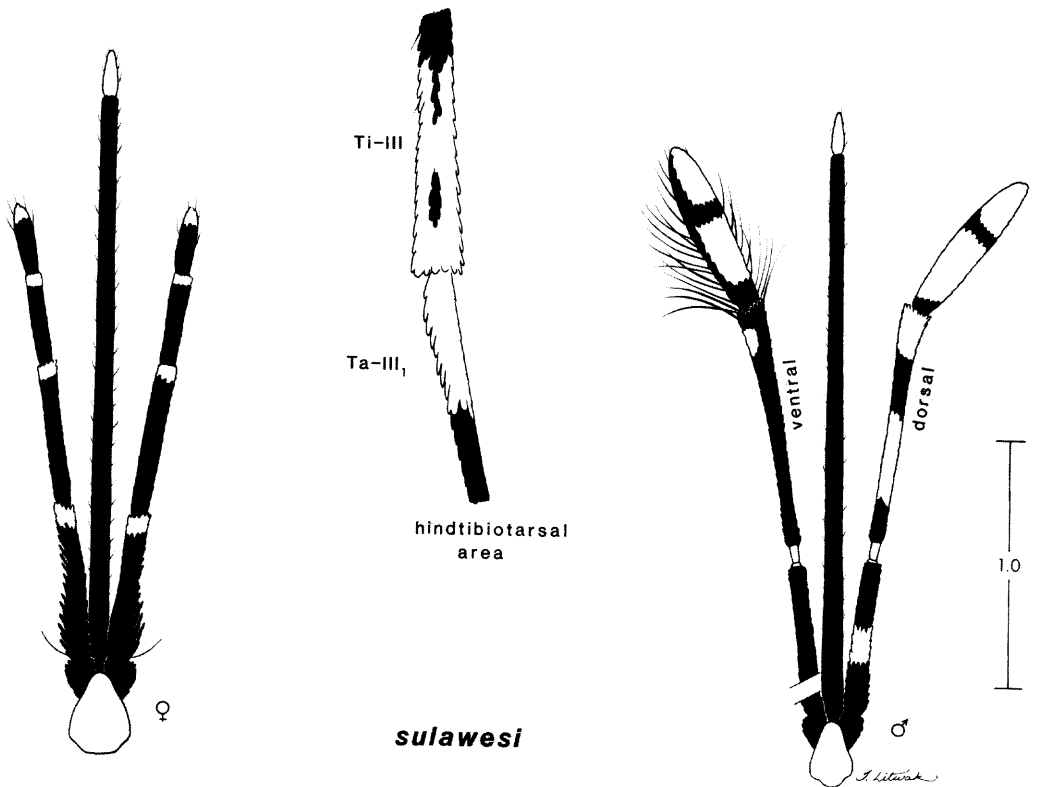
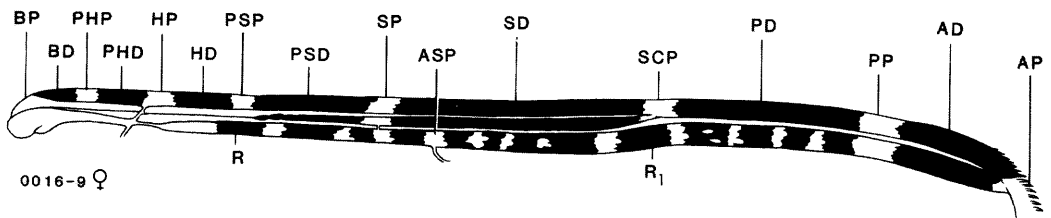
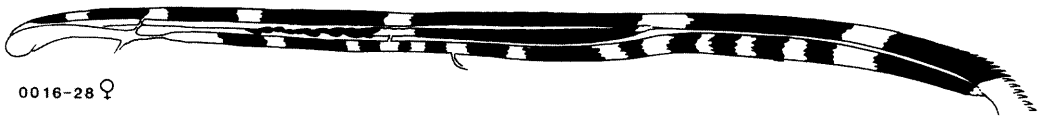
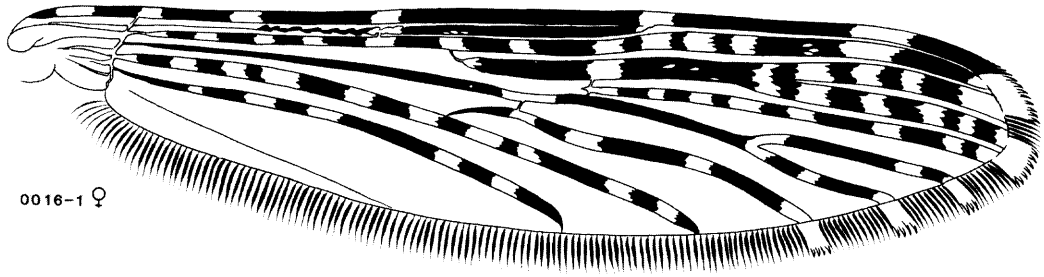




Fig. 3

