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Keys to the Anopheline Mosquitos of Cambodia with Reference to Species Occurring in Some Neighbouring Territories

by

W. W. BÜTTIKER¹ and P. F. BEALES²

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Introduction

When part of the anopheline fauna of some Asian countries was fairly well known, simplified entomological keys for the identification of the fourth stage larvae and female adults were compiled to assist entomologists and technicians engaged in malaria control. Thus a considerable amount of work was carried out on the distribution and morphology of anophelines, especially vector species, particularly in the regions where malaria organisations were staffed with personnel interested in taxonomy. The theory and practice of selective mosquito control, sometimes referred to as species sanitation, is dependent on the accurate identification of the species to be controlled. Up-to-date taxonomic keys are a prerequisite for a species sanitation approach.

In 1958 the World Health Organisation's Advisory Team on Malaria Eradication No. 3 was assigned to Cambodia, and as a result of the entomological investigations the authors were encouraged to

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prepare this publication. It is a new endeavour to assist the local malaria workers, since the old entomological keys in use were found to be by no means complete or accurate, and several of the more up-to-date keys and standard books were not available. The authors therefore present here the taxonomic keys for the identification of the fourth stage larvae and adults of the anopheline mosquitos so far recorded from Cambodia. The keys are so composed that the species are separated according to their natural affinities and that they give as much morphological information about each species as is possible. In addition several species known to exist in some of the neighbouring territories such as Viet Nam, Burma, Thailand, The Malay Peninsula and the Philippine Islands, have been included, one of the reasons being that in recent years there have been new records from Cambodia and it seems likely that the complete anopheline fauna is, as yet, unknown.

A good taxonomic key should be based upon a morphological study of the species concerned over their entire geographical ranges, in order to consider the natural morphological variations of each species. This, of course, has not been possible but the knowledge gained by working with many of the species in six different countries in Asia, has been used to its fullest extent.

The issue of entomological keys some considerable time ago appeared to have terminated taxonomic investigations in many countries and the identification of species came to be considered an easy matter which could be learnt by assistants and malaria inspectors in a comparatively short period. Unfortunately there was also, at one time, some prejudice against systematic work. Recent progress in this field, however, shows that many results from previous experimental investigations are open to doubt because the identity of the species dealt with is uncertain and a correct discrimination between "harmless" and "dangerous" carriers has not invariably been made.

Taxonomy is the basis for all entomological field and laboratory work and it is therefore highly desirable that investigations be carried out on certain groups of anopheline species which are badly in need of thorough taxonomical studies such as the "minimus", "sundaicus" and "subpictus" groups and others. The general keys now in use could then be revised and made as accurate as possible with drawings of the highest quality.

The considerable practical importance of exact taxonomical studies of anopheline mosquitos has been demonstrated by a number of entomologists. There are groups of species or subspecies where one form is an efficient and another a less efficient malaria vector in different areas, or even in the very same place. Since the investigations on the *A. maculipennis* complex (Swellengrebel and de Buck, 1938), several other groups of species have been studied from the morphological, biological and epidemiological points of view, for example :

Species Group or Species	Important Malaria Vector	Less Important Vector or Non-Vector	Region	References (main literature only)
<i>maculipennis</i> group	<i>A. labranchiae atroparvus</i> VAN THIEL 1927	<i>A. maculipennis messeae</i> FALLERONI 1926	Europe	SWELLENGREBEL AND DE BUCK (1938)
<i>hyrcanus</i> group	<i>A. nigerrimus</i> GILES 1900	Not yet known	Malaya (Asia)	REID (1953)
<i>A. sundaicus</i> (RODENWALDT) 1925	<i>A. sundaicus</i> salt water form	<i>A. sundaicus</i> fresh water form	Asia	Senior WHITE, RAMAKRISHNA and RAO (1947), RAO (1956)
<i>A. stephensi</i>	<i>A. stephensi stephensi</i> LISTON 1901	<i>A. stephensi mysorensis</i> SWEET and RAO 1937	India	BOYD (1949), SWEET and RAO (1937), SWEET, RAO and RAO (1938)
<i>minimus</i> group	<i>A. minimus minimus</i> THEOBALD 1901 <i>A. minimus flavirostris</i> (LUDLOW) 1914 <i>A. varuna</i> IYENGAR 1924 <i>A. culicifacies</i> GILES 1901	<i>A. varuna</i> IYENGAR 1924 <i>A. mangyanus</i> (BANKS) 1906 <i>A. varuna</i> IYENGAR 1924 <i>A. varuna</i> IYENGAR 1924	Asia Philippines India Ceylon	RAO (1955) Senior WHITE GOSH and RAO (1945)
<i>gambiae</i> group	<i>A. gambia</i> GILES 1902	<i>A. gambiae</i> var. <i>melas</i> (THEOBALD) 1903	W. Africa	RIBBANDS (1944, HOLSTEIN (1954)
<i>funestus</i> group	<i>A. funestus</i> GILES 1900	<i>A. funestus</i> var. <i>confusus</i> EVANS and LEESON 1935 <i>A. rivulorum</i> LEESON 1935 <i>A. parensis</i> GILLIES 1962	Africa	EVANS (1931), DE MEILLON (1947) (see also GILLIES (1962) on <i>A. parensis</i>)
<i>umbrosus</i> group	<i>A. letifer</i> SANDOSHAM 1944 (?)	<i>A. separatus</i> (LEICESTER) 1908	Malaya (Asia)	GATER (1935), REID (1950) REID (1963)
<i>barbirostris</i> group	<i>A. campestris</i> REID 1962	<i>A. misc species</i>	S. E. Asia	REID (1962)
<i>leucosphyrus</i> group	<i>A. balabacensis balabacensis</i> BAISAS <i>A. leucosphyrus</i> DÖNITZ 1901	<i>A. pujutensis</i> COLLESS 1948 <i>A. riparis</i> KING and BAISAS 1930 <i>A. hackeri</i> EDWARDS 1921 <i>A. leucosphyrus</i> DÖNITZ 1901	S. E. Asia Sarawak/ Malaysia	COLLESS (1956)

It may be observed from this table that most of these vectors occur in the Asian Region.

A. minimus, for example, is regarded as one of the most efficient vectors throughout its distribution, probably because of its apparently high "anthropophilic" and "endophilic" tendencies. On the other hand *A. varuna* is an important vector in N.E. India but seems to be quite harmless elsewhere in India and in Ceylon. It is not sufficiently known how much is due to environment, climatic conditions and zoophilism and how much to physiological properties ("non-infective strains"). Further studies need to be carried out to elucidate whether the efficiency of various vectors can be explained by the existence of (1) biological strains (2) different but closely resembling species or (3) different subspecies. It is evident that morphological, biological and physiological investigations would, particularly in view of further development of insecticide resistance, prove to be of great importance.

Finally the necessity of using good optical instruments is also important. This is stressed by B. A. R. GATER (1935), one of the pioneers in medical entomology :

"It has been stated that the identification of imagines can be performed with a handlens. To some extent this is true but as our knowledge of the anopheline fauna improves, it becomes evident that the handlens can no longer be relied upon and that greater detail must be considered when discriminating between species which are superficially similar. There is nothing new in this... but is apt to be disregarded by those unacquainted with the difficulties involved. However, it must not be forgotten that the anopheline fauna of Malaya is still under investigation and that the more detailed such studies are the more numerous will be the problems presented for solution. The case of *A. umbrosus* may be given as an example.

This "species" has yielded varying results as a carrier of malaria in the hands of different workers. Recently a new species, which owing to its similarity had hitherto been labelled *A. umbrosus*, was described. More recent work on a number of similar forms, all which would be labelled *A. umbrosus* with our present standards of identifications, has revealed the fact that at least two different forms exist. Herein then lies a probable explanation of the varying results with this "species" as a natural and experimental carrier of malaria.

If the basis of anti-malaria work is the accurate identification of species, the fundamental requirement of accurate identification is a knowledge of morphology."

Introduction to the Keys

The following keys have been composed to give as much morphological information about each species as is possible, with a view to assisting local workers to ascertain the precise Anopheline fauna of Cambodia, which is as yet not completely known.

The keys include species definitely known to occur in Cambodia, most having been collected by the authors, and species known to occur in neighbouring territories such as Vietnam, Burma, Malaya Peninsula, Thailand, and the Philippine Islands.

Terminology

The morphological terminology utilised in the keys to the adults is that of Christophers, 1933, but for the keys to the larvae the revised nomenclature for the chaetotaxy of the mosquito larva by Belkin (1950) has been used.

No complete survey of the anopheline fauna in Cambodia as a whole has ever been undertaken and the exact number of species which occur is therefore uncertain. In several instances there has been a confusion in nomenclature, in particular

- | | | |
|------------------------|---|--|
| <i>A. minimus</i> | } | Having been referred to under one name <i>A. minimus</i> |
| <i>A. pampanai</i> | | |
| <i>A. pallidus</i> | | Previously recorded as <i>A. fuliginosus</i> . |
| <i>A. sundaicus</i> | | Previously recorded by several authors as <i>A. ludlowae</i> |
| <i>A. splendidus</i> | | Previously recorded as <i>A. maculipalpis</i> and <i>A. maculipalpis</i> var. <i>indiensis</i> . |
| <i>A. balabacensis</i> | | Previously recorded as <i>A. leucosphyrus</i> . |
| <i>A. hyrcanus</i> | | group, having been split up recently into several species. |
| <i>A. barbirostris</i> | | misc. species. |

The construction of the identification keys was not an easy matter mainly due to the lack of sufficient material to study individual variations. Much help, however, was obtained from several specialists at malaria and medical research institutes, which resulted in a more complete and more up-to-date picture of the anopheline fauna of Indochina and particularly of Cambodia.

There is still considerable difficulty in separating certain species from closely associated members and until such times as thorough investigations reveal the true significance of the main morphological characters to be used in separating them absolute positive identifications will be difficult. A more certain conclusion can be obtained, however, by studying large populations of the mosquitos in question and by rearing from larvae and examining the 4th stage larval skins, the pupal skins and the adults.

In this publication the authors used the term "complex" or have taken the identification only as far as the main members when dealing with the "difficult" species as mentioned in the foregoing paragraph. Examples of such instances occurring in the area under discussion are as follows, — and it is the opinion of the authors that even greater care than usual should be exercised when separating these members.

<i>A. aitkenii</i>	“group”	
<i>A. barbirostris</i>	„	
<i>A. gigas</i>	„	
<i>A. maculatus</i>	„	
<i>A. minimus</i>	„	
<i>A. pallidus</i>		
<i>A. philippinensis</i>		
<i>A. subpictus</i>	„	(including <i>A. sondaicus</i> and closely associated members)

The term group has been used in its widest possible sense.

New distribution records of the following species were noted from Cambodia and one new species was described.

<i>A. crawfordi</i>	REID 1953.
<i>A. fluviatilis</i>	JAMES 1902.
<i>A. indiensis</i>	THEOBALD 1901.
<i>A. maculatus willmori</i>	(JAMES) 1903.
<i>A. pampanai</i>	BÜTTIKER and BEALES 1959.
<i>A. peditaeniatus</i>	(LEICESTER) 1908.
<i>A. philippinensis</i>	LUDLOW 1902.
<i>A. hodgkini</i>	REID 1962 and <i>A. campestris</i> REID 1962 (?).

Species recorded to date from Cambodia

At the present time (1958) only twenty species, four sub-species and one variety, of Anopheline mosquitos have been found in Cambodia and are listed below. All species were collected by the authors with the exception of those marked with an asterisk, and unless otherwise stated many specimens were examined.

Genus *Anopheles* MEIGEN

Subgenus *Anopheles* MEIGEN 1818.

- * *A. (A.) aitkenii bengalensis* PURI 1930.
- A. (A.) annandalei interruptus* PURI 1929. One adult specimen only.
- A. (A.) barbirostris* complex. *A. barbirostris*, *A. hodgkini* and *A. campestris* (?) REID (1962).
- A. (A.) crawfordi* REID 1953 ? Three damaged adults, possibly this sp.
- A. (A.) indiensis* THEOBALD 1901 ? One damaged adult only.
- * *A. (A.) insulaeflorum* (SWELLENGREBEL & SWELLENGREBEL DE GRAAF) 1919 (1920).
- A. (A.) peditaeniatus* (LEICESTER) 1908. One good adult specimen.

Subgenus *Cellia* THEOBALD 1902.

- A. (C.) aconitus* DÖNITZ 1902.
- A. (C.) annularis* VAN DER WULP 1884.
- A. (C.) balabacensis balabacensis* BAISAS 1936.

- A. (C.) karwari* (JAMES) 1903.
A. (C.) kochi DÖNITZ 1901.
A. (C.) maculatus maculatus THEOBALD 1901.
A. (C.) maculatus willmori (JAMES) 1903.
A. (C.) minimus minimus THEOBALD 1901.
A. (C.) pampanai BÜTTIKER & BEALES 1959.
A. (C.) philippinensis LUDLOW 1902.
A. (C.) splendidus KOIZUMI 1920.
A. (C.) subpictus subpictus GRASSI 1899.
A. (C.) subpictus var. *indefinitus* (LUDLOW) 1904.
A. (C.) sundaicus (RODENWALDT) 1925.
A. (C.) tessellatus THEOBALD 1901.
A. (C.) vagus vagus DÖNITZ 1902.

List of the Species Included in the Keys.

Genus *Anopheles* MEIGEN

- Subgenus *Anopheles* MEIGEN 1818.
A. (A.) aithkenii aithkenii JAMES 1903.
A. (A.) aithkenii bengalensis PURI 1930.
A. (A.) albotaeniatus (THEOBALD) 1903.
A. (A.) alongensis VENHUIS 1940.
A. (A.) annandalei interruptus PURI 1929.
A. (A.) argyropus (SWELLENGREBEL) 1914.
A. (A.) baezai GATER 1933.
A. (A.) barbirostris group. (For further detailed identification see REID 1962).
A. (A.) barbumbrosus STRICKLAND & CHOUDHURY 1927.
A. (A.) crawfordi REID 1953.
A. (A.) gigas var. *formosus* LUDLOW 1909.
A. (A.) gigas var. *sumatrana* SWELLENGREBEL & RODENWALDT 1932.
A. (A.) indiensis THEOBALD 1901.
A. (A.) insulaeflorum (SWELLENGREBEL & SWELLENGREBEL DE GRAAF) 1919 (1920).
A. (A.) lesteri BAISAS & HU 1936.
A. (A.) letifer SANDOSHAM 1944.
A. (A.) lindesayi cameronensis EDWARDS 1929.
A. (A.) lindesayi benguetensis KING 1931.
A. (A.) nigerrimus GILES 1900.
A. (A.) palmatus (RODENWALDT) 1926.
A. (A.) peditaeniatus (LEICESTER) 1908.
A. (A.) separatus (LEICESTER) 1908.
A. (A.) sinensis WIEDEMANN 1828.
A. (A.) umbrosus (THEOBALD) 1903.

Subgenus *Cellia* THEOBALD 1902.

- A. (C.) aconitus* DÖNITZ 1902.
A. (C.) annularis VAN DER WULP 1884.
A. (C.) balabacensis balabacensis BAISAS 1936.
A. (C.) culicifacies culicifacies GILES 1901.
A. (C.) fluviatilis JAMES 1902.
A. (C.) jamesi THEOBALD 1901.
A. (C.) jeyporiensis eyporiensis JAMES 1902.
A. (C.) jeyporiensis var. *candidiensis* KOIZUMI 1924.
A. (C.) karwari (JAMES) 1903.
A. (C.) kochi DÖNITZ 1901.
A. (C.) ludlowae (THEOBALD) 1903.
A. (C.) maculatus maculatus THEOBALD 1901.
A. (C.) maculatus willmori (JAMES) 1903.
A. (C.) minimus minimus THEOBALD 1901.
A. (C.) pallidus THEOBALD 1901.
A. (C.) pampanai BÜTTIKER & BEALES 1959.
A. (C.) philippinensis LUDLOW 1902.
A. (C.) ramsayi COVELL 1927.
A. (C.) splendidus KOIZUMI 1920.
A. (C.) subpictus subpictus GRASSI 1899.
A. (C.) subpictus var. *indefinitus* (LUDLOW) 1904.
A. (C.) sundaicus (RODENWALDT) 1925.
A. (C.) tessellatus THEOBALD 1901.
A. (C.) vagus vagus DÖNITZ 1902.
A. (C.) varuna IYENGAR 1924.

A Key to the Adult Anopheline Mosquitos of Cambodia including species recorded from neighbouring territories

1. Wing with three dark areas or less on the costa involving vein 1. (Subgenus *Anopheles*, MEIGEN) 2
Wing with four or more dark areas on the costa involving vein 1. (Subgenus *Cellia* THEOBALD 1902) 25
2. Wing entirely without pale markings 3
Wing with pale markings. Costa with at least a small apical pale area 7
3. Head scales very narrow, rod like (***insulaeflorum***, ***palmatus*** and ***aitkenii*** females) 4
Head scales not unusually narrow . . . ***alongensis*** VENHUIS, 1940
4. Phallosome of male terminalia about one-third as long as the coxites, its tip not thickened 5
Phallosome about two-thirds the length of the coxites and with the tip thickened ***palmatus*** (RODENWALDT)* 1926.
5. Phallosome of male terminalia with some fine spines laterally towards the tip
insulaeflorum (SWELLENGREBEL & SWELLENGREBEL DE GRAAF) 1919.
Phallosome without any spines 6
6. Outer part of the dorsal lobe of the harpago of male terminalia usually with three spines ***aitkenii aitkenii*** JAMES 1903.
Outer part of the dorsal lobe of the harpago usually with two spines
aitkenii bengalensis PURI 1930.
7. Apical part of the hind femur with a tuft of long, outstanding, black scales, followed by a broad area of very long, outstanding, white scales. Costa with a humeral pale interruption towards the base and a subcostal pale spot present ***annandalei interruptus*** PURI 1929.
Apical part of hind femur without a tuft of black and white scales. Costa with or without a humeral pale area towards the base, and a subcostal pale spot may or may not be present 8
8. Hind femur with a long white band on the distal half 9
Hind femur without a long white band on the distal half 10
9. All wing veins apically dark except 2.1 and 6. Hind femur with a pale band at the base equal to two-thirds or more the length of the distal white band . . . ***lindesayi cameronensis*** EDWARDS 1929.
At least one other wing vein with an apical pale spot. Hind femur usually pale for once or twice its diameter at the base dorsally; usually about the same amount ventrally or up to one-sixth its length
lindesayi benguetensis KING 1931.
10. Basal quarter of costa mainly pale 11
Basal quarter of costa mainly dark, though there may be scattered pale scales 12
11. Mid-femur without a large pale spot on dorsum towards the apex.
Wing vein 6 with a pale spot on the distal half. Wing fringe all dark

* An author's name in brackets indicates that the species was originally placed in a different genus to that with which it is now associated.

- from vein 3 onwards except for a pale spot between vein 5.2 and vein 6 **gigas** var. **formosus** LUDLOW 1909.
Mid-femur without (also) a large pale spot on dorsum towards apex.
Wing vein 6 with (also) a pale spot on distal half. Wing fringe all dark from vein 3 onwards except for a pale spot between vein 5.1 and vein 5.2
- gigas** var. **sumatrana** SWELLENGREBEL & RODENWALDT 1932.
12. Costa from base to subcostal pale spot entirely dark. Basal one-third of vein 1 and extreme base of vein 5 entirely dark
(**umbrosus** group)* 13
Costa between base and subcostal pale spot generally with a few pale scales. Basal one-third of vein 1 and extreme base of vein 5 with pale scales 16
13. Palpi with obvious pale bands, segment 5 entirely white. Wings brightly marked **separatus** (LEICESTER) 1908.
Palpi entirely dark. Wings dark, with a few pale markings 14
14. Propleural setae present 15
Propleural setae absent **letifer** SANDOSHAM 1944.
15. Front and hind tarsi with pale bands, those of the hind tarsi from one to three times as long as wide. Basal dark mark on wing vein 5 extending halfway or more to the bifurcation. The thorax with one to six subalar (mesepimeral) setae, without associated scales
umbrosus THEOBALD 1903.
Tarsi entirely without pale bands or with minute ones rarely as long as wide. Basal dark mark on wing vein 5 not extending halfway to the bifurcation. The thorax with nine to nineteen subalar setae, nearly always with one or two associated scales **baezai** GATER 1933.
16. Female without a ventral scale tuft on abdominal segment VII. No fringe spot at wing vein 5.2. Pale scales on the costa, when present, confined to the extreme base, proximal to the humeral cross vein*. Hind tarsal segment 5 completely white and at least half of hind tarsal segs. 3 + 4 pale **albotaeniatus** (THEOBALD) 1903.
Female with a ventral scale tuft on abdominal segment VII. With or without a wing fringe spot at vein 5.2 and with or without pale scales on the costa. Hind tarsal segment 5 not completely white and half of hind tarsal segs. 3 + 4 may or may not be pale 17
17. Palpi entirely dark, male palpi mainly dark may have a few pale scales. No tuft of scales on the clypeus 18
Palpi with pale scales forming short bands. A tuft of scales present on each side of the clypeus 19
18. White scattered scales present on the ventral aspect of the abdomen. Palpi very shaggy. Wings with a narrow pale fringe spot at termination of vein 3. **barbirostris** complex.
No white scattered scales present on the ventral aspect of the abdomen. Palpi not very shaggy. Wings with a broad pale fringe spot at vein 3
barbumbrosus STRICKLAND & CHOUDHURY 1927.

* REID J. A., HODGKIN E. P. (1950).

lighter, with pale scales, usually numerous, on vein 1 between the sub-costal and preapical pale spots

peditaeniatus (LEICESTER) 1908.

25. Hind leg with a long white area on either side of the tibio-tarsal joint. Femora and tibiae speckled. Proboscis uniformly dark, with the exception of the labella, and approximately equal to, or shorter than, the fore femur, and at the most only slightly longer than the palpi. Presector dark spot on vein 1 extending basally no further than the level of the centre of the humeral dark accessory spot of the costa, usually no further than the level of the presector pale spot. Hind tarsal segment 4 almost always with a prominent basal pale band. Wing vein 3 with at least five, usually more, obvious dark spots **balabacensis balabacensis** BAISAS 1936.
Hind leg without a broad white band on either side of the tibio-tarsal joint. Without the above combination of the remaining characters 26
26. Vein 3 usually with from five to ten obvious dark spots. Halteres entirely white scaled. On the thorax the mesonotum with hair-like scales. Femora and tibiae speckled. Palpi with three long, white bands, and a short pale band at the joint of segments 2 and 3, these segments each having a patch of pale scales. Proboscis with the apical half yellow-golden brown **tessellatus** THEOBALD 1901
Vein 3 usually with less than five, generally three obvious dark spots and without the above combination of the remaining characters 27
27. Tips of the hind tarsi white 40
Tips of the hind tarsi not white 28
28. Fore-tarsi with fairly long pale bands involving the apex and base of most segments 29
Fore-tarsi unbanded or with only very short bands which when present usually only involve the apex of the segments . . . 33
29. Femora and tibiae speckled 30
Femora and tibiae not speckled 31
30. Middle dark spot on the wing with three dark areas in vein 1. Fringe spot between wing vein 5 and 6 commonly present. Tarsi of the mid-legs usually without basal pale banding. Main leaflets of phallosome of male genitalia long, somewhat S-shaped, with some marked serrations **ludlowae** (THEOBALD) 1903.
Middle dark spot on the wing with two dark areas in vein 1. Fringe spot between wing veins 5 and 6 not usually present. Tarsi of the mid-legs may have very narrow basal banding. Leaflets of phallosome without obvious serrations, short or long . . . **sundaicus** (RODENWALDT) 1925.
(all forms)
31. Presector dark spot on vein 1 usually less than half as long as that on the costa or absent. Female proboscis with a patch of white or yellow scales towards the extremity, usually ventrally. Prehumeral dark accessory costal spot undivided but having a patch of white scales dorsally. Female palpi with the intervening dark area between the apical and the subapical pale bands one-third to one-fifth as

long as the apical pale band. Leaflets of the phallosome large, the first very long the others progressively shorter

vagus vagus DÖNITZ 1902.

Presector dark spot on vein 1 usually more than half as long as that on the costa. Female proboscis uniformly dark. Prehumeral dark accessory costal spot without a patch of white scales but may be divided by pale interruptions. Female palpi with the intervening dark area between the apical and subapical pale bands, equal to, or half, the length of the apical pale band, variable. Leaflets of the phallosome large or small 32

32. Female palpi with the length of the intervening dark area between the apical and subapical pale bands variable, averaging about half the apical pale band. Prehumeral dark accessory costal spot usually undivided and extending to the extreme base of the costa

subpictus var. **indefinitus** (LUDLOW) 1904.

Female palpi with the intervening dark area between the apical and subapical pale bands about the same length as the apical pale band. Prehumeral dark accessory costal spot nearly always divided or in part obliterated, and not extending to the extreme base of the costa, which has more pale scaling than in var. *indefinitus*

subpictus subpictus GRASSI 1899.

33. Mesonotum covered with obvious white scales 34
Mesonotum covered with hairs or hair-like scales, if scales are present they are confined to the anterior promonotory of the mesonotum 35

34. Dark area between the apical and subapical pale bands of the females palpi about as long as or longer than the apical pale band. Tarsal segments with short but distinct white apical bands

jeyporiensis jeyporiensis JAMES 1902.

Dark area between the apical and subapical pale bands of the female palpi much shorter, half or less than half the length of the apical pale band. The tarsal segments with short but distinct white bands also

jeyporiensis var. **candidiensis** KOIZUMI 1924.

35. Female palpi with the apical pale band and the subapical pale band as long as or longer than the intervening dark area 36
Female palpi with the apical pale band and the subapical pale band shorter than the intervening dark area 39

36. Pale fringe spot usually present at the termination of vein 6 on both wings. Proboscis with the apical half distinctly pale all over

aconitus DÖNITZ 1902.

- * No pale fringe spot present at the termination of vein 6 on both wings. Proboscis all dark or with some pale scaling on the ventral and dorsal aspects of the apical half 37

37. Basal quarter of costa all dark on both wings, no humeral or presector pale areas present. Apical half of the proboscis with faint sometimes marked pale scaling on the ventral and dorsal aspects ("flavescence")

varuna IYENGAR 1924.

* In *A. minimus* occasionally there is an indication of a fringe spot on one wing, rarely on both wings, at vein 6.

- Basal quarter of the costa with one or more humeral or presector pale areas. Proboscis all dark except for the very tip, the labella . . . 38
38. Basal quarter of the costa with one obvious pale area * (presector pale area) usually on both wings but may be only on one. No obvious pale rings on the tarsal segments. Not a patch of grey scales on the basal portion of vein 1 in the humeral region, this portion pale to the base of the wing. Proboscis entirely dark except for the labella
minimus minimus THEOBALD 1901.
- Basal quarter of the costa with two obvious pale areas (presector and humeral pale areas) on both wings. Obvious short pale rings on apex of most tarsal segments. A patch of grey scales present on the basal portion of vein 1 in the region of the humeral pale spot. Proboscis also entirely dark except for the labella
pampanai BÜTTIKER & BEALES 1959.
39. Pale wing fringe spots normally present at one or two vein terminations only. Vein 1 with a dark spot at the base of the wing internal to the presector dark area, on vein 1. Vein 3 mainly dark. Basal one-quarter of the costa usually with a pale interruption
culicifacies culicifacies GILES 1901.
- Pale wing fringe spots well marked at all vein terminations except vein 6. Vein 1 pale at the base of the wing internal to the presector dark area on vein 1. Vein 3 mainly pale. Basal one-quarter of the costa all black, no pale area **fluviatilis** JAMES 1902.
40. Femora and tibiae speckled 41
 Femora and tibiae not speckled 46
41. Abdomen with a row of conspicuous black scale-tufts on the ventral surface, clearly visible, on lateral view, to the naked eye. Female palpi with four pale bands, the distal three being very long. Distal half of the proboscis pale **kochi** DÖNITZ 1901.
- Abdomen without conspicuous scale tufts on the ventral surface. Female palpi with three pale bands. Proboscis all dark 42
42. Hind tarsal segments 3 and 4 partly white, tarsal segment 5 wholly white 43
 Hind tarsal segments 3, 4 and 5 uninterruptedly white, the white area including a portion of segment 2 44
43. Dorsum of abdomen mainly clothed in hairs except for the last segments, where there are white or cream-coloured, and some black, scales. Abdominal segment II without a cluster of white or cream-coloured scales on the dorsum
maculatus maculatus THEOBALD 1901.
- Dorsum of abdomen mainly clothed in white or cream-coloured scales with some black scales on the last segment and the genitalia. Abdominal segment II with a cluster of white or cream-coloured scales on the dorsum . . . **maculatus willmori** (JAMES) 1903.
44. Female palpi with two more or less equal, long apical pale bands, separated by a short black band ; segments 2 and 3 with some distinct speckling, in the male also **splendidus** KOIZUMI 1920.

* As an extreme variation just a few pale scales present only.

- Female palpi with only the apical pale band long, the subapical pale band being short, no speckling on segments 2 and 3 45
45. Abdomen with the dorsum of segment VII and VIII thickly clothed with golden hairs and scales. Basal quarter of costa mainly pale, the two black spots small **jamesi** THEOBALD 1901.
Abdomen with the dorsum of segments VII and VIII not so clothed. Basal quarter of costa mainly dark, the pale areas small, the dark areas large **ramsayi** COVELL 1927
46. Tarsal segments 3 and 4 of hind leg with a black band, tarsal segment 5 wholly white 47
Tarsal segments 3, 4 and 5 of hind leg wholly white 48
47. Female palpi with four distinct pale bands, the subapical pale area very long. Wing with an extra pale fringe spot between vein 5 and vein 6. Phallosome of male genitalia with about six leaflets on each side, the largest broad, approaching half the length of the phallosome and serrated on the apical half only . . . **karwari** (JAMES) 1903.
Female palpi with three pale bands, the subapical pale band about equal in length to the apical pale band. Wing without a pale fringe spot between veins 5 and 6. Phallosome with about four leaflets on each side, the largest being serrated along most of its length
majidi YOUNG & MAJID 1928.
48. Vein 5 mostly dark or at least a dark area at origin of vein 5.1
annularis VAN DER WULP 1884.
Wing vein 5 mostly pale, without a dark spot at origin vein 5.1 49
49. Abdomen with few or no pale scales, except apically on ventral or dorsal aspects. Usually no defined clusters of pale scales on the pleura in front of the wing base. Usually a pale area at the apex of tarsal segment 1 of the hind leg . . . **philippinensis** LUDLOW 1902.
* Abdomen with scattered pale scales on most segments ventrally and on five or six segments dorsally. Clusters of pale scales on the pleura in front of the wing base. Never with a pale area at the apex of tarsal segment 1 of hind leg **pallidus** THEOBALD 1901.

**A Key to the 4th Instar Larvae of the Anopheline Mosquitos
of Cambodia including species recorded from neighbouring
territories (chaetotaxy after Belkin)**

1. Bases of the inner clypeal hairs (head hairs 2) close together, often nearly touching, the distance between the base of one inner clypeal hair and the base of the corresponding outer clypeal hair (head hairs 3) on the same side, is greater than or equal to the distance between,

* *A. philippinensis* is often found with the apical pale area of the female palpi divided by a complete or incomplete black ring, giving the impression of four pale bands, usually there are three distinct pale bands. This extra black ring has been noted in other species in various countries

e.g. *A. (Cellia) subpictus subpictus* GRASSI 1899 — India,
A. (Cellia) superpictus GRASSI 1899 — Afghanistan.

- the two inner clypeal hairs. (In *A. aitkeni* (JAMES) 1903 and *A. albo-taeniatus* (THEOBALD) 1903 these distances are equal)
 subgenus **Anopheles** MEIGEN 1818 2
- Bases of the inner clypeal hairs far apart, never touching, distance between the base of one inner clypeal hair and the base of the corresponding outer clypeal hair on the same side, is less than the distance between the two inner clypeal hairs
 subgenus **Cellia** THEOBALD 1902 27
2. Antennal hair (Antennal hair 1) simple or with only a few branches at the tip ; arising from dorso-external surface of the antenna. Frontal hairs (head hairs 5, 6 and 7) either simple or branched, but always poorly developed 3
 Antennal hair branched ; arising from internal or dorsal surface of the antenna. Frontal hairs usually branched, not poorly developed 4
3. Antennal hair divided into three at the tip. Subantennal hair (head hair 11) long with numerous branches. All the frontal hairs branched though poorly developed. Upper lateral hair (hair 6) on abdominal segments IV and V slender, long and bifurcated from about the middle, on VI short, delicate, split in to three to six branches at the tip
alongensis VENHUIS 1940.
 Antennal hair simple, stout and short. Subantennal hair long with three to seven branches distally. Inner frontal hairs (head hair 5) fairly long, simple or with two to three branches distally. Upper lateral hair on abdominal segments IV-VI long with numerous short branches. One long pleural hair on the metathorax finely barbed
annandalei interruptus PURI 1929.
4. Hair 1 not developed on any of the abdominal segments, the leaflets represented by filamentous branches 5
 Developed palmate hairs (hair 1) at least on some abdominal segments 7
5. Terminal antennal hair (antennal hair 4) with one or two of the branches rather stout and hooked. Outer clypeal hairs with four to seven branches. Post clypeal hairs (head hair 4) small, not reaching the bases of the inner clypeal hairs, with two to four branches. Inner clypeal hairs simple, occasionally with a few fine branches at the tip. Upper lateral hair (hair 6) on abdominal segment III with thirteen to twenty branches. Hair 0 on abdominal segment III with three to four branches. Antennal hair (Antennal hair 1) with seven to thirteen branches **letifer** SANDOSHAM 1944.
 Terminal antennal hair with all the branches filamentous, not stout or hooked. Outer clypeal hairs with eleven to twenty five branches. Without the above combination of the remaining characters . . . 6
6. Tips of the inner clypeal hairs frayed with small fine branches. Antennal hair with thirteen to twenty one branches. Upper lateral hair on abdominal segment IV with seven to ten branches. Post clypeal hairs small with one or two branches **baezai** GATER 1933.
 Inner clypeal hairs simple. Antennal hair bushy with twenty five to thirty six branches. Upper lateral hair on abdominal segment IV with three to four branches. Post clypeal hairs small and simple
separatus (LEICESTER) 1908.

7. Palmate hairs fully developed on two abdominal segments only, IV and V. Stigmal club with a long filament, present on the fan shaped plate of the spiracular apparatus. Post clypeal hairs (head hair 4) small not reaching the bases of the inner clypeal hairs. Outer clypeal hairs with ten to twenty two branches
umbrosus (THEOBALD) 1903.
 Palmate hairs well developed on abdominal segments III to VI. Without the above combination of the remaining characters 8
8. Anterior tergal plates very large, occupying nearly half or more of the dorsum of each segment. The inner submedian prothoracic hair (prothoracic hair 1) is peculiar to the species being palmate in appearance, and having a short rounded stem from which eighteen to nineteen branches radiate. Outer clypeal hairs one-quarter the length of the inner, simple or bifid near the base. Post clypeal hairs bifid near the base **palmatius** (RODENWALDT) 1926.
 Anterior tergal plates small except on abdominal segment VIII. The inner submedian prothoracic hair with the usual longitudinal stem, being simple, branched at the tip or with anything up to seventeen branches. Without the above combination of the remaining characters 9
9. Antennal hair small, less than half the length of the antennal shaft, the branches reaching nowhere near the end of the shaft. Outer clypeal hairs simple or with not more than five branches, not bushy 10
 Antennal hair large, half or more the length of the shaft, the branches reaching nearly to the end of the shaft or beyond. Outer clypeal hairs usually bushy, with at least six, usually many more branches 18
10. Inner clypeal hairs with two to six long branches 11
 Inner clypeal hairs without long branches 13
11. Inner clypeal hairs split into two branches from about the middle 12
 Inner clypeal hairs with three to six branches arising from about the middle **aitkenii bengalensis** PURI 1930.
12. Inner clypeal hairs with fine lateral hairs on the middle third
aitkenii treacherii PURI 1949.
 Inner clypeal hairs without fine lateral hairs on the middle third
aitkenii aitkenii JAMES 1903.
13. Inner clypeal hairs placed about the same distance apart as that between the outer and inner hairs on one side; with fine lateral hairs on the middle third **aitkenii stantoni** PURI 1949.
 Inner clypeal hairs placed close together, no fine hairs on any part 14
14. Inner clypeal hairs stout, long, simple, and touching at the base usually; hair 1, on abdominal segment I developed with lanceolate leaflets. Outer clypeal hairs about two-fifths the length of the inner clypeal hairs, stout and simple. Post clypeal hairs slender, shorter than the outer clypeal hairs, with three or four branches. Inner submedian prothoracic hairs with a few branches only, about eight to ten
insulaeflorum (SWELLENGREBEL & SWELLENGREBEL DE GRAAF) 1919.
 Inner clypeal hairs long, not quite touching at the base, separated by at least the width of a basal tubercle. Hair 1 on abdominal seg-

- ment I not developed having a few filamentous branches only. Without the above combination of the remaining characters 15
15. Outer and post clypeal hairs simple, or post clypeal hairs only slightly branched distally 16
Outer and post clypeal hairs branched, with from about two to eight branches 17
16. Both the inner and outer clypeal hairs stout and simple. Outer clypeal hairs half or more than half the length of the inner clypeal hairs. Post clypeal hairs nearly as long as the outer clypeal hairs, simple or occasionally bifid. Upper lateral hairs (hair 6) on segments IV and V long, dividing near the base into two to three branches
lindesayi cameronensis EDWARDS 1929.
Inner clypeal hairs slender and simple. Outer clypeal hairs stout or slender, simple and a little over one-third the length of the inner clypeal hairs. Post clypeal hairs longer than the outer clypeal hairs, and with two to five branches, sometimes simple. Upper lateral hairs on segments IV and V with two to three branches
lindesayi benguetensis KING 1931.
17. Outer clypeal hairs less than one-third the length of the inner clypeal hairs, with two or three branches distally sometimes with a few fine side hairs on the stem. Post clypeal hairs with three fine branches arising from the base. Leaflets of hair 1 on abdominal segments III-VII with poorly differentiated filaments, blade with some marked serrations
A. gigas var. **sumatrana** SWELLENGREBEL & RODENWALD 1932.
Outer clypeal hairs one half or more the length of the inner clypeal hairs, with two to six branches sometimes simple. Post clypeal hairs with three to eight branches from towards the base, usually three to four. Leaflets of hair 1 on abdominal segments III-VII bluntly tapered without filaments, and either smooth or with a few serrations on the edges **A. gigas** var. **formosus** LUDLOW 1909.
18. Bases of the inner clypeal hairs nearly touching 19
Bases of the inner clypeal hairs not touching, the distance between them being about the same as the distance between the bases of the inner and outer clypeal hairs of one side
albotaeniatus (THEOBALD) 1903.
19. Inner submedian prothoracic hair (prothoracic hair 1) with branches nearly as long as the whole hair arising from near the base. Outer clypeal hairs with approx from 12-50 branches 20
Inner submedian prothoracic hair simple or with a few short branches at the tip. Outer clypeal hairs with approx from 40-90 branches 21
20. Outer clypeal hairs with approx twenty-seven to fifty branches. Post clypeal hairs (head hair 4) short usually with two to five branches arising from near the base **barbirostris** complex.
Outer clypeal hairs with twelve to twenty-four branches. Post clypeal hairs often short, simple or bifid from the base
barbumbrosus STRICKLAND & CHOUDHURY 1927.
21. Mesothoracic hair 5 small with sinuate, horizontally spreading, branches, arising together from the base
peditaeniatus (LEICESTER) 1908.

- Mesothoracic hair 5 not so, the branches straight, stiff and more or less erect 22
22. Sutural hair (head hair 8) with numerous branches, thirteen to twenty three, commonly seventeen. Antennal shaft rather slender, usually with rather large, coarse erect teeth. Tergal plates on abdominal segment VIII between two-thirds and three-quarters as long as wide, usually tapering posteriorly more or less in the form of a truncated wedge. Pigmentation of the palmate hairs usually uniform and rather dense. Saddle hair (hair 1 anal segment) strong, at least as long as the width of segment VIII. Usually seven long teeth on the pecten, rarely fewer **argyropus** (SWELLENGREBEL) 1914. Without this combination of characters. If the sutural hair has more than twelve branches, then either tergal plate VIII is large and transverse rectangular, less than two-thirds as long as wide, and the palmate hairs are large with the pigmentation generally less dense and not uniform, paler towards the base of the leaflets (*sinensis*, *nigerrimus*) or the saddle hair is weak, less than the width of segment VIII, and the pecten rarely has more than six long teeth (*indiensis*) . . . 23
23. Palmate hairs large, the pigmentation often not uniform nor very dense, but paler basally, often extending well into the tips of the leaflets. Tergal plate on segment VIII transverse, usually less than two-thirds as long as wide. Spiracles large 24
Palmate hairs somewhat smaller, pigmentation commonly uniform and dense and not extending much into the tips of the leaflets. Tergal plate on abdominal segment VIII usually less transverse, two-thirds or more as long as wide. Spiracles smaller 25
24. Abdominal segment VI, hairs 5 and 7 with six to eleven branches, average eight. Sutural hair with eight to thirteen branches, average eleven **sinensis** WIEDEMANN 1828.
Abdominal segment VI, hairs 5 and 7 with two to five branches, usually three or four. Sutural hair with twelve to twenty four branches, average seventeen **nigerrimus** GILES 1900.
25. Sutural hair with eleven to seventeen branches average thirteen. Abdominal segment III, hair 7 with ten to sixteen branches. Saddle hair weak, not as long as the width of segment VIII. Pecten seldom with more than six long teeth **indiensis** THEOBALD 1901.
Sutural hair with five to eleven branches, average nine. Abdominal segment III, hair 7 with five to eleven branches. Pecten seldom with less than seven large teeth. Saddle hair strong or weak . . . 26
26. Hair 5 on abdominal segment II with six to ten branches, average nine. Saddle hair strong, about as long as the width of abdominal segment VIII **lesteri** BAISAS & HU 1936.
Hair 5 on abdominal segment II with ten to eighteen branches, average thirteen. Saddle hair weak, usually shorter than the width of abdominal segment VIII **crawfordi** REID 1953.
27. One of the long prothoracic pleural hairs (prothoracic hair 10) feathered 28
None of the long prothoracic pleural hairs (hair 9 & 10) feathered but perhaps one (hair 10) split about the middle into two to three branches 42

- with a convex posterior border extending to about the middle of the segment and enclosing the small rounded posterior tergal plate 37
 Anterior tergal plates on abdominal segments III-VII may be large or small but not exceptionally large, and with the posterior tergal plates always lying separately from them 40
37. Inner, outer and posterior clypeal hairs (head hair 2, 3 + 4) simple. Hair 0 on abdominal segment IV may arise from, or lie away from the anterior tergal plate and may be simple or branched . . . 38
 Inner clypeal hairs with short scattered branches. Outer clypeal hairs simple or with short branches. Posterior clypeal hairs branched from the base. Hair 0 on abdominal segment IV sometimes arising from the anterior tergal plate but often lying a little posterior to or at the border of the plate, simple or bifid **aconitus** DÖNITZ 1902.
38. The leaflets of metathoracic hair 3 (palmate) with a rounded or pointed tip, no filament. The posterior margin of the anterior tergal plate on abdominal segment II may be concave or convex. Hair 0 on abdominal segment IV may arise from or lie away from the anterior tergal plate, and may be branched or simple 39
 The leaflets of metathoracic hair 3 having a long, tapering, pointed filament. Posterior margin of the anterior tergal plate on abdominal segment II convex, enclosing the posterior tergal plate. Hair 0 on abdominal segment IV arising from within the anterior tergal plate and simple **varuna** IYENGAR 1924.
39. Posterior margin of the anterior tergal plate on abdominal segment II, concave, with the posterior tergal plate lying in the concavity. Hair 0, on abdominal segment IV long, and arising from well within the anterior tergal plate, nearly always simple, occasionally forked on one side. Basal tubercles of the submedian prothoracic hairs (prothoracic hairs 1, 2 and 3) very prominent and nearly always all fused
pampanai BÜTTIKER & BEALES 1959.
 Posterior margin of the anterior tergal plate on abdominal segment II, convex, enclosing the posterior tergal plate. Hair 0 on abdominal segment IV usually with three branches from the base and always lying outside the anterior tergal plate, a short distance from it. Basal tubercles of the submedian prothoracic hairs very prominent but generally not fused completely
minimus minimus THEOBALD 1901; **fluviatilis** JAMES 1902.
40. Inner, outer and posterior clypeal hairs (head hairs 2, 3 + 4) simple. The anterior tergal plates may be comparatively large or small 41
 Inner clypeal hairs with conspicuous lateral branches. Outer clypeal hairs with a large number of short lateral branches. Anterior tergal plates comparatively large
jeyporiensis jeyporiensis JAMES 1902;
jeyporiensis var. **candidiensis** KOIZUMI 1924.
41. Inner clypeal hairs of normal length, much less than one-half as long as the fronto-clypeus. Filaments of the abdominal palmate hairs (hair 1) about one-half or more than half as long as the blade of the leaflets. Sutural hairs (head hair 8) long and simple
culicifacies culicifacies GILES 1901.

- Inner clypeal hairs exceptionally long, about one-half as long as the fronto-clypeus. Filaments of the abdominal palmate hairs only about one-quarter the length of the blades of the leaflets. Sutural hairs branched **majidi** YOUNG & MAJID 1928.
42. Both the long metathoracic pleural hairs (metathoracic hairs 9 + 10) feathered or one feathered and one with four to six long branches 43
None of the long metathoracic pleural hairs 9 + 10 feathered or branched 46
43. Inner clypeal hairs simple and long. Outer clypeal hairs simple and short, less than half (about one-quarter to one-third) the length of the inner clypeal hairs. Post clypeal hairs (head hair 4) short, about the same length as the outer clypeal hairs, the bases always lying between the bases of the inner clypeal hairs, and only slightly posterior to them, almost horizontally in line **vagus vagus** DÖNITZ 1902.
Inner clypeal hairs simple and long. Outer clypeal hairs simple or sometimes branched, half or more than half the length of the inner clypeal hairs. Post clypeal hairs quite long at least half the length of the outer clypeal hairs and lying between the bases of the inner and outer clypeal hairs but posterior to them 44
44. Hair 1 on abdominal segment I having developed leaflets with filaments. Upper lateral hair (hair 6) on abdominal segment IV with a short stalk, usually with two to three branches arising from near the base 45
Hair 1 on abdominal segment I undeveloped with three to nine slightly flattened branches. Upper lateral hair on abdominal segment IV with a long stalk split about the middle into four to six branches
ludlowae (THEOBALD) 1903.
45. Hair 4 on the mesothorax with three or more branches. Long prothoracic and mesothoracic pleural hairs never all simple, always with one, two, or three branches if not more on at least one of the hairs. Head hair 12 ventral aspect, usually with more than three branches at least on one side seldom three. Post mandibular hair (head hair 13) ventral aspect, with five or more branches at least on one side
sundaicus (RODENWALDT) 1925.
(Fresh and salt water forms).
Hair 4 on the mesothorax with two branches. Long prothoracic and mesothoracic pleural hairs all simple or with one or two branches. Head hair 12 ventral aspect with three branches or less. Post mandibular hair, ventral aspect, with less than five branches
subpictus GRASSI 1899; **subpictus** var. **indefinitus** (LUDLOW) 1904.
46. Inner submedian prothoracic hair (prothoracic hair 1) with a slender stem having two to ten branches, and arising from a comparatively inconspicuous basal tubercle which is always separate from that of the middle submedian prothoracic hair (prothoracic hair 2). All the long pleural hairs on the thorax simple 47
Inner submedian prothoracic hair with a strong flattened stem and ten to twenty four branches, average sixteen, and with a prominent basal tubercle which is partly or entirely fused with the basal tubercle of the middle submedian prothoracic hair. All the long pleural hairs on the thorax also simple **balabacensis balabacensis** BAISAS 1936.

47. Hair 1 on abdominal segments I and II with lanceolate leaflets. Inner submedian prothoracic hair usually with six to ten branches. Sutural hair (head hair 8) simple or forked at the tip **kochi** DÖNITZ 1901. Hair 1 on abdominal segments I and II with the branches filamentous or slightly flattened only. Inner submedian prothoracic hair with two to five branches. Sutural hair with two to four branches **tessellatus** THEOBALD 1901.

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Authorities consulted

The species in the *hyrcanus* group are keyed out after REID (1953).

The key characters for the four species in the "umbrosus" group mentioned here are taken from the paper by REID and HODGKIN (1950) in which they give a key to most species in this group and notes on the biology, and transmission of malaria.

Regarding the *leucosphyrus* group, the papers by COLLESS (1956 & 1957) have been consulted. As no other species in this group is yet known to occur commonly in Cambodia or its bordering territories other than *A. balabacensis balabacensis*, this is the only member mentioned here.

Full use has been made of the notes by GATER (1934 & 1935) as well as the papers by KING (1931 & 1932). We are indebted to Dr. F. E. BAISAS for valuable notes and observations on some of the Philippine species by personal communication.

In regard to the *Anopheles barbirostris* group full use of Reid's paper (1962) has been made.

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