MEDICAL ENTOMOLOGY STUDIES - II

THE SUBGENUS *ANOPHELES* IN THAILAND

(Diptera: Culicidae)[1]

By

Bruce A. Harrison[2] and John E. Scanlon[3]

ABSTRACT

This is a comprehensive revision of the subgenus *Anopheles* in Thailand that involved the examination of over 10,000 specimens of 32 species and one subspecies. Included in the 96 full-page figures are: 92 plates of whole pupae and larvae, many habitus drawings of females, male genitalia, wings and other selected characters. Major sections included are: zoogeography, format-treatment, morphology, taxonomy in general, taxonomy of supraspecific categories, keys and the descriptions. Species descriptions include sections on: synonymy, descriptions of female, male, pupa and larva, type-data, distribution, taxonomic discussion, biology and where applicable, medical significance. Special emphasis is placed on the keys, descriptions, type discussions, intraspecific and interspecific variations, affinities, behavior and a specific level review of medical significance. A key to all the known adult females of the genus *Anopheles* in Thailand is included as an appendix.

The male, female, pupa and larva of *A. aberrans* n. sp., are described and illustrated. Pupae of *insulaeflorum* and *palmatus* are described for the first time. Stages and genitalia for the following species are illustrated for the first time: *campestris* pupa; *donaldi* pupa; *hodgkini* male genitalia; *insulaeflorum* male genitalia; *palmatus* adult abdomen, male genitalia and pupa; and *pollicaris* male genitalia and pupa. A lectotype is designated for *baezai*, and *Stethomyia pallida* Ludlow, is moved from synonymy under *aitkenii* to synonymy under *bengalensis*.

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INTRODUCTION

Background

This publication is the result of studies undertaken in Thailand by the senior author during the period 1967-1970 and the junior author during the period 1961-1964, under the auspices of the Southeast Asia Treaty Organization (SEATO) Medical Research Laboratory. Since 1964, this work has been an integral part of the Southeast Asia Mosquito Project (SEAMP), Department of Entomology, Smithsonian Institution.

The anopheline mosquito fauna of Thailand is large and complex, and in recent years it has become apparent that there are complex species groups in the fauna, which defy taxonomic clarification by classical morphological means alone. Still, it has required the application of these classical techniques, coupled with observations on the habits and distribution of the morphologically distinguishable taxa to place us, at least, in the position where definition of the species in complexes by cross-breeding, cytogenetic, or other methods can proceed on a sound basis. At the time the present study was undertaken the most recent faunal checklist for the mosquitoes of Thailand (Thurman 1963) contained 21 species and subspecies in the subgenus *Anopheles*. During the course of our subsequent studies it seemed advisable to prepare an interim checklist (Scanlon, Peyton and Gould 1968) in which there were 29 species of the subgenus *Anopheles*, with an additional 4 species listed as doubtful records. In a subsequent work by Reid (1968), an additional species of this subgenus was reported from Thailand. The present work recognizes an additional 3 species in Thailand, and thus, deals with a total of 33 species. It is quite possible that new species will be added when the more heavily forested areas and some of the more cryptic habitats (Peyton 1970) have been further sampled. Additional new records should occur when the fauna of the presently inaccessible border areas is better known.

The great bulk of the specimens examined in the course of this work resulted from the collections of the U. S. Army Medical Component, SEATO, made throughout Thailand from 1961 - 1973. These collections were usually made in connection with specific disease problems, but whenever possible specimens were reared and biological data taken on all species, regardless of immediate medical importance. Consequently, a major portion of the mosquito fauna of Thailand has been collected, and the majority of specimens discussed herein are reared adults with associated immature skins. These specimens have been deposited in the MEP collection. The National Museum of Natural History (USNM) also possesses a considerable number of Thailand *Anopheles* deposited by earlier workers (D. C. and E. B. Thurman, O. R. Causey, E. I. Coher and P. F. Beales). In addition, USNM collections were examined for specimens of the subgenus *Anopheles* from areas outside Thailand which might shed light on the range of variation for each of the species considered. Specimens were examined from other collections listed in the acknowledgements and in appropriate portions of the text. The specimens in the MEP collections will be deposited in the regular collections of the USNM.

The earliest publication containing references to Thailand anophelines was that of Theobald (1910), who reported *barbirostris* and *rossii* Giles (= *vagus* Dönitz). This was followed by Stanton's (1920) study of the mosquito fauna of various far eastern ports which included records of Bangkok mosquito species. Stanton's primary interest was evaluating the danger of yellow fever epidemics following the opening of the Panama Canal. The first papers dealing specifically

with the genus *Anopheles* and the role of anopheline species in the transmission of malaria in Thailand were those of Barnes (1923 a, b) who listed some 17 species (only 2 in the subgenus *Anopheles*) with notes on their biology and vector relationships. Barnes' records were repeated by Barraud and Christophers (1931) as were those of the other early workers cited above. In addition, these authors discussed a collection made by J. A. Sinton along the railroad line from Bangkok to Chiangmai, and in those 2 cities. They listed 20 *Anopheles* for the country, one of which they regarded as a doubtful record. Additional early records of anophelines in Thailand were published by Anigstein (1932); Christophers (1933); Covell (1927); Payung-Vejjasastra (1933) and Causey (1937 a, b). The last named provided a rather complete analysis of the anopheline fauna then known, particularly in relation to the terrain and hydrography of the country. Causey's anopheline data were, however, largely based on his Bangkok collections. For areas outside Bangkok, Causey noted the more extensive work of Anigstein, who also provided an excellent account of the terrain and hydrography of Thailand as related to the breeding of *Anopheles*. These relatively meager observations were being made at a time when very significant observations were being published on the epidemiology of malaria and on the taxonomy and biology of anophelines by British workers in India and Malaya, and the French in Indochina.

During the period of World War II and shortly thereafter a number of short papers were published on the malaria encountered in prisoner of war camps in Thailand (Wilson and Reid 1949; De Fluiter 1948), which included records of *Anopheles* species. In the postwar era interest in mosquitoes in general, including the anophelines, expanded rapidly and lists of species and biological data were published by Bonne-Wepster and Swellengrebel (1953); Foote and Cook (1959); Puri (1949); Iyengar (1953); and Thurman (1959). The last publication summarized to some extent the large scale collecting efforts of D. C. and E. B. Thurman in northern Thailand. Their efforts were almost entirely devoted to culicine species. The long series of papers by Reid, culminating in his monograph on the Malayan and Borneo *Anopheles* (1968), contain many records of Thailand *Anopheles* species. In the course of studying the Thai anophelines numerous biological and epidemiological observations were made, and thousands of specimens have been examined in the field and from many museum and other collections. Consequently, a number of publications have appeared which are most pertinent to malaria epidemiology and the anopheline fauna of Thailand. These are: Gould, Esah and Pranith (1965); Gould, Scanlon and Ward (1966); Harrison (1972, 1973); Harrison and Scanlon (1974); Harrison, Scanlon and Reid (1973); Peyton and Scanlon (1966); Rattanarithikul and Harrison (1973); Scanlon and Esah (1965); Scanlon and Peyton (1967); Scanlon, Peyton and Gould (1967, 1968) and Scanlon and Sandhinand (1965).

Zoogeography

The Kingdom of Thailand lies between approximately 6 degrees and 21 degrees north latitude, and extends roughly from 98 degrees to 105 degrees east latitude. The Kingdom is irregularly shaped, somewhat in the shape of an elephant's head, with the trunk forming the portion extending southward to the Malaysian border. The country is divided into 71 Provinces or Changwats, forming the first order administrative units. The list of Province names employed here (Fig. 1) and in earlier publications in this series conform to the Official Standard Names Gazeteer No. 97 of the U. S. Board of Geographic Names, Washington, D. C. A few of these names differ slightly in orthography from the standard Romanized names proclaimed in the Royal Gazette of the Kingdom of Thailand, number 84, 1967,

which were employed in Scanlon et al. (1968). The differences are so slight that no confusion should result from using that publication in conjunction with the present work.

Much of the population of Thailand, and most of the industry, is located on the broad central alluvial plain near Bangkok (= Krung Thep). The central feature of this plain is the Chao Phrya River (= Maenam Chao Phrya) and its numerous branches and tributaries. This is one of the richest rice producing areas in the world, and an aerial view of the region conveys the impression of a vast plain compounded of varying proportions of earth and water. Until fairly recently most of the transportation depended on the countless canals and natural waterways. During the rainy season mosquito production in the surface waters is immense, and breeding continues to some extent throughout the year.

Southward and westward from Bangkok the country narrows rapidly to form the Isthmus of Kra, separated from Burma in the northern portion by the Bilauk Taung mountain range (1,097 - 1,158 m). The more southern portion of the peninsula consists of coastal plains on the east and west coasts of varying widths, with central ranges of low hills. Toward the southern border tropical deciduous forest gives way to wet and rain forests. There are rather extensive stretches of mangrove on the west coast and much smaller groves on the Gulf of Thailand side.

West of Bangkok there is a moderately high range of mountains forming the border with Burma and running northward to northwestern Thailand. The entire northwestern portion of the country is mountainous, with intervening fertile valleys. These mountains are relatively low and covered for the most part by tropical deciduous forest, with teak (*Tectona grandis* Linnaeus) as one of the dominant large trees. Only a few of the tallest mountains (Doi Inthanon, 2,599 m; Doi Pui 1,683 m) carry a pine-oak forest cover at the higher altitudes. The various ranges of hills and mountains in this northwestern part of the country are separated by various tributaries which flow southward to form the Chao Phrya River. Most lines of commerce and communication follow these valleys and streams and move in a north-south direction. The mountains are high enough to show some effect on mosquito species distribution (Scanlon and Esah 1965) but no real barrier exists to movement northward into Burma and China, as evidenced by the list of species of *Anopheles* shared with those areas, given below.

Southeast of Bangkok there is a coastal plain with some mangrove areas, with inland hills and rather isolated mountains which approach the coast at points, particularly near the Cambodian border in Chanthaburi and Trat provinces (Fig. 1). These provinces have extensive areas of tropical wet forest, in many ways resembling the southern peninsular portion of the country near the Malaysian border.

One of the most striking geographical features of the country is northeast of Bangkok and called the Korat Plateau. This plateau is bordered on the south by a line of hills and mountains in a general east-west direction. To the northeast is a vast area of cultivated land and deciduous forest that forms part of the drainage basin of the Mekong River. The plateau is generally drier than the rest of Thailand, except for the southern slopes of the mountain chain which have areas of evergreen cloud forest. The highest peak along the chain is Khao Laem (1,341 m) in Nakhon Nayok Province. From about that point the fringing mountain chain turns northward and becomes the complex, but rather low, Dong Phraya Yen range to the border of Laos.

From the forgoing account it can be seen that there is considerable diversity to the geography of Thailand. This is compounded to some extent by the climatic pattern. Most of the country receives a single monsoon, with the rainy season

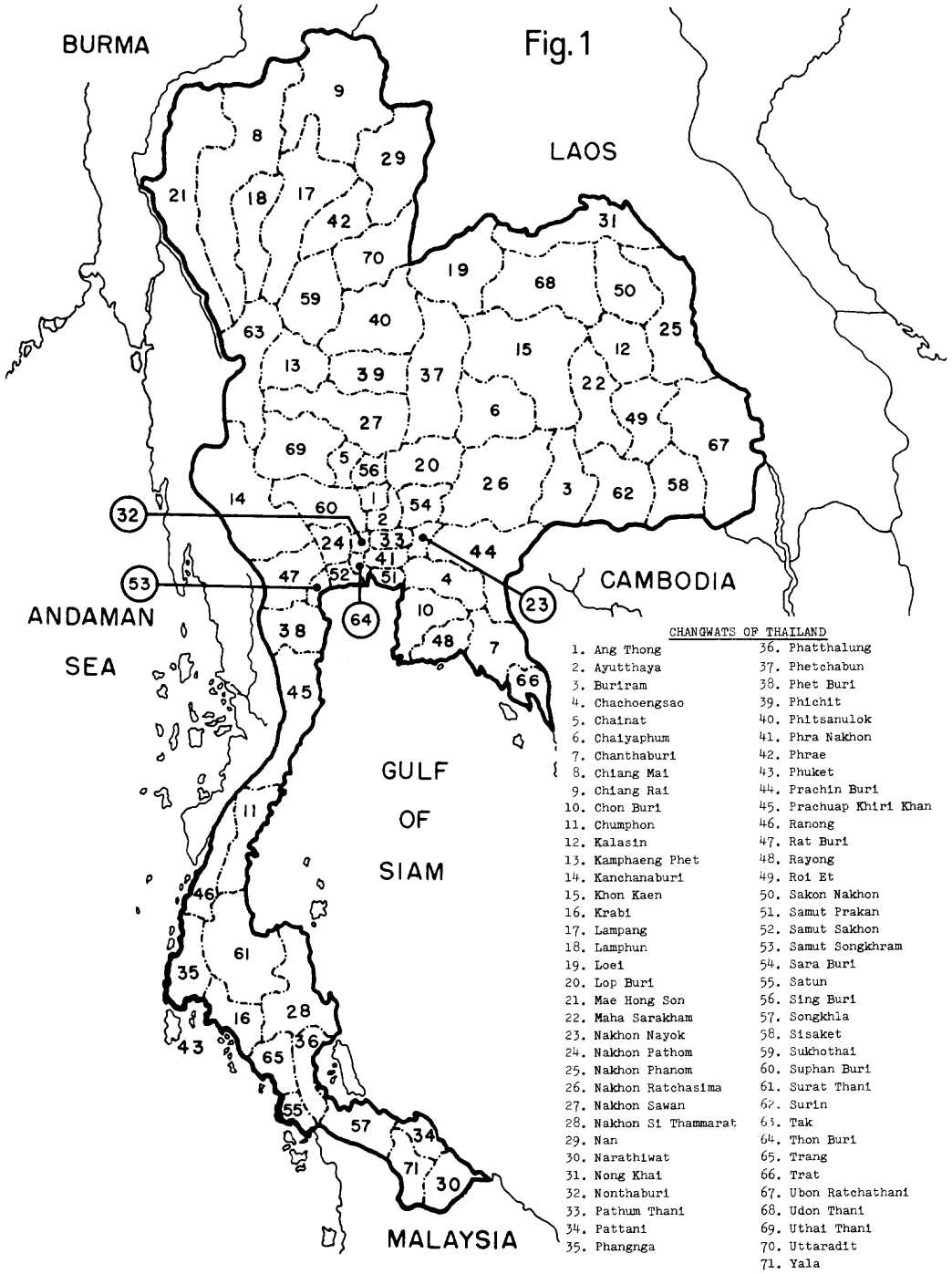


Fig. 1

CHANGWATS OF THAILAND

1. Ang Thong
2. Ayutthaya
3. Buriram
4. Chachoengsao
5. Chainat
6. Chaiyaphum
7. Chanthaburi
8. Chiang Mai
9. Chiang Rai
10. Chon Buri
11. Chumphon
12. Kalasin
13. Kamphaeng Phet
14. Kanchanaburi
15. Khon Kaen
16. Krabi
17. Lampang
18. Lamphun
19. Loei
20. Lop Buri
21. Mae Hong Son
22. Maha Sarakham
23. Nakhon Nayok
24. Nakhon Pathom
25. Nakhon Phanom
26. Nakhon Ratchasima
27. Nakhon Sawan
28. Nakhon Si Thammarat
29. Nan
30. Narathiwat
31. Nong Khai
32. Nonthaburi
33. Pathum Thani
34. Pattani
35. Phangnga
36. Phatthalung
37. Phetchabun
38. Phet Buri
39. Phichit
40. Phitsanulok
41. Phra Nakhon
42. Phrae
43. Phuket
44. Prachin Buri
45. Prachuap Khiri Khan
46. Ranong
47. Rat Buri
48. Rayong
49. Roi Et
50. Sakon Nakhon
51. Samut Prakan
52. Samut Sakhon
53. Samut Songkhram
54. Sara Buri
55. Satun
56. Sing Buri
57. Songkhla
58. Sisaket
59. Sukhothai
60. Suphan Buri
61. Surat Thani
62. Surin
63. Tak
64. Thon Buri
65. Trang
66. Trat
67. Ubon Ratchathani
68. Udon Thani
69. Uthai Thani
70. Uttaradit
71. Yala

extending from May to November, which creates a tropical savannah climate (van Randwijk and Willems 1964). The extreme southeastern mountains and much of the peninsular portion of the country receive much higher amounts of rainfall, and portions of the peninsula receive rain from the northeast and the southwest monsoons, creating a rain forest climate.

Although many gaps remain in the distributions of the species of the subgenus known in Thailand (Table 1), an examination of their presently known distributions reveals some interesting patterns. It appears that there are relatively few if any, terrain barriers to movement on the north-south axis. Many of the species encountered in Thailand are found in much of Southeast Asia[1], and it is difficult to make any generalizations concerning these, except on an individual basis. As might be expected, some of these species show a considerable amount of variation over their very wide ranges (e.g. *nigerrimus*, page 68). These variations, where applicable, are discussed under each species.

Allowing for this individual variation, it appears that the Thailand species of the subgenus *Anopheles* share a great many characters with those in neighboring areas. There are many species in Peninsular Malaysia and Borneo that do not enter Thailand, but the fauna of South Thailand bears a strong affinity to that of Malaysia. There also appears to be relatively few differences from the Indonesian forms, at least for the Greater Sundas. Inadequate numbers of specimens were available from other parts of Indonesia to permit much speculation. The situation with the Philippines is quite different. While many of the Philippine species are obviously closely related to members of the same species groups in Thailand (*nigerrimus* - *pseudosinensis*; *barbirostris* - *franciscoi*; *barbumbrosus* - *vanus*), the overall impression is one of 2 quite distinct faunas.

Reid (1950, 1968) commented on the distribution of a number of species of the subgenus *Cellia* which occur in the northern part of Peninsular Malaysia generally near the Thai border, but disappear slightly further south, only to occur again on various islands of the Malaysian and Indonesian chains. Similar discontinuities appear to be found in reptiles, butterflies and other groups (Reid 1950). Although such discontinuities are not apparent among the members of the subgenus *Anopheles*, there are a number of species in Groups I and III (e.g. *pursati*, *argyropus*, *sinensis* and *sintonoides*) which are widespread on the mainland, but which disappear on the Malayan peninsula or the island chains. The reverse is true of a number of species in Group II (ex. *donaldi*, *montanus*, *pollicaris* and *stricklandi*) that occur in the Malaysian region, extending north into southern Thailand and then disappearing. These trends are not balanced, for there appears to be more penetration of the southern area by the species of Group I than northward penetration by the members of Group II. Nevertheless, these trends support the distinct anopheline faunal change which occurs in the vicinity of the Thai-Malaysian border. In the absence of topographic barriers this phenomenon is probably due to climatic factors, in particular the seasonal rainfall patterns which cause the change from a tropical monsoon to a wet forest type vegetation. There seems to be a definite correlation between the forest vegetation-rainfall pattern and the Malaysian centered members of the subgenus, thus, one would expect to find some Group II species in

[1]As defined by de Meillon (1969) this includes: Bangladesh, Andaman Islands, Burma, Thailand, Cambodia, Laos, North and South Vietnam, Malaysia, Singapore, China south of the Yangtze River, Taiwan, Southern Ryukyu Islands, Philippines and Indonesia. Also included are Assam and Brunei, while Indonesia is restricted to that area west of Weber's zoogeographical line.

TABLE 1. Geographical affinities of species of the subgenus *Anopheles* in Thailand

Group I - Species with a wide distribution in Southeast Asia

argyropus
baezai
barbirostris
barbumbrosus
bengalensis
insulaeflorum
nigerrimus
nitidus
peditaeniatus
sinensis

Group II - Species which occur in Thailand, but appear to have their center of distribution in Malaysia and Indonesia.

asiaticus
campestris
crawfordi
donaldi
fragilis
hodgkini
lesteri paraliae
letifer
montanus
palmatus
pollicaris
roperi
separatus
stricklandi
umbrosus
whartoni

Group III - Species which apparently have a wide distribution on mainland Southeast Asia, but disappear in peninsular Thailand or Malaysia.

interruptus
pursati
sintonoides

Group IV - Infrequently collected species known only from Thailand, or Thailand and adjacent countries.

aberrans - (Thailand)
bulkleyi - (Thailand)
kyondawensis - (Burma and Thailand)
tigertti - (Thailand)

the southeastern Thailand provinces of Chanthaburi and Trat, where the rainfall pattern is much like that of the southern provinces. This does in fact occur, for such species as *baezai*, *hodgkini*, *roperi* and *whartoni* have been collected in that area; however, additional collections are needed from that area of Thailand to confirm this pattern. Further support for the correlation of the wet forest type vegetation with the Group II species is found in peninsular Thailand. The Group II species in southern Thailand generally extend up further into Thailand on the west side of the peninsula, than on the east side. In fact, 7 members of Group II (*baezai*, *hodgkini*, *montanus*, *palmatus*, *roperi*, *sintonoides* and *stricklandi*) have been collected in Ranong, the most northern Thailand province on the west side of the peninsula. Ranong has large tracts of tropical wet forest and records the highest annual precipitation of any province in Thailand. In addition, this province is adjacent to the southernmost extension of Burma, suggesting the possible extension of some of the Group II species into that country.

At present, no satisfactory explanation is available to completely clarify the faunal shift which occurs in the vicinity of the Thai-Malaysian border. Although climatic factors can apparently be correlated with some of the species, this explanation cannot be used in interpreting the disappearance of some of the *Cellia* species in Peninsular Malaysia and then their reappearance in Malaysia or Indonesia. The geological history of this area is complex, and there is no doubt that the main elements of the Sunda Platform (Peninsular Malaysia, Java, Borneo and Sumatra) formed a single land mass, broadly connected with Thailand and the other continental area of Southeast Asia in relatively recent times. For additional data the reader is referred to Dobby (1950) and to Zeuner (1941).

Format and Treatment

The format followed here is essentially the same as that followed in earlier publications of the Southeast Asia Mosquito Project (SEAMP). The synonymy has been abbreviated, and only the more important entries have been listed. For a more complete synonymy for a particular taxon the reader should consult Stone, Knight and Starcke (1959) and the additions and corrections to that work by Stone (1961, 1963, 1967, 1970). Additional detailed synonymy for most species included in the present work will also be found in Reid (1968) and Christophers (1933). Within the parentheses following each citation, the symbols ♂, ♀, P, L, and E indicate that the publication deals with at least some part of the male, female, pupa, larva or egg respectively; a single asterisk (*) following the symbol indicates that at least some portion of the stage was illustrated. Abbreviations for references conform to the BIOSIS 1972 List of Serials, BioSciences Information Service of Biological Abstracts, Philadelphia.

The synonymy is followed by a diagnosis, each species is described in some detail, starting with the female, followed in order by the male, pupa and larva. The egg stage has not been used routinely in this publication, but it may be referred to in some cases to illustrate a particular point. For the most part the morphological terminology employed follows Belkin (1962), particularly as concerns the setal numbers for larval and pupal stages. Additional terminology, where applicable, follows Knight (1971) and Knight and Laffoon (1971) and also draws heavily upon Reid (1968).

Each species is usually accompanied by at least 3 plates illustrating the adult, pupal and larval stages. Most of the figures follow an identical format, but in some cases additional drawings have been provided to illustrate special morphological features. Almost all of the drawings are based upon several

specimens selected from Thailand collections. In the very few cases where extra-territorial specimens were used that fact is noted.

Wherever possible the 1st figure for each species consists of: a drawing of the female, with left wing and legs removed; the male terminalia as they appear in the usual microscopic preparation, prepared as a phantom view, to show the relationships of the various parts; an enlarged drawing of the claspette; an enlarged drawing of half the leaflets at the tip of the aedeagus; and a dorsal view of the male head, with the antennal flagellae removed and the left maxillary palpus turned to show the lateral aspect.

The 2nd drawing of the typical set of figures consists of the pupal skin and a map showing the approximate known distribution of the species in Thailand. The pupal cephalothorax is shown dissected, with only the left side shown, including the respiratory trumpet, but excluding the major portion of the wing case and the tubular portions of the cases of the appendages. The metathorax is shown attached to the abdomen, and it and the abdominal segments are prepared showing the dorsal setae on the left side of the drawing, the ventral setae and structures on the right. The letter C is used to designate the metathorax in this drawing and Roman numerals are used to designate the abdominal segments.

The 3rd drawing of most sets consists of: the larval head, with dorsal structures on the left, ventral structures on the right; the thorax and first 6 abdominal segments, with dorsal and ventral structures treated as in the head drawing; a lateral view of the terminal abdominal segments; the mental plate; and, in some cases the aulaeum or other detailed structures.

The letters P, M and T designate the prothorax, mesothorax and metathorax respectively, and Roman numerals are used to designate the abdominal segments.

A scale line has been provided with most figures of each stage to permit assessment of relative sizes among the various species.

The species descriptions are followed by a listing of the type-data for the species in question, and for other names listed in the synonymy.

The distribution section discusses the distribution of the species in Thailand based on specimens examined, followed by a synopsis of the distribution elsewhere in Southeast Asia. Species distribution records listed in Scanlon et al. (1968) were based on specimens identified prior to this revisionary study, and have been changed or corrected as necessary during this study. The Thailand records are based on such a large volume of material in most cases (often several hundred reared specimens) that it has seemed most suitable to give them by administrative province only. In a few cases, with rare species, specific collection data have been provided. The records from outside Thailand are by country and in some cases major political subdivision. Distributional citations from outside Southeast Asia were used only when necessary to illustrate a particular point. Specimens in the USNM collection or other collections examined during this study are so indicated, and separated from citations based only on the literature. In discussions in the body of the text we have frequently used geographic terms which have not survived the political vicissitudes of recent years, but which are well known to biologists and zoogeographers (e.g. Malaya, Borneo and Indochina).

Morphology

Figures 2 - 4 are included as a guide to the most commonly used morphological features of the various stages discussed. The figures are intentionally brief and confined to external characters. Specifics about frequently used char-

Figure 2. *Anopheles (A.) sinensis*. Lateral view to illustrate selected morphological features.

A. Female:
1. labium (proboscis)
2. labellum
3. maxillary palpus
4. clypeus scales
5. flagellomere
6. pedicel
7. vertex
8. occiput
9. anterior pronotum
10. propleural setae
11. upper midcoxal setae
12. halter
13. sternum VII scale tuft
14. cercus

B. Male:
1. labium (proboscis)
2. maxillary palpus, segment 4
3. flagellomere 12
4. pedicel
5. anterior promontory of scutum
6. scutum
7. scutellum
8. hindcoxa
9. hindtrochanter
10. hindfemur
11. tergum III
12. sternum III
13. basimere
14. distimere

Fig. 2

ADULT MORPHOLOGY

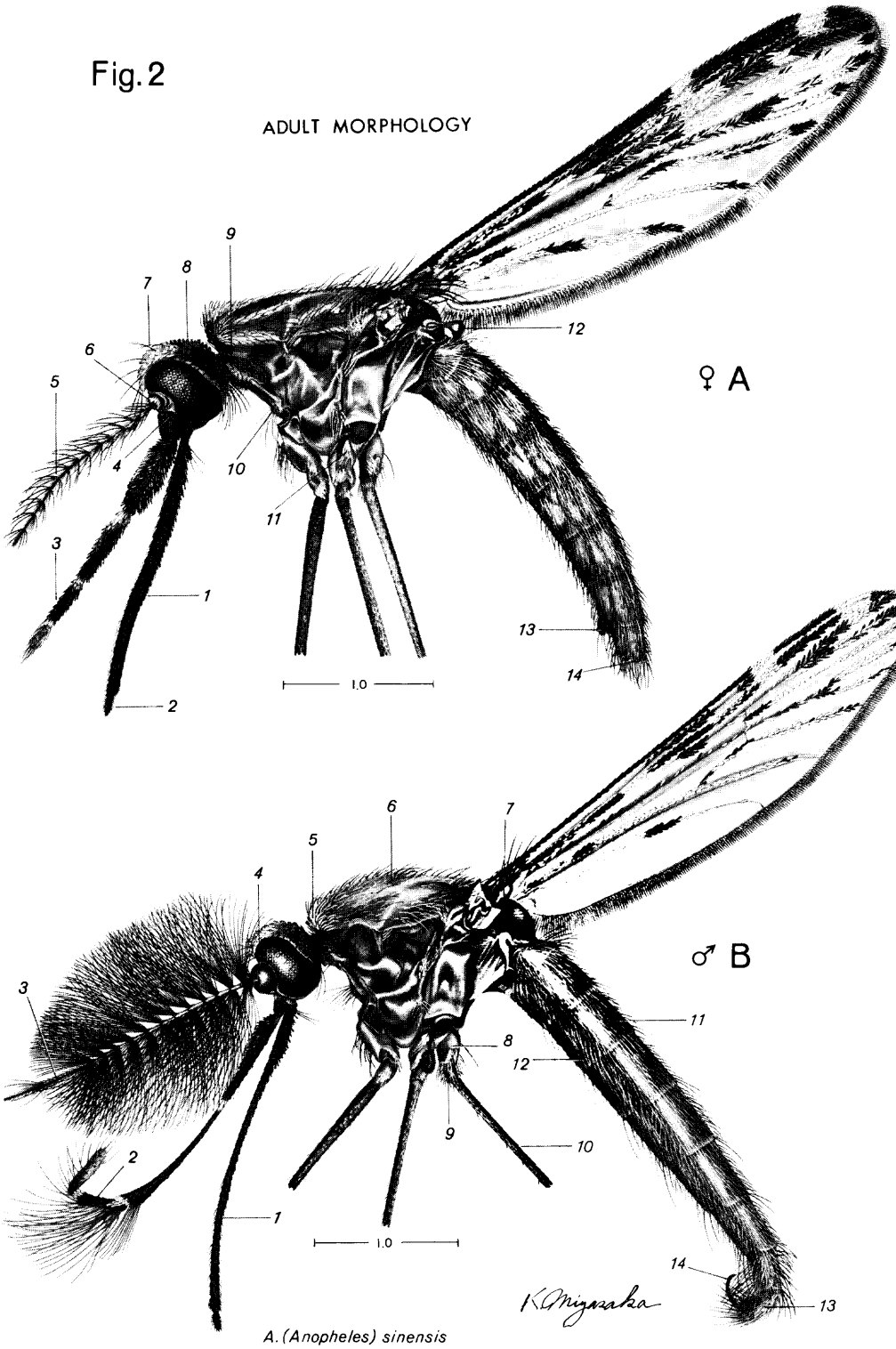


Figure 3. Adult morphology.

A. Wing of *Anopheles* species denuded of scales.

1. upper calypter (squama)
2. remigium
3. costa
4. vein R
5. subcosta
6. vein R_S (radial stem)
7. origin of R_{4+5}
8. crossvein r-m
9. vein R_{2+3}
10. vein R_2
11. vein R_3
12. vein R_1
13. vein R_{4+5}
14. vein M_{1+2}
15. vein M_{3+4}
16. vein Cu_1
17. vein M
18. vein Cu_2
19. crossvein M-Cu
20. plical fold
21. fringe scales
22. vein Cu
23. vein 1A
24. humeral crossvein

B. Wing, showing most useful costal spots.

1. inner prehumeral accessory dark spot
2. prehumeral pale spot
3. humeral pale spot
4. humeral dark spot
5. presector pale spot
6. presector dark spot
7. sector pale spot
8. middle dark spot
9. subcostal pale spot
10. preapical dark spot
11. preapical pale spot
12. apical dark spot
13. fringe spot 1A
14. accessory sector pale spot

C. Lateral view of female.

1. anterior promontory of scutum
2. anterior pronotal lobe
3. posterior pronotal lobe
4. anterior spiracle
5. prealar lobe
6. scutellum
7. halter
8. sternum I
9. metathoracic or posterior spiracle
10. mesepimeron
11. meron
12. sternopleuron
13. propleuron
14. vertex
15. occiput
16. upper mesepimeral setae

D. Dorsal view of thorax.

1. anterior promontory
2. anterior pronotum
3. fossa
4. scutal angle
5. lateral area
6. parascutellum
7. prescutellar area
8. scutellum

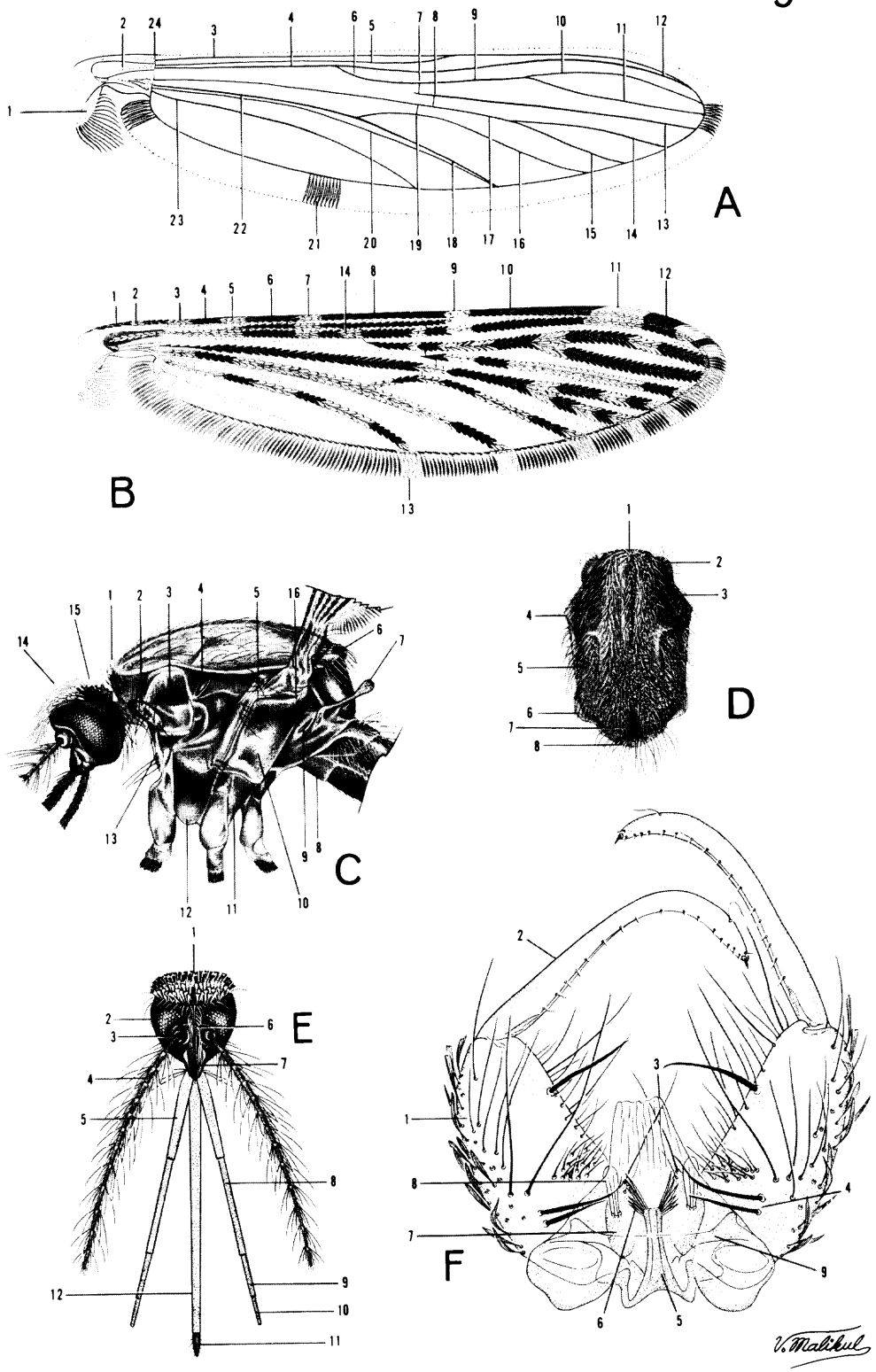
E. Female head, anterior view (scales of the maxillary palpi and proboscis removed).

1. erect scales of the vertex
2. compound eye
3. pedicel
4. 3rd flagellomere
5. segment 2, maxillary palpus
6. Frontal tuft
7. clypeus
8. segment 3 of maxillary palpus
9. segment 4 of maxillary palpus
10. segment 5 of maxillary palpus
11. labellum
12. labium

F. Male genitalia, ventral view (dorsal before rotation).

1. basimere
2. distimere
3. proctiger
4. parabasal spines
5. aedeagus
6. leaflets of aedeagus
7. claspette
8. club on claspette
9. tergum IX

Fig.3



Adult morphology

acters or characters that are exceptions to the rule are found in the following discussion. Readers desiring a more detailed exposition of anopheline morphology are referred to Christophers (1933), Gater (1934, 1935) and Reid (1968). Figures 2 - 3 deal specifically with various adult morphological characters, including the differentiating sex characters (antennae, maxillary palps and genitalia), while Fig. 4 deals with those basic characters pertinent in larval and pupal morphology. The following structures will be found the most useful during the examination of adults. *Head*: The degree of antennal development is a differentiating character between the sexes. Male anophelines typically have bushy (plumose) antennae. One exception is *acaci*, from Borneo and the Philippines, which has female-like antennae. Other than bushiness, both sexes exhibit the same basic antennal structure (minute scape, large globular pedicel and 13 flagellar segments). The more basal flagellomeres may bear a few scales. The width of the erect scales on the vertex is a very useful character in the separation of species in the *Anopheles* series. The maxillary palps are 5 segmented (1st segment vestigial in females) and exhibit sexual differentiation in that the last 2 segments of the male palps are distinctly flattened and club shaped. Both sexes normally exhibit palps approximately equal in length to the proboscis; however, the female of *brevipalpis* from Malaysia exhibits palps approximately 0.75 the length of the proboscis (Reid 1968). The palps are typically covered with decumbent or erect scales and frequently exhibit color patterns which are very important in identification. The labium and labellum make up the discernable proboscis, which is covered with decumbent or erect, unicolorous scales in the Thailand members of the subgenus *Anopheles*. The clypeus is usually bare in anophelines; however, the presence of scales on the clypeus is an important identifying character of the *hyrcanus* species group. *Thorax*: When viewed from above, the thorax consists almost entirely of the expanded scutum of the 2nd thoracic segment. The coloration of the scutum and the occurrence, shape, arrangement and coloration of its scales and setae are important characters. The scutal color pattern generally fades fast and is of little value in the subgenus *Anopheles*; however, a distinct pattern is detectable on *umbrosus*. Generally the prescutellar space is bare, but the size and concentration of setae in the area is of importance in the *aitkenii* species group. The occurrence of scales on the anterior pronotal lobes is a valuable character used in separating the *Myzorhynchus* and *Lophoscelomyia* series from the groups of the *Anopheles* series found in Thailand. The occurrence and number of propleural setae is important in a number of cases. Pleural scaling and setation is less useful in anophelines than in culicines, but the occurrence of pleural scales and the number of setae on the prealar lobe and upper mesepimeron (subalar setae of Reid 1968) are significant in the subgenus *Anopheles*. *Wings*: Wing markings are extremely important in anopheline identification. A wing (Fig. 3) of a member of the subgenus *Anopheles* has been used to illustrate the occurrence and nomenclature of wing markings. The wings of members of the subgenus *Anopheles* generally exhibit much less spotting than those of subgenus *Cellia*; however, the nomenclature and position (when present) of the spots remains the same. The reader must take care when trying to determine wing color patterns, for the same vein may have different colored scales on the dorsal and ventral sides of the wing, thus giving a different pattern when viewed from each respective side. Such areas as the remigium and humeral crossvein and their respective scale patterns are highly significant and should be viewed under high magnification. The pale fringe spots at the terminations of some veins are often difficult to see without adjusting the lighting to favor transmitted or reflected light,

or a combination of both. In addition to the fringe scales, there is a line of tertiary fringe scales along the extreme wing margin which is rarely used in taxonomic works, but can serve as an indication of a fringe spot. Anopheline wing patterns are highly variable in some groups; consequently, one should anticipate intraspecific variation in making specific determinations.

Due to differences encountered in the relative position of the preapical pale costal spot, an arbitrary decision was made to define this spot as the one proximal to the tip of vein R_1. However, in the *umbrosus* group this spot usually ends level with the tip of R_1; and we have chosen to continue calling it the "preapical" spot, while Reid (1950, 1968) refers to this as an "apical" spot. In certain members of the *asiaticus* group only one pale spot occurs near the tip of the wing, in such cases this spot is called the apical pale spot even though it does begin slightly prior to the tip of R_1. Another member of the *asiaticus* group, *interruptus*, has an upper spot from just above the tip of R_1 down to R_2 and a lower spot adjacent to the tip of R_{4+5}. We interpret both of these spots as being apical, thus, members of the *asiaticus* group do not have a preapical pale spot on the leading margin of the wing. *Legs*: The occurrence and pattern of pale annulations on some of the leg segments (particularly the tarsomeres) are highly significant taxonomic characters in anophelines. These markings, like wing patterns, can be quite variable, thus caution is necessary in evaluating leg patterns. Other significant leg characters in the taxonomy of the subgenus *Anopheles* are the occurrence of scales on the base of coxae and the occurrence and coloration of erect scales on the apex of the hind femur. *Abdomen*: In most anopheline species the abdomen is devoid of scales, thus when present they are highly significant. Scattered scales on abdominal sterna are significant in the *barbirostris* species group, and the occurrence of a scale tuft on the 7th abdominal sternum is useful in identifying the *barbirostris* and *hyrcanus* species groups. Infrequently, the occurrence and coloration of scales on the male genitalia serve as useful characters. *Male Genitalia*: The genitalia of anophelines are not as useful in species differentiation as are those of most culicines; however, characters of subgeneric, series and in some cases, specific value, have been recognized in *Anopheles*. The parabasal spines, located on the morphologically dorsal surface of the large, conical basimere are used in subgeneric classification. The basimere bears other setae, and particularly scales which may be of specific significance. The apical distimere has not been found to furnish useful characters for identification. The structure and appendages of the claspette are important and may be readily seen in simple slide preparations of the intact genitalia. A club, composed of fused setae, is often present on the dorsal lobe of the claspette, and this may present quite a different appearance when the claspette is dissected and viewed from the lateral aspect. The claspette drawings made for the species herein were made with the claspette flat as in the usual dorsal or ventral aspect. The aedeagus is a tubular structure, but appears to be flat in the normal microscope preparation. In addition, this structure is usually strongly arched, as will be apparent in the following illustrations. The aedeagus itself is of little value in the taxonomy of the subgenus *Anopheles*, except in the case of the *aitkenii* species group where denticles on its tip are highly significant. The occurrence and number of paired leaflets found at the tip of the aedeagus are very important and are used in the differentiation of the series in the subgenus. In this study, these structures with the tip of the aedeagus were dissected free, stained and mounted as flat as possible on a slide. The appearance of the leaflets prepared thus is quite different than that normally seen in whole genitalia mounts. *Female Genitalia*: Genitalia preparations were made for most of the

included species, but few useful characters were found. *Cibarial Armature*: This internal structure, examined briefly during this study, was used by Christophers (1933) and others in defining species groups in the subgenus *Cellia*. The armature has been found to be of little use in separating the species of the subgenus *Anopheles*, except in the case of certain members of the *umbrosus* species group (Reid 1968). For literature pertinent to this subject the reader is referred to Christophers (1933), Gater (1935) and Reid (1968).

While whole mounted larvae have been used in anopheline taxonomy for years, the practice of mounting whole pupae never became popular, mainly because of difficulties encountered in mounting the bulky body. Early workers frequently assigned and described a given larva to a given adult on the basis of whole mounted larvae and reared adults from the same collection. Certainly, this method has led to errors and much taxonomic confusion. During the last 25 years taxonomists have become much more aware of the value of correlating cast immature skins with the resulting imago for increased taxonomic proficiency. During this period a general (not total) concensus has evolved on the nomenclature and general homology of the chaetotaxy of the larval and pupal stages. With these problems essentially resolved, the taxonomy of anophelines has been enhanced by the study of the respective immature skins. Now, pupal chaetotaxy is as important in anopheline taxonomy as the study of the adult, larvae or egg. In fact, the pupal stages of some members of the subgenus *Anopheles* possess the most reliable differentiating characters at the species level.

As mentioned earlier, the chaetotaxy and nomenclature used herein primarily follows Belkin (1962) and Reid (1968). For explanations and the differences between the various systems the reader is referred to the above references as well as Knight (1971). *Pupa*: The following pupal illustrations (Fig. 4, A - D) are basic and designed to point out body regions and structures (not chaetotaxy) that will hereafter be presumed known by the reader. The illustrations were prepared from mounted skins, in which the head and thorax (minus the metathorax) was opened along the midline and flattened (Fig. 4A), while Fig. 4B, depicts the metathorax and abdomen. On the head the pigmentation pattern of the antennal case can be of specific value in the *hyrcanus* group. The most frequently used thoracic characters involve the paired respiratory trumpets which furnish series, specific and infraspecific characters. Two basic types of trumpets are found in the subgenus *Anopheles*. (A) Angusticorn (Fig. 81): Simple and tubular, having the longest axis vertical, more or less in line with the stem of the trumpet, and with a single split (cleft) or notch of varying depth on one side. (B) Laticorn (Fig. 11): More complex, with longest axis more or less transverse to the stem, the rim sometimes with a second split opposite the meatal cleft, or if longest axis not transverse to stem, then there is a lobe, often complex on the rim. Members of the subgenus *Cellia* have only the angusticorn type trumpet, while the majority of the species of the subgenus *Anopheles* in Thailand have some variation of the laticorn type. The occurrence and patterns of pigmentation on the wing cases is of value in the *hyrcanus* group. Most abdominal (including metathorax) characters involve chaetotaxy patterns, however, some general morphological characters are pertinent. On the venter of the 1st abdominal segment is a pair of spiracular sensillae, while on segments II - VII these spiracular sensillae are located dorso-laterally. Additional pairs of dorsal sensillae are found on segments III - V. These spiracular and dorsal sensillae are sometimes easily confused (particularly the dorsal sensillae) with setal alveoli. The occurrence of small denticles on the hind margin of the abdominal tergites is of value in identifying *montanus* and most of the members of the *umbrosus* group. Sexual differentiation of the pupal stage

is possible by determining the length of the genital lobe, which is located at the posterior end of the abdomen and ventral to the paddles. The male (Fig. 4C) has a longer genital lobe than the female (Fig. 4D). In the *hyrcanus* species group, the sexes can also be differentiated in the pupal stage by the shape of the palpal case (Figs. 11, 14). The male has the tip of this structure long and narrow, while it is short and broad on the female. The value of characters found on the paired paddles cannot be overstressed. Their shape (length-width relationship) can be highly significant, as can be the occurrence and pattern of pigmentation on these structures. The outer paddle margin has a basal area of minute denticles which presents a refractory appearance in transmitted light. These structures tend to become larger and more tooth-like toward the apex and then give way abruptly or gradually to filamentous hair-like structures. The relative proportion of the paddle margin occupied by either one or both types of structures that is refractory to light is called the refractory index, measured (following Reid) in a straight line from the base of the paddle to the end of the refractile area, divided by the length from the base of the paddle to the base of the paddle hair (1-P). The long filamentous structures on the outer margin of the paddles are generally referred to as the paddle fringe. The concentration and length of the fringe is often of taxonomic significance.

The larval drawings accompanying the species descriptions were prepared from 4th stage larvae, slide mounted dorsal side up, with the terminal abdominal segments cut and placed laterally to display the setae and pecten. Where possible, larvae were from the same series in which larval skins had been compared with pupal skins and imagos to assure correct identification.

Larva: The characters most frequently utilized in anopheline larval taxonomy involve chaetotaxy arrangement and degree of branching. Both of these aspects of chaetotaxy are subject to variation and this variation will be encountered by workers in the field; consequently, previous studies should be consulted where the range of inter-intraspecific variation has been documented for a species or group (see Reid 1953). Of the head chaetotaxy, 2, 3 and 4-C in the Belkin system (the inner, outer and posterior clypeal setae) are probably the most pertinent. Also important are 5 to 7C (the frontals) 8-C (the inner sutural) and 9-C (the outer sutural). The remaining dorsal and ventral setae are used infrequently. The ventral mental plate is strongly sclerotized and pigmented and can be taxonomically significant. The thoracic and abdominal chaetotaxy is also highly significant. Such setae as 1-P, 14-P, 1-M and the pleural setal groups of the thorax are used frequently in taxonomy. The extent of sclerotization of basal tubercles can be significant, as can be color patterns, however, color patterns are most often used with living larvae. The occurrence, distribution and extent of development of palmate setae is highly significant. A palmate seta is one in which the branches have undergone various degrees of flattening and pigmentation. These setae are typically located on some or all of the abdominal segments except the 8th and 10th, but may also be found on the metathorax. Setae 1 of the prothorax and mesothorax frequently exhibit a fan-like shape, but are not considered palmate setae. On the abdomen the chaetotaxy of segment I is reduced and somewhat unusual, that of segments II - VII is similar in overall pattern while segment VIII exhibits a highly modified setal pattern. Aside from the spiracular apparatus (Fig. 4J), segment VIII also bears the lateral pecten plate, which is sclerotized and has caudally directed teeth. The number and conformation of the pecten teeth may be of taxonomic importance in some species groups. Each of the abdominal segments usually bears at least one sclerotized dorsal (tergal) plate, and frequently 2. The size of the anterior tergal plate can be very significant (see *palmatus*, in

Figure 4. Larval and pupal morphology.

A. Pupal cephalothorax (less metanotum).

1. head shield
2. trumpet
3. mouthpart cases
4. antenna case
5. leg cases
6. wing case

B. Pupal metathorax and abdomen.

1. metanotum
2. ventral spiracular sensillum
3. float seta
4. halter case
5. dorsal sensillum
6. seta 9-VI
7. paddle
8. dorsal spiracular sensillum

C. Terminal portion of male anopheline pupa (dorsal).

1. genital lobe
2. midrib
3. seta 1-P

D. Terminal portion of female anopheline pupa (dorsal).

1. genital lobe
2. hair-like paddle fringe

E. Head of anopheline larva (ventral).

1. mouth brushes
2. mental plate
3. labial plate
4. ocular bulge
5. collar

F. Tip of larval antenna (dorsal).

1. dorsal sabre piece
2. seta 4-A

G. Terminal segments of larval abdomen (lateral).

1. median dorsal valve
2. dorsolateral valve
3. ventrolateral valve
4. pecten plate
5. saddle
6. anal gill

H. Thorax (dorsal, left; ventral, right).

1. prothoracic group of pleural setae
2. mesothoracic group
3. metathoracic group
4. metathoracic palmate seta

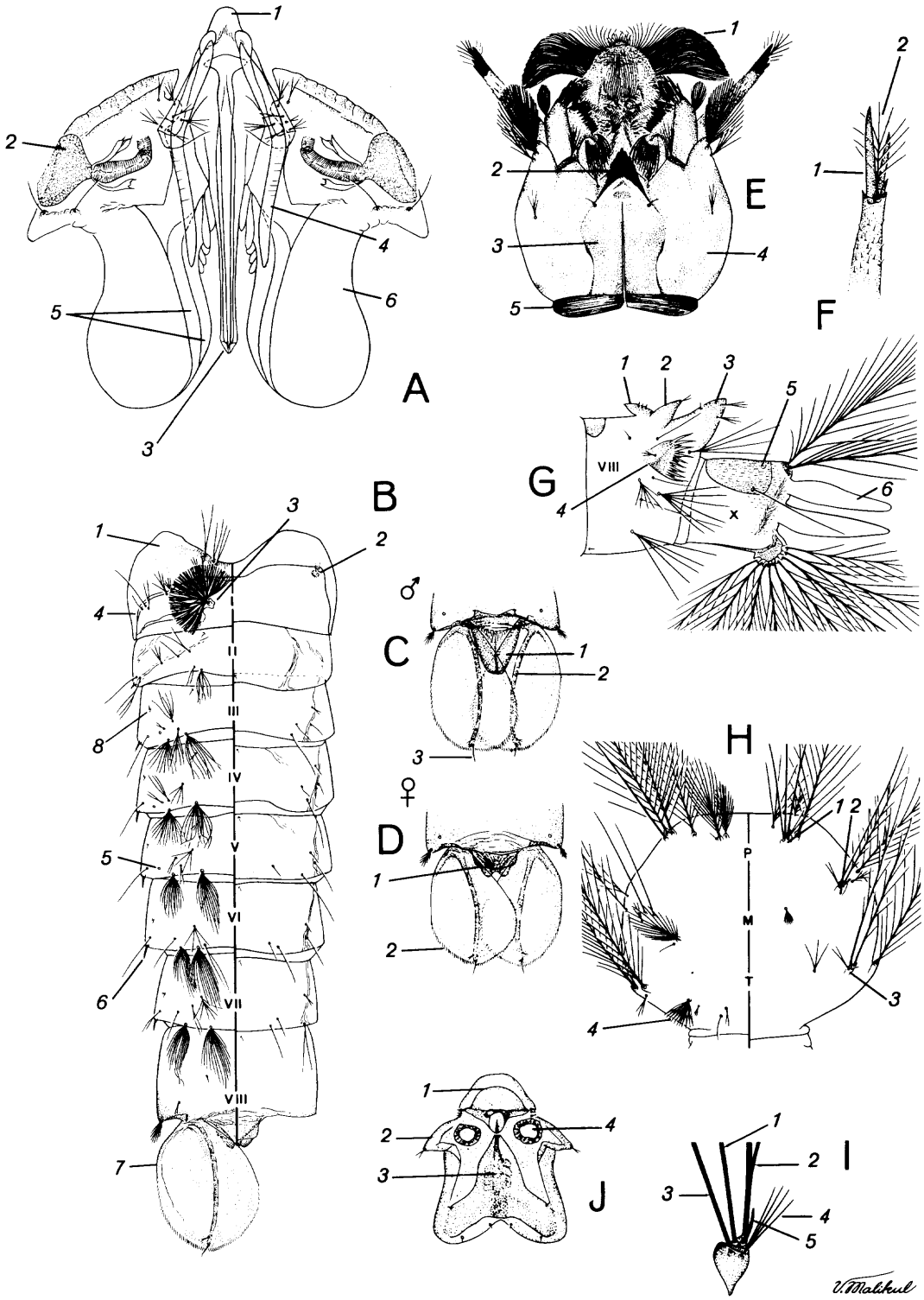
I. Prothoracic pleural setal group (left side, ventral view).

1. seta 10-P
2. seta 9-P
3. seta 12-P
4. seta 11-P
5. spine separating anterior (9 - 10) and posterior (11 - 12) pairs of setae.

J. Spiracular apparatus (ventral).

1. median dorsal valve
2. dorsolateral valve
3. ventrolateral valve
4. spiracle

Fig. 4



Larval and pupal morphology

the *aitkenii* group). The larvae of *montanus*, members of the *umbrosus* group and infrequent specimens in the *barbirostris* and *hyrcanus* groups, have a small ventral plate immediately in front of 14-VIII. For convenience, this plate has been illustrated here on segment VIII. Puri (1931) originally noted this plate and placed it at the caudal margin of segment VII. This interpretation was followed by Reid (1950, 1968), but Belkin (1962) and Zavortink (1973) have shown this plate on the cephalic margin of segment VIII. We have examined a large number of larvae with this character from both the lateral and ventral views, and suspect this plate is actually intersegmental as is so-called seta 14-VIII and seta 14 on the more anterior segments. Occasionally numerous tiny spicules may be noted, particularly on the venter of some of the abdominal segments. These have been noted occasionally by various authors, even used as taxonomic characters. However, their significance is not understood and they are best disregarded (except for *sintonoides*), particularly since their occurrence is not consistent. Such structures may be correlated to an environmental factor such as the hairiness factor found in *Aedes* larvae (Colless 1956). The terminal or anal segment, regarded as segment X by morphologists, bears a dorsal plate (saddle), setae and gills, but is seldom used in the taxonomy of southeast Asian *Anopheles*. The spiracular apparatus follows the same basic plan in almost all the species described herein. The anterior median dorsal valve normally has a small transparent knob caudally, but this extends into a posterior "stigmal club" on *pollicaris*, a pigmented "stigmal knob" on *tigertti* and members of the *culiciformis* group and a "stigmal filament" on *umbrosus*. The only similar structure found in Asian *Anopheles* is found in the *bancrofti* group of Australia, New Guinea, Philippines and Celebes and in *atratipes* Skuse, an Australian species currently placed in the *Anopheles* series.

Egg. The egg stage has proved extremely useful in delimiting species in the *maculipennis* species group in the Palaearctic region. Eggs of many of the anophelines found in Thailand have been described to some extent, largely from India (Christophers 1931, 1933), Ceylon (D'Abrera 1944), the Philippines (Urbino 1936) and Malaya (Reid 1968). Nevertheless, it should be noted that the eggs of at least 10 of the following species are unknown and studies are needed on anopheline eggs in Southeast Asia to help unravel the taxonomy of some of the species complexes. Insufficient material was available to illustrate the eggs of the Thailand species, but reference is made to the descriptions given by the foregoing authors where applicable. *Aberrant or unusual specimens*: In the course of field work occasional specimens are found which exhibit unusual characters or an unusual arrangement of characters. On rare occasions in the past such specimens have been mistakenly identified as new species, thus creating problems. Hopefully, with the aid of the recent outline of the genetic mutants found in anophelines, (Kitzmiller and Mason 1967) modern workers will recognize such aberrations for what they are and confirm the existence of some of these inherited variations in wild populations. Such unusual characters as melanistic wing scale patterns and anomalies in the tergal plate pattern and chaetotaxy of larvae and/or pupae were observed during this study. The foregoing case of melanistic wing scale pattern presented a completely unidentifiable adult, fortunately, associated immature skins were available to clarify its identity. Another unusual character exists in the male of *acaci*, which exhibits female-like antennae. Although this species is currently known only from Borneo and the Philippines, the close relationship of *acaci* to some of the Thailand *aitkenii* group species warrants further study.

To many workers keys are the most important results of such efforts as this, and when the identity of vectors of pathogens is in question this may well

be true. However, keys are only working tools and all persons concerned should realize the fallibility of keys in view of total population concepts and the previously mentioned aberrant specimens. This is particularly true in view of the recent recognition of many cryptic species and sibling groups among the mosquitoes. In essence, the identity of some species can only be ascertained by ethological characters, or the association of immature skins with the adult e.g., *barbirostris* and *campestris*. Unfortunately, such time consuming identification techniques are not always feasible when a medical entomologist is confronted with a mosquito-borne disease epidemic. In such situations the use of the word "group" is often advantageous (i.e., *barbirostris* group, *hyrcanus* group, etc.). This liberal approach to taxonomic identifications should be used only during medically or economically urgent situations. Under routine situations workers who are not taxonomically oriented or lack an associated taxonomic capability can send specimens or series of specimens to specialists for verification.

The keys used herein are artificial, designed primarily for reliability and time conservation, and should not be construed to indicate relationships, even though such may be the case. The authors have followed the system of arrangement used by Reid (1968), where the keys are located with the given series or species group. This arrangement allows the user to quickly turn to the descriptions and taxonomic discussions for confirmation or help. Some entirely new keys are presented, but most are adaptations in one fashion or another of earlier Reid keys, which have been altered to fit the Thai fauna or the desires of the authors. Footnotes have been added to certain couplets to indicate possible problem areas or alternate solutions.

Certain species considered doubtful records for Thailand by Scanlon et al. (1968), are disregarded in this publication. Accordingly, the keys have been altered to exclude those species (*gigas formosus* and *gigas sumatrana*).

Taxonomy

The subfamily Anophelinae may be defined as those mosquitoes species in which: 1) the adult exhibits no scales or very few scales on the abdomen, particularly on the sterna; the female maxillary palps are approximately as long as the proboscis; the female has only one spermatheca; and the males have the 2 terminal segments of the maxillary palps enlarged to form a distinct club. 2) the pupa has seta 9 on abdominal segments III - VI single, spine-like and located in the latero-caudal corners; and the tip of the paddle has a pair of setae, one of which is ventral and subapical. 3) the larva differs from all other mosquitoes by the absence of a well developed and sclerotized respiratory tube, and have the spiracles opening from a spiracular plate on segment VIII.

Three genera are presently recognized in the subfamily, *Chagasia* Cruz, *Bironella* Theobald and *Anopheles* Meigen. The 1st of these is found only in the Neotropical Region, the 2nd only in the Australian. We deal here only with the genus *Anopheles*, which is widely distributed in the tropical and temperate areas of the world.

GENUS *ANOPHELES* MEIGEN

Anopheles Meigen 1818: 10. Logotype: *Anopheles maculipennis* Meigen (International Commission on Zoological Nomenclature 1959).

(The synonymy for the genus as here recognized is given in detail by Stone, Knight and Starcke 1959, under the appropriate subgenera).

Readily distinguished from other mosquitoes in Asia by the following combination of characters: *Female*. Palps at least 0.75 the length of the proboscis; scutellum rounded; abdominal scaling usually poorly developed; one spermatheca. *Male*. Segments 4 and 5 of the maxillary palpus developed as a club, directed laterally. *Larva*. Lacks a respiratory tube, the spiracles opening on the body wall of segment VIII. *Pupa*. Paddle undivided, or slightly invaginated, seta 9 of the abdominal segments spine-like on IV - VII. In addition, the adults may usually be recognized in life by their resting attitude, usually forming an acute to right angle with the surface, the larvae also have a characteristic attitude, resting parallel with the surface with the palmate setae of the abdomen in contact with the surface film.

A more comprehensive description is as follows:

FEMALE *Head*. Eyes widely separated, several long setae usually projecting forward between them forming frontal tuft of erect setae and scale-like setae; head scales of several types, scales of occiput and vertex erect, fan-shaped and often apically notched; interocular space up to vertex with ocular scales and line of ocular setae internal to scales; ocular line without scales laterally and ventrally; antenna with rounded pedicel, lacking protuberances, often with small number of scales, flagellomeres with whorls of sparse setae, without matted setae or other modifications, but basal segments may have flattened scales; clypeus sometimes with scales; maxillary palpus generally as long as proboscis or at least 0.75, that length, with 5 segments, basal segment minute; proboscis covered with scales, scales decumbent or erect, labium flexible, sometimes with slender setae ventrally and near tip, labellum without scales, generally lighter in color than labium; ventral area of head with tuft of postgenal setae; neck supported by long cervical sclerites. *Thorax*. Scutum elongate, slightly convex, often with distinct lines in median and submedian areas, may have covering of minute setae, sometimes with well developed dorsocentral and acrostichal setae; anterior promontory often with a well developed scale tuft, sometimes with additional antero-lateral tufts; scutellum without lobes, with fairly evenly spaced setae and sometimes scales; anterior pronotum (apn) with setae, sometimes with scales; posterior pronotum (ppn) bare; propleuron (ppl) usually with 1 - 5 setae, sometimes bare; spiracular area (sp) with or without setae; sternopleuron (stp) with upper and lower setal groups; upper mesepimeron (mep) with setae, lower mesepimeron usually bare. *Wing*. With well developed usually pale and dark decumbent and plume scales, fringe scales present; cell R_2 at least as long as vein R_{2+3}; vein R_3 always connected to R_{2+3} at the base; vein 1A reaching the wing margin distal to the origin of vein Cu_1. *Halter*. Stem usually pale, knob pale or dark scaled. *Legs*. Long, slender, without tibial bristles, pulvillus absent, claws usually simple, base of femur sometimes markedly swollen. *Abdomen*. Generally without scales, or with these usually restricted to ventral tufts. *Genitalia*. Single spermatheca; tergum and sternum VIII truncate or broadly rounded; tergum IX a narrow band; tergum X semicircular, covering cerci; cerci truncated cones, bluntly pointed, may have setae.

MALE. Similar to female in general habitus, usually smaller and slight in general appearance. *Head*. Pedicel larger, partially obscuring clypeus, without scales; flagellomeres with strongly plumose setal whorls except for 2 most distal segments; palpus about as long as proboscis, 4th and 5th segments slightly or conspicuously swollen, turned laterally in life, with long hairs at apex of 3rd segment and on margins of 4th and 5th segments. *Thorax*. Markings similar to those of female. *Wing*. Usually more narrow than that of female, markings similar, but with fewer scales and paler, with fewer dark areas in species with

bicolored wings. *Legs*. Markings usually less vivid than on female, foretarsomere 5 longer than, or at least equal to foretarsomere 4 and bearing a basal protuberance with setae, claw with submedian and sometimes basal teeth; tarsomeres 4 - 5 and claws of remaining legs like those of female. *Abdomen*. With fewer scales than female, except on the basimeres. *Genitalia*. Tergum and sternum IX forming complete ring at base of basimeres; basimere simple, without lobes, with one or more groups of specialized setae or spines; distimere simple, tubular, with apical spine and several small setae; claspette well developed, with one to 4 lobes and associated setae; aedeagus simple, tubular, with or without apical leaflets or spines; proctiger largely membranous, with lateral thickening on some species, generally without taxonomically useful characters.

PUPA. *Cephalothorax*. With 9 pairs of setae, 1 to 3-C in ocular group near midline, 4 and 5-C more anterior and lateral, 6 and 7-C posterior to 4 and 5-C and 8 and 9-C posterior to trumpet; trumpet open and with margin bearing at least one cleft of varying width and depth. Abdomen. For typical setation see Fig. 6, numbered according to the Belkin (1962) system; seta 9 (lateral seta) simple, spinelike, inserted on posterior corners of segments II - VII, usually with branches on segment VIII; seta 3-VI mesad of 1-VI except in umbrosus group. *Paddle*. Oval in outline, external buttresses and midrib distinct; both margins usually with more or less distinct fringes of fine spines on distal portions, often with smaller hyaline denticles near base; seta 1-P terminal, straight or markedly hooked, 2-P ventral and cephalad of 1-P.

LARVA. Integument usually glabrous, but may bear simple to elaborate spicules covering most of thorax and abdomen. *Head*. Generally longer than wide, without marked concavity posterior to antennae. Mouthparts not highly modified, mental plate and aulaua developed; setae 0 and 1-C inserted on preclypeal area; 2 and 3-C (inner and outer anterior clypeals) well developed; 4-C (posterior clypeal) smaller than 2 and 3-C in most species; 5 to 7-C (frontals) usually strong, feathered, inserted in irregular line; 11-C (subantennal) large, plumose; antenna short, simple, with variously developed spicules; seta 1-A simple or branched, inserted in basal 0.5; 2 and 3-A spiniform, sabre-like, 4-A usually branched. *Thorax*. Setae 1 to 3-P near midline, usually separate, sometimes with common base; pleural setal groups (9 - 12) well developed on all 3 thoracic areas; seta 1-M often strongly developed, plumose; seta 3-T often developed as palmate seta. *Abdomen*. Anterior tergal plates varying in size, on segments I - VII smaller single or paired plates may occur posterior to the main plate on some species; seta 1 frequently developed as palmate on most abdominal segments, but filamentous on all segments in some Asian species; lateral setae (6 - 7) strongly developed on segments I - II, seta 6 strongly developed on segment III and variously developed on segments IV - VI; segment VIII with dorsal spiracular apparatus and paired lateral pecten plates; segment X with sclerotized saddle, not complete on ventral aspect, saddle seta (1-X) simple or branched; setae 2 and 3-X plumose, 3-X usually stout and hooked distally; 4-X consists of 9 pairs of setae arising from sclerotized grid.

DISTRIBUTION. Species of the genus *Anopheles* occur in temperate, subtropical and tropical regions of the world, with the exception of island groups in the Pacific and isolated islands in the Atlantic. The arctic areas are free of *Anopheles*, even at latitudes where certain *Aedes* species are abundant. Southeast Asia has a rich and varied anopheline fauna at the species level, and no reasonably large island or portion of the mainland is without representative species. It is possible that some of the higher mountains in the area have a

poor representation of the genus, but little collecting has been done at higher altitudes.

TAXONOMIC DISCUSSION. The genus *Anopheles* is probably the most thoroughly studied genus in the family Culicidae, primarily because of the importance of its species as vectors of human malaria parasites. The intense early interest of a host of workers, many relatively untrained in taxonomy, gave rise to a multiplicity of specific and generic synonyms. Edwards (1932) brought considerable and lasting order out of this chaos, uniting all of the forms covered by the description given above in the genus *Anopheles*, with 4 subgenera, and a number of groupings of species below the subgeneric level. The system adopted here (Stone, Knight and Starcke 1959) follows Edwards' revision rather closely, and recognizes the following subgenera: *Stethomyia* Theobald; *Anopheles* Meigen; *Nyssorhynchus* Blanchard; *Kerteszia* Theobald; *Lophopodomyia* Antunes; and *Cellia* Theobald. The subgenera *Anopheles* and *Cellia* occur in Thailand and only the former is considered here.

The subgeneric classification of *Anopheles* is based primarily on the number and position of the parabasal spines on the basimere of the male genitalia (Edwards 1932; Christophers 1933), but for the 2 subgenera found in Thailand there are a number of other satisfactory criteria which are outlined in the keys below.

Most workers regard the genus *Anopheles* as the most primitive in the Culicidae, but Belkin (1962) believes that they are highly specialized and not ancestral to other groups in the family. In the absence of significant fossil records for the mosquitoes it is difficult to assess this question and it is beyond the realm of this study.

BIOLOGY. The overwhelming majority of *Anopheles* species have their immature stages in various types of ground water, ranging from water-filled animal footprints to running stream margins and the margins of lakes and marshes. Southeast Asia has a particularly rich fauna of treehole and bamboo breeding *Anopheles* species; but apparently there are few axil breeding species, such as those found in the Bromeliaceae of the New World. One Thailand species, *tigertti* passes its immature stages in the holes dug by fresh water crabs. Further collections may reveal more species in this habitat. The greatest numbers of anopheline larvae are found in the broad rice producing areas of Thailand, but even quite small water bodies can hold an amazing number of larvae.

Generally, anopheline larvae require relatively clean water for development, but some species, like *barbirostris* are found in highly polluted water near human habitation. Most species are found in still or very slightly moving water, but *aberrans* and *bengalensis* are found in the eddies of small hill streams. Again, most species are restricted to fresh water, but *baezai* is usually found in brackish water along the coast. In summary, almost any body of water within the confines of Thailand may be expected to yield some *Anopheles* species if examined in sufficient detail.

As far as known, the larvae of all the *Anopheles* species in Thailand are filter feeders, lying parallel with the surface with the head rotated so that the morphologically ventral surfaces lie in contact with the surface film. The mouthbrushes are in constant movement to bring small floating or suspended particles into reach. Limited observations on the treehole breeding species in Thailand indicate that the larvae behave in the same manner in these limited confines. Unlike the immature stages of some other treehole inhabiting species in *Anopheles* or other genera, there is little evidence that the larvae of the species in Thailand have developed a predatory feeding habit.

The female anophelines of Thailand appear to feed on mammal and bird blood, with the former predominating. The feeding habits of many of the forest-inhabiting species (e.g., *aberrans*, *asiaticus* and *insulaeflorum*) remain largely unknown. It is possible that some of these feed on common cold-blooded vertebrates in the country, but there is no evidence for this as yet. Many of the species discussed below can be collected resting by day in houses and other structures, but many species occur in Thailand which are rarely, if ever, encountered in artificial resting places. *Anopheles* adult mating and feeding activity is almost entirely restricted to the hours of greatly reduced light, or darkness. The females of some forest species (*umbrosus* group) will take a blood meal during the day, under heavy forest shade.

In Thailand, members of the genus *Anopheles* are vectors of human and simian malaria and filarial parasites. They have not been implicated in the transmission of viral diseases, but isolation efforts along these lines should be attempted, particularly in view of the virus-*Anopheles* relationships discovered in Africa during the last 15 years.

KEY TO THE SUBGENERA OF *ANOPHELES* IN THAILAND

ADULTS AND IMMATURE STAGES

Costa entirely dark scaled, or divided by pale spots into not more than 3 dark marks involving both veins C and R-R_1; male basimere with 3 spines (2 parabasal and 1 internal), the inner most parabasal shorter and stouter than the outer; larval seta 1-A branched (except in several species with seta 5, 6, 7-C reduced); setae 2-C inserted close together, closer (rarely equal) than distance between 2-C and 3-C on either side; male pupae with end of genital lobe obtuse, without pair of knobs; pupal seta 1-P usually short and straight. . . . . *Anopheles*

Costa divided by pale spots into 4 or more dark marks involving both veins C and R-R_1; male basimere with cluster of 4 - 5 parabasal spines, no internal spine; seta 1-A simple; setae 2-C inserted at least as far apart as the distance between 2-C and 3-C on either side; genital lobe on male pupae with a pair of rounded points or knobs on apex; pupal seta 1-P usually long and hooked or curved. . . . . *Cellia*

SUBGENUS *ANOPHELES* MEIGEN

Anopheles Meigen 1818: 10. Logotype: *Anopheles maculipennis* (International Commission on Zoological Nomenclature 1959). Christophers 1915: 383.

(For detailed synonymy see Stone, Knight and Starcke 1959; Stone 1961, 1963, 1967, 1970. The latest views on the classification of the subgenus are found in Reid and Knight 1961.)

In addition to the characters given in the above key, the following may assist in the correct subgeneric placement of the Thailand species.

FEMALE. Cibarium without teeth.

MALE. Basimere with at least the inner parabasal spine set on a distinct prominence.

PUPA. Laticorn and angusticorn type trumpets, members of the subgenus *Cellia* exhibit only the latter type.

LARVA. Setae of the 3 pleural groups generally all simple; branched antennal seta usually inserted on the inner aspect of the antennal shaft.

DISTRIBUTION. Species of subgenus *Anopheles* are widespread in both the New and Old World, with the numbers of species in each area roughly similar. In Thailand, more species of the subgenus were collected in the southern portion of the country and areas with tropical wet forests than in other areas, but large numbers of individuals of species in the *hyrcanus* and *barbirostris* groups were found throughout the country.

TAXONOMIC DISCUSSION. It is generally accepted that the subgenus *Anopheles* is more primitive than *Cellia*. Reid (1968) has discussed the relationships among species groups in the subgenus, and with species of the subgenus *Cellia* in detail. A number of systems have been proposed to indicate the relationships among species of the subgenus (Christophers 1915; Edwards 1932) and we have followed the most recent of these (Reid and Knight 1961). Edwards (1932) used the infrasubgeneric categories "group" and "series"; but Reid and Knight wisely substituted the term "section" for group, since the latter term is now so widely used in connection with studies of sibling species aggregations.

Reid (1970) explained his usage of the terms "species-complex" and "species-group". The former refers to "suspected species of groups before they have been sufficiently analyzed to establish that the forms they contain are distinct species". The latter refers to those same species, but after their suspected identity has been established. We are following Reid (1968) who used the term "species-group" for the units covered herein, however, we feel that more cryptic species probably exist, and our understanding of these groups in terms of their components and distribution in the entire Oriental faunal region is still incomplete.

The infrasubgeneric catagories recognized and discussed here have no formal standing under the International Code of Zoological Nomenclature. They are convenience categories only, useful for highlighting the natural relationships among the species of the subgenus. The Reid and Knight (1961) classification system is as follows.

SUBGENUS *ANOPHELES* - LATICORN SECTION
Myzorhynchus Series
- ANGUSTICORN SECTION
Anopheles Series
Lophoscelomyia Series

PRIMARY KEYS

KEYS TO THE SECTIONS, SERIES AND SPECIES GROUPS OF THE SUBGENUS *ANOPHELES* IN THAILAND

ADULTS

1. Costa divided by pale spots into 4 or more dark marks involving both costa and vein R-R_1. . . . . (Subgenus *Cellia*)
   Costa divided by pale spots into not more than 3 dark spots involving both costa and vein R-R_1, or costa all dark. (Subgenus *Anopheles*). . . 2

2. (1) Wing scales all dark; anterior pronotal lobe without scales.
(ANGUSTICORN SECTION, In part)
(*Anopheles* series, p. 144) . . . 3
Wings with pale and dark scales; anterior pronotal lobe with scales. . 4

3. (2) Erect head scales long and narrow, only slightly expanded apically; antennal flagellomeres without scales.
aitkenii sp. group (p. 147)
Erect head scales widely expanded apically; flagellomere 1 with dark scales. . . . . *culiciformis* sp. group (p. 176)
sintonoides (p. 181)

4. (2) Apex of hindfemur with conspicuous tuft of white scales preceded by tuft of black scales. . . . . (ANGUSTICORN SECTION, In part)
(*Lophoscelomyia* series, p. 132)
asiaticus sp. group (p. 135)
Hindfemur without distal broad white band or tufts.
(LATICORN SECTION)
(*Myzorhynchus* series, p. 29) 5
(For separation of males of this series see p. 30.)

5. (4) Clypeus with patch of dark scales on each side; basal 4 - 8 flagellomeres with pale scales. . . . . *hyrcanus* sp. group (p. 36)
Clypeus without scales; 1st (basal) flagellomere only, with scales. . . 6

6. (5) Sternum VII with tuft of black scales. . *barbirostris* sp. group (p. 78)
Sternum VII without scales. 7

7. (6) Hind tarsomere 5 all white. . . . . *albotaeniatus* sp. group (p. 31)
montanus (p. 34)
Hind tarsomere 5 mostly dark scaled. . . *umbrosus* sp. group (p. 105)

*PUPAE**

1. Trumpet with longest axis vertical to stem; rim of trumpet simple, without secondary cleft or tragus. 2
Trumpet with longest axis transverse to stem; rim of trumpet often with secondary cleft; if longest axis not transverse, then rim of trumpet with tragus (often complex).
LATICORN SECTION (*Myzorhynchus* series) 5

2. (1) Paddle broad, seldom more than 1.5 times as long as wide; seta 5 on V - VII usually no stouter than seta 1 on V - VII; male genital lobes with apical knobs. . . . . (subgenus *Cellia*)
Paddle usually elongate, about 1.75 times as long as wide; if not elongate then seta 5 on V - VII is much stouter than seta 1 on V - VII; male genital lobes obtuse, not ending in knob.
ANGUSTICORN SECTION 3

**kyondawensis* known only from larval stage.*

3. (2) Seta 9 on V - VII frayed, or smooth and hooked at tip; seta 5 on V - VII very strong; seta 1 on V - VII very small and weak; bamboo and tree hole habitats. . . . . (*Lophoscelomyia* series, p. 132)
asiaticus sp. group (p. 135)

Seta 9, 1 and 5 on V - VII not so; not from bamboo or tree holes (except *sintonoides*). . . . . (*Anopheles* series, p. 144) 4

4. (3) Trumpet with shallow meatal cleft, meatus (stem) more than 0.5 as long as trumpet; paddle seta 1 long and hooked; leaf axil, bamboo and tree hole habitats. . . . . *culiciformis* sp. group (p. 176)*
sintonoides (p. 181)

Trumpet with deep meatal cleft, meatus 0.33 or less as long as trumpet; paddle seta 1 simple and straight; ground water habitats.
aitkenii sp. group (p. 147)

5. (1) Hind margins of abdominal tergites with denticles (except *baezai*); trumpet rim with tragus or deep secondary cleft (Fig. 6). 6

Hind margin of abdominal tergites without denticles; trumpet rim without tragus, but may have shallow secondary cleft (Fig. 11). . . . 7

6. (5) Trumpet with deep secondary cleft; lateral spines (seta 9) long.
albotaeniatus sp. group (p. 31)
montanus (p. 34)

Trumpet without secondary cleft, but with tragus; lateral spines usually short. . . . . *umbrosus* sp. group (p. 105)

7. (5) Seta 1-VII a strong tuft, with 15 or more branches.
barbirostris sp. group (p. 78)

Seta 1-VII with not more than 13 branches.
hyrcanus sp. group (p. 36)

LARVAE

1. Bases of setae 2-C wide apart, closer to the bases of setae 3-C than to one another; seta 1-A small or minute and nearly always simple.
(Subgenus *Cellia*)

Bases of setae 2-C closer to one another than to bases of setae 3-C; seta 1-A branched, often large. (In a few forms either setae 2-C are rather wide apart and seta 1-A is branched, or setae 2-C are close together, with seta 1-A simple and setae 5, 6, 7-C, reduced).
(Subgenus *Anopheles*) 2

2. (1) Branches of seta 1-A not reaching much beyond the middle of the antennal shaft, whole seta usually less than 0.5 length of shaft.
(ANGUSTICORN SECTION) 3

Branches of seta 1-A long enough to reach close to or beyond the end of the shaft, whole seta usually more than 0.5 length of shaft.
(LATICORN SECTION)
(*Myzorhynchus* series, p. 29). 5

**kyondawensis* known only from larval stage.

3. (2) Setae 5, 6, 7-C all well developed and feathered; seta 4-C branched from base. . . . . (*Anopheles* series, p. 144)
aitkenii sp. group (p. 147)
Setae 5, 6, 7-C reduced, some or all short and few-branched or simple; seta 4-C simple or branched only on distal half. 4

4. (3) Seta 6-VI simple or with 2 - 4 branches; seta 11-C shorter than antenna, or if as long as antenna then plumose from base.
(*Anopheles* series, p. 144)
culiciformis sp. group (p. 176)
Seta 6-VI with more than 10 branches; seta 11-C longer than antenna, simple or with 4 - 8 strong branches arising approximately midway.
(*Lophoscelomyia* series, p. 132)
asiaticus sp. group (p. 135)

5. (2) Abdomen with fully developed palmate setae on at least 5 segments. . 6
Abdomen without developed palmate setae, or with such setae only on 2 - 3 segments. . . . . *umbrosus* sp. group (p. 105)

6. (5) Seta 1-P with long branches from near the base; seta 1 on segment II palmate and usually pigmented (except *barbumbrosus*).
barbirostris sp. group (p. 78)
Seta 1-P simple or with only short branches near the tip, less often from about half way; seta 1 on segment II palmate and unpigmented. 7

7. (6) Seta 3-C bushy, divided from near the base into 40 or more branches; seta 1-P simple or infrequently with 2-5 short branches on the distal half. . . . . *hyrcanus* sp. group (p. 36)
Seta 3-C not bushy, divided about halfway from the base into less than 15 branches; seta 1-P with 3 - 7 short, subequal branches arising from the tip or about midway. . . . *albotaeniatus* sp. group (p. 31)
montanus (p. 34)

LATICORN SECTION

Reid and Knight 1961: 474.

This section was proposed for those species which exhibit complex trumpet shapes. In general these species usually have the longest axis transverse to the stem and a secondary cleft is often present, in addition to the meatal cleft. The rim of the trumpet is often folded and may exhibit a series of sharp ridges (spines) much like a file. In addition, there is often a complex lobe or tragus protruding from the rim. This latter structure is always present in those species in which the longest axis appears more vertical. For a comprehensive discussion of the relationship of this section with the other sections and subgenera of the genus refer to Reid and Knight (1961).

MYZORHYNCHUS SERIES

Edwards 1932: 36.

In addition to the characters presented in the keys, members of this series

may also be recognized by a combination of the following characters.

ADULT (General). Basal 0.33 of forefemur always swollen; head scales always broad; tarsi usually with pale bands; coxae often with scales; wings nearly always with pale areas. *Female*. Palpi usually with erect scales, giving shaggy appearance. *Male*. Claspette compact, with some setae on dorsal lobe fused to form club; aedeagus leaflets usually present.

PUPA. Seta 1, V - VII shorter than segments, usually branched, often as long as seta 5, V - VII and sometimes tufted with many branches.

LARVA. Seta 1-A large, approximately 0.5 or more length of antennal shaft, with branches from the base; 3-C often with many branches; 4-C branching from base; 5, 6, 7-C long with numerous branches; 11-C approximately equal to antennal shaft in length with many branches from base; 11-P short, stout, with short branches from base; seta 6 longer on segments 1 - III than on IV - VI.

The males of the respective species groups in this series are more difficult to define than the females; consequently, they have been frequently misidentified in the past. The following key should identify most of the specimens encountered.

KEY TO THE MALES OF THE SPECIES GROUPS OF THE *MYZORHYNCHUS* SERIES IN THAILAND.

1. Palpi with extensive pale scales, either on mesal sides of segments 2 - 3, base of segment 3 or on segments 4 - 5 (club). 2
   Palpi dark scaled, or with very narrow pale bands (usually on segments 4 - 5). 3

2. (1) Remigium and base of veins R and Cu completely dark scaled. *separatus* (p. 128)
   Remigium and base of veins R and Cu with at least a few scattered pale scales. . . . . *hyrcanus* sp. group (p. 36)

3. (1) *Hind tarsomere 5 entirely pale scaled. *albotaeniatus* sp. group (p. 31) *montanus* (p. 34)
   Hind tarsomere 5 mostly dark scaled. 4

4. (3) Basal half of costa usually with scattered pale scales; vein Cu_2 usually with fringe spot; pleuron, coxae and usually abdominal sternites with some pale scales, veins R_S-R_{2+3} and M entirely dark scaled to fork. *barbirostris* sp. group (p. 78)
   Basal half of costa dark scaled; vein Cu_2 without fringe spot; pleuron and coxae usually, and abdominal sternites always without pale scales. Usually vein R_S-R_{2+3} or vein M with some pale scales prior to fork (except *separatus*). . . . . *umbrosus* sp. group (p. 105)

DISTRIBUTION. This series is confined to the Eastern Hemisphere and appears most heavily concentrated in the Oriental faunal region. Reid (1968)

*If hind tarsomere 5 missing, then *montanus* has: prehumeral and humeral pale spots on base of costa, no pale fringe spot at vein Cu_2, and pleuron, coxae and abdominal sternites without pale scales.

points out that over 40% of the anophelines occurring in Malaysia belong to this series. In Thailand approximately 36% (21) of the known anophelines belong in this series. These are distributed among the *albotaeniatus*, *barbirostris*, *hyrcanus* and *umbrosus* species groups. The single member of the *albotaeniatus* species group, *montanus*, is rather rare, while most of the members of the *umbrosus* species group seem to be limited to southern Thailand, or areas with tropical wet forests. The *barbirostris* and *hyrcanus* species groups have some widely distributed members and others with limited distributions.

TAXONOMIC DISCUSSION. All of the species recognized from Thailand are usually large except *pursati*, and all are somewhat dark with a definite anopheline habitus (spotted wings) and resting attitude. One species not currently recognized from Thailand (*brevipalpis* Roper), was suggested (Reid 1968) as possibly occurring in Thailand. This species is rather unique to the series, for the resting attitude is almost culicine and it has shortened palps and wings without spots. Workers in southern Thailand should be on the lookout for this species. It is easily separated from the other unicolorous anophelines (*Anopheles* series) by the presence of scales on the anterior pronotum, a character not found in the *culiciformis* and *aitkenii* species groups.

ANOPHELES ALBOTAENIATUS SPECIES GROUP
(*albotaeniatus* species group, Reid and Knight, 1961)

Anopheles albotaeniatus (Theobald) 1903b.

GENERAL. Posterior margin of wing without pale fringe spot; hindtarsi with broad pale bands.

FEMALE. Palpi black and shaggy; sternum VII without scale tuft, but may have few minute, scattered scales.

PUPA. Terga with small denticles on posterior margin (pupae of only 2 species described).

LARVA. Fully developed palmate seta on abdominal segments III - VII; seta 3-C with 30 or less branches.

DISTRIBUTION. The *albotaeniatus* group as currently defined includes 6 species and is thought to be restricted to the Southeast Asian faunal region. However, *saperoi* Bohart and Ingram, described from Okinawa in the northern half of the Ryukyus, may extend into the Palaearctic region. Another species *ohamai* Ohama, is known only from Ishigaki Island in the southern Ryukyus. Two other species, *balarensis* Mendoza and *ejercitoi* Mendoza, are known only from adults collected on Luzon Island, Philippines. The 2 remaining species, *albotaeniatus* (Theobald) and *montanus*, are both recorded from the Malay Peninsula and Thailand. Iyengar (1953) recorded *albotaeniatus* from southern Thailand; however, subsequent collections made by Harinasuta et al. (1964) and SEATO Medical Research Laboratory personnel including the authors, during the period 1961-1971 in most of southern Thailand, failed to yield specimens of this species. Consequently, we have dropped *albotaeniatus* from the Thailand records until confirming specimens can be produced. The distribution of *albotaeniatus*, sensu stricto, includes: Sulawesi (van Hell 1952), Sumatra, Java, Borneo and Peninsular Malaysia (where Reid 1968, says it is uncommon). This is apparently another species belonging to the Malay-Indonesian faunal group (see Table 1, p. 7) that extends up onto the mainland via the Malay Peninsula and then disappears shortly before reaching the Thai border or shortly thereafter. The one remaining species in the group, *montanus*, is found in Thailand.

TAXONOMY. Within the group, 4 of the 6 species are poorly known, thus most taxonomic discussion is necessarily based on the 2 better known species, *albotaeniatus* and *montanus*. The adult females have been described for all the species. Those of *albotaeniatus*, *balerensis*, *ejercitoi* and *montanus* are all similar with: broad pale bands on hindtarsi and hindtarsomere 5 entirely pale; narrow apical fringe spot on the wing; posterior margin of wing without pale fringe spots; and sternum VII without tuft of scales. The female of *ejercitoi* also has 2 very distinctive characters, lower mesepimeral setae and scattered scales on the abdominal sterna. Both characters are not found on the other 5 members and are common only in the *barbirostris* subgroup of the *barbirostris* species group. The females of the remaining 2 species, *ohamai* and *saperoi*, do not seem closely related to the others, but are closely related to each other, if not synonymous (Ohama 1947). Both exhibit: narrow hind tarsal bands with hindtarsomere 5 partially dark scaled; wide apical pale fringe spot on the wing; abdominal sternum VII with a tuft of scales; and the scutum with a pale central area flanked by dark lateral areas.

Pupae have been described for only *albotaeniatus* and *montanus* and they have one very important character in common, i.e., denticles on the hind margins of the abdominal terga. Otherwise, they differ in the basic axis and structure of the trumpet, and also seta 9 on the abdomen.

Larvae have been at least partially described for 4 species, *albotaeniatus*, *ohamai*, *montanus* and *saperoi*. Those of *albotaeniatus* and *montanus* have a number of characters in common: fully developed palmate setae (1) on segments III - VII; pale and partially developed palmate setae on segments I - II; 1-P single or branched distally; seta 3-C with few branches; and a small ventral plate on abdominal segment VIII. Larvae of *albotaeniatus* also exhibit widely separated setae 2-C a character unusual in this subgenus, and seta 11-P with 3 - 4 fine branches from the base, unlike those found on *montanus*. The larval stages of *ohamai* and *saperoi* are poorly known. Both apparently have: pale and partially developed palmate seta 1 on I - II; fully developed palmate setae on segments III - VII; seta 1-A, small and branched; seta 1-P branched; and seta 4-C long and simple (*saperoi*) or long and 2 - 3 branched (*ohamai*). The small branched 1-A and single 4-C seta on *saperoi*, and also an egg without a frill, led Reid (1968) to imply some affinities to the *lindesayi* species group. These characters are distinct from the groups in the *Myzorhynchus* series, and when associated with the adult differences, would lead one to suspect *saperoi* (possibly *ohamai* also) are not members of the *albotaeniatus* group.

In regards to the relationship of this group with other species groups in the series, Reid (1968) said, "The group is intermediate between the *barbirostris* and *umbrosus* groups; the larvae have a full complement of palmate hairs as in the *barbirostris* group, but resemble the *umbrosus* group in lacking a fringe spot on the hind margin of the wing at the end of vein 5.2. The pupae of only two species (*albotaeniatus* and *montanus*) are known and they resemble those of the *umbrosus* group in having teeth on the hind margins of the tergites." We feel that other characters and considerations also need examination to ascertain the affinities of this group.

ADULTS. The females are definitely close to the *umbrosus* group in that they lack fringe spots on the hind margin of the wing, scales on the pleuron and coxae and a scale tuft on abdominal sternum VII (except *saperoi-ohamai*). *Anopheles ejercitoi* also exhibits 2 characters (see above) showing affinities to the *barbirostris* subgroup of the *barbirostris* group. Adults of *ohamai* and *saperoi* exhibit: a tuft of scales on abdominal sternum VII and a wide apical

fringe spot on the wing, showing affinities to the *hyrcanus* group and the *vanus* subgroup of the *barbirostris* group; and some affinity to the *lindesayi* group and to some members of the *umbrosus* group by the pale central area of the scutum that is flanked by dark lateral areas. Reid and Knight (1961) placed considerable weight on the ornamentation of legs in their classification of the subgenus *Anopheles*. If such characters do reflect phyletic relationships, then the broad hind tarsal banding in this group suggests a close relationship to the *hyrcanus* and African *coustani** groups.

PUPAE. The tergal denticles found on the pupae of *albotaeniatus* and *montanus* are otherwise found only in the *umbrosus* group. The pupa of *albotaeniatus* has 3 additional characters much like the *umbrosus* group; a trumpet with the longest axis vertical, a large lobe (tragus) on the rim, and short, rounded seta 9. The pupa of *montanus*; however, has a trumpet with the longest axis transverse to the stem, a deep secondary cleft in the trumpet rim and long setae 9, and all characters showing affinities to the *hyrcanus* and *barbirostris* groups.

LARVAE. All larvae currently described (*albotaeniatus*, *ohamai*, *montanus* and *saperoi*) have well developed palmate setae on segments III - VII and pale, poorly developed palmate setae on segments I - II. In the Southeast Asian *Myzorhynchus* series, this combination is found only in the *hyrcanus* group and the *vanus* subgroup of the *barbirostris* group. Members of the *barbirostris* subgroup of the *barbirostris* group have well developed and pigmented palmate setae on at least segments II - VII. Setae 1-P of *albotaeniatus* and *montanus* are like those of the *hyrcanus* and *umbrosus* groups and unlike those found in the *barbirostris* group, which are always branched from the base. In addition, the ventral plate found on sternum VIII of these 2 species is a distinct *umbrosus*-like character. The setae 3-C of *ohamai* and *saperoi* have few branches, much like the *umbrosus* group and the *vanus* subgroup of the *barbirostris* group.

A clear interpretation of the relationship of this group to the other Southeast Asian members of the *Myzorhynchus* series is not possible and will remain thus until more is learned about the 4 imperfectly known members and the distribution of the group. Based on the known members, we can say: 1) the group may not be a natural assemblage; 2) the group seems most closely related to the *umbrosus* group; 3) there are some affinities to the *hyrcanus* group and *vanus* subgroup of the *barbirostris* group; and 4) there is very little evidence for a relationship to the *barbirostris* subgroup of the *barbirostris* species group.

BIOLOGY. The members of this group are primarily forest-swamp forest dwellers, which rarely attack man. Some members have been observed biting man during the day under forest shade.

MEDICAL SIGNIFICANCE. None of the species are involved in the transmission of malaria parasites. The report (Iyengar 1953) of *albotaeniatus* as a vector of *Brugia malayi* (Brug) requires confirmation.

*Reid and Knight (1961) pointed out this apparent relationship with *obscurus* (Grünberg); however, note the unique egg of this species (Gillies and de Meillon 1968) compared to Southeast Asian *Myzorhynchus* members (Reid 1968).

ANOPHELES (ANOPHELES) MONTANUS STANTON AND HACKER
(Figures 5, 6, 7)

Anopheles albotaeniatus var. *montanus* Stanton and Hacker 1917: 273 (♂, ♀*, L)
Anopheles montanus Stanton and Hacker, Christophers 1924: 30.
Anopheles peditaeniatus of Walch 1930: 44 (L*); Stoker 1931: 129 (L*) (= *montanus*).
Anopheles (Anopheles) montanus Stanton and Hacker, Edwards 1932: 42; Reid 1950: 312; Reid 1968: 148 (♂*, ♀*, P*, L*, E*).

Adults may be recognized by a combination of unbanded palps, abdominal sternum VII without a scale tuft and hindtarsomeres with wide pale bands, particularly tarsomere 5 which is entirely pale. The pupa is easily recognized by a deep secondary cleft in the trumpet rim, denticles on the hind margins of the terga, and long setae 9 on the abdominal segments. The larvae resemble members of the *hyrcanus* group, but have 1 - 12 branches on seta 3-C, seta 1-P with 3 - 7 branches on the distal half and a small plate on abdominal sternum VIII.

FEMALE (Fig. 5) *Head.* Central vertex scales pale, lateral scales dark, white frontal bristles between eyes; pedicel deep brown without scales, 1st flagellomere only with dark scales; palpus dark scaled, basal scales somewhat erect, those toward apex appressed; proposcis about as long as palp, dark scaled; labellum paler than labium. *Thorax.* Anterior promontory with small central patch of pale scales and few lateral dark scales; scutum without scales, with numerous pale setae and mottled integument, not divisible into distinct pale and dark areas; anterior pronotum with strong tuft of dark scales and setae; posterior pronotum without scales or setae. Pleural setae: 2 - 3 propleural, 4 - 6 spiracular, 12 - 15 prealar, 3 - 4 upper and 5 - 6 lower sternopleural, and 5 - 6 upper mesepimeral, pleuron without white scales, often with few cryptic opaque scales on postspiracular area. *Wing.* Costa normally with 4 pale spots; prehumeral, humeral, subcostal and preapical; prehumeral and humeral spots may be absent, or just a trace of these on one or both wings; preapical fringe spot narrow, beginning before and extending down to tip of R_1; remigium dark scaled; humeral crossvein with tuft of black scales; vein R-R_1 usually with distinct pale spots at sector and apical positions, but without pale subcostal spot; apical fringe spot narrow, from R_3 to R_{4+5} or infrequently beyond; bases of veins R, Cu and 1A usually with few scattered pale scales. (Also see taxonomic discussion.) *Legs.* Coxae without scales. Foreleg: femur dark and swollen basally; tibia dark; tarsus with narrow pale bands at joints of tarsomeres 1 - 2, 2 - 3, and at apex of 3. Midleg: femur and tibia dark without pale knee spot; tarsomeres 1 - 3 and occasionally 4 with very narrow, apical pale bands. Hindleg: femur dark, with minute knee spot; tibia with distinct basal and narrow apical pale bands; tarsomeres with narrow apical pale bands on 1 - 3 bases of 2 - 3 narrowly pale, 4 with broader basal and apical bands, and 5 entirely white. *Abdomen.* Dark, without scales, but with numerous pale yellow setae.

MALE (Fig. 5). Resembles female in general appearance, but with more extensive pale scaling on wings and legs. *Head.* Palpi entirely dark scaled. *Wing.* Base of costa with at least well defined prehumeral and humeral pale spots; infrequently, entirely pale proximal to humeral crossvein; numerous pale scales on bases of veins R, Cu and 1A; vein Cu to fork commonly with only 1 - 3 black scales. *Legs.* Pale hind tarsal bands markedly broader than on female. *Genitalia.* Parabasal spines arising from a marked prominence, outer spine longer, more curved and with larger base; internal mesal spine

some distance from apex of the basimere; claspette bilobed, dorsal lobe with club, ventral lobe usually with 2 unequal setae, both relatively strong but, 3rd seta sometimes present; aedeagus leaflets 3 - 4 pairs, larger leaflets with few denticles near tip; proctiger with lateral sclerotization.

PUPA (Fig. 6) *Cephalothorax*. Wing case with variably pigmented pattern of dark spots and bars. *Trumpet*. Meatal cleft and secondary cleft very deep, permitting trumpet to open widely in life. *Abdomen*. Seta 9 peg-like on II - III, long and pointed and faintly pigmented on IV - VII; seta 5 with more branches than seta 1 on most segments; seta 3-III inserted in line and between setae 1 and 5; terga of most segments with patches of small denticles, most obvious on caudal margin of segments. *Paddle*. Index approximately 1.3; refractile border 0.5 - 0.6 paddle length; seta 1-P with 2 - 4 distal branches.

LARVA (Fig. 7). Living larvae dark brown with abdominal segment III pale. *Head*. Setae 2-C simple, bases close together, but not touching; 3-C divided into 6 - 13 branches some distance from base; 4-C small, with 3 - 6 branches at tip. *Antenna*. Seta 1-A with about 12 branches, usually reaching apex of antenna; 4-A prominent, with 9 - 12 branches. *Thorax*. Seta 1-P small, with 3 - 7 branches near tip; 2-P with 8 - 10 branches; 3-P simple, short; seta 3-T palmate, lightly pigmented, with branches fairly slender; pleural setae simple; seta 11-P short, with 6 - 10 branches; 14-P very long, with 9 - 12 branches. *Abdomen*. Sterna frequently with patches of small spicules; seta 1, I - VII palmate, pale and poorly developed on I - II, well developed and darkly pigmented except for filament and apex of blade on III - VI; well developed, but lightly pigmented on VII; seta 6-III with many branches (26 - 33), seta 6, IV - V, 0.7 - 1.0 length of 6-III, with 1 - 3 branches; setae 5, 9 large, with numerous branches on most segments; abdominal sternum VIII with small (sometimes bilobed) plate near cephalic margin; pecten with 4 - 6 long teeth separated by many smaller teeth; seta 1-X simple.

TYPE-DATA. Syntypes of *montanus* from the type-locality, "Ulu Gombak, Malay States" are present in the British Museum (Natural History)[BMNH]; however, the specimens representing the type-series have not been defined. Stanton and Hacker (1917) clearly described the ♀, ♂(including genitalia) and larva of *montanus* in the original description. In the BMNH there are 6♀, 4♂ and 2 larval skins which were collected by Hacker in the years immediately surrounding the original description (early 1917), and all agree well with that description. These specimens, however, were received at the BMNH in 2 shipments. The 1st shipment was logged in the BMNH on 14 July 1916, has accession #1916-168 and includes 1♀ and 1♂ collected by Hacker in March 1916 at the type-locality. The 2nd accession was logged in the BMNH on Nov. 1920 and is numbered 1920-454. This accession includes 1♀ and 1♂ (with prepared genitalia mount) labeled "Ulu Gombak, Malay States, Dr. H. P. Hacker, 1920-454", and 4♀♀, 2♂♂ and 2 larval skins (1♀ and 1L. skin associated, #479F.2) labeled "Malay States, Dr. H. P. Hacker, 1920-454." Conceivably, all the above specimens could be syntypes, however, we feel the ♀ and ♂ in accession 1916-168 should not be considered syntypes because larvae were not included in that accession, and because that shipment was received at the BMNH over 6 months preceding the description of *montanus*. These 2 specimens (1916-168) are almost certainly referred to by Stanton and Hacker (1917: 273) when they say, "We are indebted to Mr. F. W. Edwards of the British Museum who has kindly examined our specimens and aided us in fixing the systematic position of this Anopheline." This statement implies that those 2 specimens were not necessarily considered representative of a new variety when sent to Edwards. Because of these circumstances, the specimens received at the BMNH in 1916

were probably not used by Stanton and Hacker (in Malaya) for their varietal description, while those in accession 1920-454 are almost certainly the specimens used for that purpose and should be considered the syntypes of *montanus*. Possibly correspondence exists at the BMNH which could resolve this problem.

DISTRIBUTION. In THAILAND, restricted to the southern peninsular provinces where tropical wet forests are common. Specimens (10♂, 6♀, 47 larvae, and 33 larval and pupal skins) were examined from the following provinces: Narathiwat, Phuket, Ranong, Songkhla and Trang. The authors also examined 5♂, 6♀, 4 larvae and 6 larval and pupal skins from MALAYSIA (Peninsular), the majority originally collected and identified by J. A. Reid. An additional 6♂, 9♀, 4 larvae and 2 larval skin specimens (including syntypes) in the BMNH were examined from: MALAYSIA (Peninsular and Malaysia); and THAILAND (Trang). There is also a literature record of this species from INDONESIA (Banka) (Reid 1968). Possibly *montanus* occurs over much of the Indonesian archipelago, at least in those areas with climatic conditions matching those of southern Thailand and Malaya (zone Afi in the Köppen classification). It is also likely that *montanus* occurs in southern Burma, since Ranong Province borders Burma and the tropical wet forests extend north into Burma.

TAXONOMIC DISCUSSION. The species most apt to be confused with *montanus* is *roperi*, which has a similar distribution in Thailand. This species is often very like *montanus* (pale spots on base of costa and basal pale band on hindtibia), but hindtarsomere 5 is mostly black, while that of *montanus* is entirely white. Specimens missing the hindtarsi would be very confusing, but should be separable on the basis of 0 - 1 propleural setae on *roperi* while *montanus* has 2 - 4. The pupa of *montanus*, with tergal denticles, long spine-like abdominal seta 9 and unique trumpet, is quite distinct and should not present identification problems. The larva is also rather distinct. The combination of well developed palmate setae, a simple or distally branched seta 1-P and the few branches on seta 3-C should readily separate this species.

One melanistic female (with associated skins) was examined from Narathiwat Province. This specimen lacks the prehumeral, humeral and subcostal pale spots, in essence the entire costa is dark scaled. The preapical pale fringe spot just before the tip of R_1 is also missing, while a faint pale apical fringe spot is present at R_3. The remainder of the wing is fairly normal except for the absence of a sector spot on vein R_1. No abnormalties were noted elsewhere on the specimen.

BIOLOGY. Sandosham (1959) reported *montanus* breeds in pools at the sides of jungle streams, particularly those with decaying leaves. Reid (1968) refers to shaded pools or small swamps at the sides of forest streams up to an elevation of about 305 m. Thailand specimens were collected from elephant footprints, stream pools and a rock pool, all adjacent to small streams in wet forest and between 76 - 305 m elevation. These collection sites all received partial to heavy shade and all but one contained many decaying leaves. None of the Thai specimens were from human biting collections, although *montanus* is reported to feed on man in hill forest in Malaya (Traub 1957). In view of its usual scarcity and restriction to jungle habitats it is unlikely to serve as a vector of human disease pathogens.

ANOPHELES HYRCANUS SPECIES GROUP OF SOUTHEAST ASIA
(*An. hyrcanus* species group, Reid 1953)
(Figures 8, 9)

Anopheles hyrcanus (Pallas) 1771; as *Culex hyrcanus*.

GENERAL. Palpi with pale bands; hindtarsi with narrow to broad pale bands; tertiary fringe scales on wing pale, at least paler than other fringe scales (except spots).

FEMALE *Head.* Palpi with pale bands; clypeus with tuft of outstanding dark scales on each side; pedicel with small pale scales on outer aspect; basal 4 - 8 flagellomeres with pale scales. *Abdomen.* Without scales except ventral tuft on sternum VII.

MALE *Head.* Palpi with pale bands or spots on segments 4, 5 and sometimes segment 3, and with scattered pale scales elsewhere; clypeus without scales; flagellum generally without scales except for few pale scales on flagellomere 1. *Abdomen.* Without scales except on the basimere of genitalia. *Genitalia.* Claspette bilobed; ventral lobe with 2, infrequently 3 large setae, mesal seta very long, lateral seta shorter; dorsal lobe with club-like spine on inner half fused from 2 - 4 separate basal stems, and normally 2 thin leaflet-like setae on outer half immediately adjacent to fused club; aedeagus with 2 - 7 pairs of leaflets, at least larger ones with serrations and approximately 0.33 length of aedeagus.

PUPA *Cephalothorax.* Palpal case exhibits sexual dimorphism, case tip of female short and blunt, that of male long and attenuated. *Trumpet.* Longest axis transverse to stem; outer wall of pinna may exhibit vertical wrinkles as in *argyropus*; rim without secondary cleft or lobe (tragus), but may have thickened saw-tooth edge. *Abdomen.* Terga without denticles on caudal margin; seta 1-VII with 13 or less branches.

LARVA *Head.* 3-C large, with 40 or more branches from near base; 1-A with numerous branches, reaching or exceeding tip of antenna. *Thorax.* 1-P short, simple or with several small branches on distal half; prothoracic pleural tubercle with long stout spine. *Abdomen.* Seta 1 palmate on I - VII, but pigmented and well developed only on III - VII.

DISTRIBUTION. The Southeast Asian members of this group are generally distributed throughout the Oriental faunal region. The Southeast Asian species described here are closely related to *hyrcanus* (Pallas) and other described Palaearctic forms which occur from Spain eastward through the Mediterranean basin, the Middle East, USSR and possibly Palaearctic Asia. The geographic point of separation for these two parts of the *hyrcanus* group in the west apparently runs north from the Indian Ocean through the mountains and desert of Baluchistan up to the Afghanistan peaks and east to the Himalaya Mountains. The line of separation in Palaearctic Asia is still undetermined. The Southeast Asian members are not known from the Australian region. The easternmost records of this group in Indonesia come from collections on Timor Island in the Sunda Chain, and Buru Island in the Moluccas (Bonne-Wepster and Swellengrebel 1953). The nominate species, *hyrcanus*, in the Palaearctic, appears to exist in a number of forms which are currently synonymized with *hyrcanus*, but which may, in fact, be good species. None of these forms appear to be synonymous with the Southeast Asian members.

The oriental segment of this species group involves at least 13 species. Eight species are currently known from the Thailand-Malaysia area: *argyropus*, *crawfordi*, *lesteri*, *nigerrimus*, *nitidus*, *paraliae*, *peditaeniatus*, *pursati* and *sinensis*. One species, *pseudosinensis* Baisas, is known only from the Philippines, and at least 4 additional species are recorded from China, Korea and Japan.

Only 2 species considered here, *nigerrimus* and *peditaeniatus*, have distributions which are known to extend west of Assam into peninsular India and down to Sri Lanka. *Anopheles peditaeniatus* possibly extends as far west as

Pakistan. In Southeast Asia these 2 species are found throughout the Indo-China peninsula down through the Malay Peninsula and on all the major islands in the Sunda Chain of Indonesia. *Anopheles nigerrimus* is recorded as far east as Halmahera Island in the Moluccas, but does not extend north of Borneo into the Philippines, where it is apparently replaced by *pseudosinensis*. This latter species, despite the name, seems to have closest affinities to *nigerrimus*. Aside from the wide distribution in Indonesia, *peditaeniatus* is also found on all the major islands in the Philippines.

Three other species, *argyropus*, *crawfordi* and *sinensis* have distributions with: the most western extension in Assam; the most southern extension in Sumatra (*crawfordi* and *sinensis*) and Java (*argyropus*); and most northeastern extension in Vietnam (*argyropus* and *crawfordi*) and China, Japan, Korea (*sinensis*).

The 3 remaining species, *lesteri paraliae*, *nitidus* and *pursati*, have somewhat different distributions. Although *lesteri lesteri* Baisas and Hu is recognized from China, Philippines, Okinawa and Japan, subspecies *paraliae* is known only from Borneo, Malaya, Thailand and South Vietnam. These two subspecies can be separated on consistent differences only in the adult stage, and no intermediates have been found. In reality *paraliae* may deserve specific status, but this decision must be based on a study of more material of both subspecies. *Anopheles nitidus* is known from India (Assam) to North Vietnam in the east and Indonesia (Sumatra) in the south. *Anopheles pursati* is apparently confined to the Indo-China Peninsula, with records and specimens from Cambodia, Peninsular Malaysia, Thailand and South Vietnam.

TAXONOMIC DISCUSSION. This is an extremely complex assemblage of species which has been treated adequately only in Malaysia (Reid 1953 and 1968), the Philippines (Baisas and Hu 1936), Japan (Otsuru and Ohmori 1960) and to some extent mainland China (Ho et al. 1962, Feng 1964; and Ma 1964, 1968a, b, c). The material examined from Thailand during this study agreed very well with the Malaysian members described in detail by Reid (1953, 1968). Minor exceptions encountered are discussed under the individual species.

The discovery of the various species of this group in Malaya by Reid (1953), was aided by detailed observations on biology. Consistent biological differences and small but consistent differences in morphology of the various stages make it clear that the species of this group form a sibling series, in the sense of Mayr (1969). Due to the close relationship of these species it is often difficult or impossible to identify a particular adult specimen, unless it is accompanied by the associated immature skins. This may pose an initial difficulty for public health workers, but continued work in a particular area should permit a rapid understanding of the limits of variation of the local species. Despite Reid's reservations as to the utility of his keys for areas outside Malaya, it appears that the Thailand fauna at least, and possibly that of Indochina, consist primarily of the same members of the *hyrcanus* group as seen by him in Malaya.

Additional collecting at higher elevations in northern Thailand may produce some of the species described from China. Collectors in that area should be alert for *lesteri lesteri* which is found in southern China and easily confused with *sinensis*.

The interpretation that is followed here for intragroup affinities is based on characters from all life stages (Table 2) and recognizes 2 subgroups (Harrison 1972). The *nigerrimus* subgroup was created to include *nigerrimus*, *nitidus* (as *indiensis*), *pursati*, and *pseudosinensis*, while the *lesteri* subgroup includes *lesteri lesteri*, *lesteri paraliae*, *crawfordi* and *peditaeniatus*. The 2 remaining species, *argyropus* and *sinensis* are isolated. This interpretation

TABLE 2. Character affinities in the Southeast Asian *hyrcanus* species group

Species	ADULT				PUPA		LARVA		EGG
	Pairs of aedeagus leaflets	Pale band on ♂ palpal seg. 3	Pale scales on base of ♂ costa	Scales on humeral crossvein	Trumpet rim structure	Branches on seta 5-V	Branches on seta 8-C	No. long pecten teeth	Deck width
argyropus	2-3	no	no	patch	wrinkles	50+	13-22	6-8	very narrow
nigerrimus	2-3	yes	yes	patch	thin	30-60	12-24	4-7	moderate
nitidus	2-3	yes	yes	patch	thin	30-50	11-21	5-7	split deck
pursati	2-3	yes	yes	patch	thin	45+	12-21	5-7	split deck
pseudosinensis	2	yes	yes	patch	thin	4-11	5-12	6-7	moderate
sinensis	3-6	no	no*	patch**	thin	9-24	7-14	7-9	wide
lesteri lesteri	4-5	no	no	none or 1-2	thick saw-toothed	10-37	5-12	7-10	narrow
lesteri paraliae	4-5	no	no	none or 1-2	thick saw-toothed	12-30	5-11	7-10	narrow
crawfordi	4-7	no	yes	none or 1-2	thick saw-toothed	30-45	6-11	6-8	very narrow
peditaeniatus	4-7	no	no	none or 1-2	thick saw-toothed	14-28	4-9	7-9	moderate

*Rare in Southeast Asia; more frequent on Palearctic form in China
**Not actually a patch, but 3-6 small scales, rarely less or bare

differs from Reid's (1953, 1963, 1968) interpretation by: (1) separating *peditaeniatus* from *argyropus* and placing it in the *lesteri* subgroup; (2) determining *argyropus* is separate, but more closely related to *nigerrimus* than *peditaeniatus*; (3) moving *sinensis* away from a close relationship with *nigerrimus* and placing it separate, but possibly intermediate between the *nigerrimus* and *lesteri* subgroups; and (4) removing *nitidus* from an intermediate position between *crawfordi* and *nigerrimus* and placing it in the *nigerrimus* subgroup.

Members of this group show more affinity to the *barbirostris* group than to the *albotaeniatus* or *umbrosus* groups. Adult females exhibit a tuft of scales on sternum VII, scales on the pleuron and coxae (except *lesteri*) and most have fringe spots on the posterior margin of the wing. These are characters found elsewhere in the series only in the *barbirostris* and *bancrofti* groups. The larvae have seta 3-C with many branches and palmate seta 1 on segments I - VII, as do the larvae of the *barbirostris* group. The pupae of the *hyrcanus* group all lack denticles on the tergites as do members of the *barbirostris* group. In addition, the pupal trumpets of the *hyrcanus* and *barbirostris* groups are similar in structure and less complicated than those found in the *albotaeniatus* and *umbrosus* groups.

BIOLOGY. The immature forms of the *hyrcanus* group are found primarily in rice fields, marshy areas, ponds with emergent vegetation, and similar habitats. The great rice producing areas surrounding Bangkok and in the valleys of the north, such as Chiang Mai, support large populations of these species. The more abundant species, such as *peditaeniatus* and *sinensis* are found essentially throughout the country, even in mountainous areas where small paddy fields are found. These 2 species are very common in the rice field habitat throughout their distribution in the Orient, and may well owe their wide distributions to man's long association and dependence on rice cultivation.

Fortunately, members of this group seem primarily zoophilic; although, human biting incidence may be quite high under a given set of ecological conditions.

MEDICAL SIGNIFICANCE. There is no evidence that any of these species transmit malaria parasites to man in Thailand. There have been repeated incriminations of *sinensis* as a major vector of malaria parasites in China; however, Ho et al. (1962) found that *lesteri lesteri* is the primary vector in the Yangtze Valley and that *sinensis* plays a secondary vector role. There is some possibility (Iyengar 1953) that members of the group serve as vectors of *Brugia malayi* in southern Thailand, but again the identity of the mosquito and parasite species needs confirmation. Workers interested in filarial transmission by the *hyrcanus* group should consult the review of this subject by Reid et al. (1962).

KEYS TO THE SPECIES OF THE *ANOPHELES HYRCANUS* GROUP IN THAILAND

FEMALES

1. Hindtarsi with broad pale bands, at least one tarsomere (4) with a basal pale band or patch. 2*
   Hindtarsi with apical pale bands only. 5

*Infrequent *lesteri paraliae* have a small basal patch of pale scales on tarsomeres 4 - 5, but these can be properly assigned by the narrow pale fringe spot at the wing apex.

2. (1) Basal dark mark on wing vein Cu short, separated by own length or more from upper dark mark on vein 1A; base of costa with scattered pale scales, frequently with small humeral pale spot; dark mark at origin of vein R_S well defined, scales between dark mark and fork mostly white; vein Cu_2 always with pale fringe spot. . . . . *nitidus* (p. 58)

Basal dark mark on wing vein Cu long, approaching within own length or less of the upper dark mark on vein 1A; base of costa dark scaled or with few scattered pale scales, but no pale humeral spot; dark mark at origin of vein R_S poorly defined, scales between dark mark and fork mostly dark; vein Cu_2 with or without pale fringe spot. 3

3. (2) Humeral crossvein with patch of dark scales; remigium mostly dark scaled; basal 0.33 and preapical dark mark on vein R-R_1 dark scaled, or with very few pale scales. 4

Humeral crossvein without scales; remigium mostly pale scaled; basal 0.33 and preapical dark mark on vein R-R_1 usually with many pale scales. . . . . *peditaeniatus* (p. 71)

4. (3) Hindtarsomere 4 with broad dark band, at least 0.6 length of segment; hindtarsomere 5 without or with very narrow (0.25 or less of segment) pale basal band; base of costa usually with several scattered pale scales; apical dark mark on vein Cu_2 short, rarely as long as apical dark mark on 1A. . . . . *nigerrimus*, in part (p. 65)

Hindtarsomere 4 with narrow dark band, 0.5 or less (lacking in rare cases) length of segment; hindtarsomere 5 with pale basal band on 40% or more of segment; base of costa without pale scales; apical dark mark on vein Cu_2 long, usually equal or longer than apical dark mark on 1A. . . . . *argyropus* (p. 50)

5. (1) Wing apex with narrow pale fringe spot, not extending beyond R_1 to R_3. 6

Wing apex with wide pale fringe spot, extending at least to R_{4+5}. . . . 7

6. (5) Humeral crossvein with dark scales; remigium mostly pale scaled; midcoxa with white scales; smallest member of group in Thailand. *pursati* (p. 75)

Humeral crossvein without scales; remigium mostly dark scaled; midcoxa without pale scales. . . . . *lesteri paraliae* (p. 61)

7. (5) Vein Cu with long basal dark mark*, at least twice as long as most basal pale mark (when present) on Cu, and approaching within own length or less of upper dark mark on 1A; costa usually with several scattered pale scales on basal 0.33; remigium mostly dark scaled; humeral crossvein with dense patch of black scales. *nigerrimus*, in part (p. 65)

Vein Cu with short basal dark mark, equal to or less length of most basal pale mark on Cu, and (usually) separated by own length or more from upper dark mark on 1A; basal 0.33 of costa usually entirely dark scaled; remigium mostly pale scaled; humeral crossvein bare or with few scales. 8

*Basal dark mark does not refer to a few dark scales or small dark spot which may occur at the absolute base of the vein.

8. (7) Wing pattern blurred; tip of vein R_1 dark scaled; apical fringe spot long, beginning at or above vein R_1; preapical dark mark on vein R_1 with some pale scales; usually pale fringe spot at tip of vein Cu_2. *sinensis* (p. 45)

Wing pattern sharp, dark marks short and well defined; tip of vein R_1 pale scaled; apical fringe spot shorter, beginning at R_2; preapical dark mark on vein R_1 without pale scales; without pale fringe spot at tip of vein Cu_2 . . . . . *crawfordi* (p. 54)

MALES

1. Palpal segment 3 with basal white band. (*nigerrimus* subgroup). . . . 2

Palpal segment 3 without distinct white basal band although some pale scales may occur on the inner surface of each palp. 4

2. (1) Wing with narrow apical pale fringe spot, at widest extending from R_1 to R_3; hindtarsomere 4 rarely with a basal pale band. *pursati* (p. 75)

Wing with wide apical pale fringe spot, extending at least to R_{4+5}; hindtarsomere 4 with basal pale band (some specimens of *nigerrimus* will lack basal bands on the hindtarsi). 3

3. (2) Wing with long basal dark mark on vein Cu approximately its own length or less from upper dark mark on vein 1A; base of costa dark scaled or with several scattered pale scales, rarely with small humeral pale spot; foretarsomere 2 with pale band seldom more than 0.25 length of segment. . . . . *nigerrimus* (p. 65)

Wing with short basal dark mark on Cu more than its own length from upper dark mark on vein 1A; base of costa nearly always with pale humeral spot, at least with numerous scattered pale scales; foretarsomere 2 with pale band usually 0.33 - 0.50 length of segment. *nitidus* (p. 58)

4. (1) Hindtarsomeres 1 - 4 with narrow apical bands only. 5

Hindtarsomeres with wide pale bands, with basal bands on tarsomeres 4 and usually 5, as well as apical bands on tarsomeres 1 - 4. . . . 7

5. (4) Wing with narrow apical pale fringe spot, at widest extending from R_1 to R_3; midcoxa without pale scales; basimere without pale scales. *lesteri paraliae* (p. 61)

Wing with wide apical fringe spot, extending at least to R_{4+5}; midcoxa with at least a few pale scales; basimere with pale scales. 6

6. (5) Wing vein R_1 with tip pale scaled; propleural setae 2 - 5; lower sternopleural setae 3 - 5. . . . . *crawfordi* (p. 54)

Tip of vein R_1 dark scaled; propleural setae 4 - 10, lower sternopleural setae 5 - 9. . . . . *sinensis* (p. 45)

7. (4) Humeral crossvein with patch of black scales; remigium mostly dark scaled; preapical dark mark on R_1 without pale scales. *argyropus* (p. 50)

Humeral crossvein without scales; remigium pale scaled, scales on anterior margin usually silvery white; preapical dark mark on R_1 with some pale scales (usually many). . . . . *peditaeniatus* (p. 71)

PUPAE

1. Seta 9-VIII without branches or with reduced branching; paddle with marginal teeth extending beyond 0.75 its length. 2
   Seta 9-VIII with well developed branches; paddle with marginal teeth rarely reaching 0.75 its length. 3

2. (1) Trumpet with parallel vertical wrinkles on sides, and thin uniform rim; seta 1-V with 17 - 40 branches. . . . . *argyropus* (p. 50)
   Trumpet without wrinkles on sides, but with thickened saw-toothed areas on the rim; seta 1-V with 1 - 6 branches. . . . *peditaeniatus* (p. 71)

3. (1) Trumpet rim thin and uniform. 4
   Trumpet rim with thickened, saw-toothed areas. 7

4. (3) Seta 5-V with 9 - 24 branches; wing case pale, with darkest pigmentation in form of distinct rows of round dark spots*, infrequently with lighter pigmentation on veins or crossbars. . . . . *sinensis* (p. 45)
   Seta 5-V tuft-like, with 30 - 60 branches; wing case completely pale to darkly pigmented, darkest pigmentation widespread, or on veins or crossbars, blurred spots may be spaced between veins and crossbars, but they are no darker than other pigmentation. 5

5. (4) Integument very lightly pigmented, with abdomen unpigmented including paddle and areas surrounding setal alveoli; apical joint and tip of antennal case with distinct dark spots. . . . . *nitidus* (p. 58)
   Integument usually moderately to darkly pigmented, including paddle and pigmented spots around setal alveoli, especially 2 on II - VII; pigmentation of antennal case when present, no darker than other pigment and not confined to apical joint and tip. 6

6. (5) Seta 1-VII with 3 - 13 branches, rarely less than 6; seta 6-VII anterior and slightly mesal to seta 9-VII; seta 1-P with 3 or more branches; light to moderate pigmentation, without dark median spots on terga III - VII. . . . . *pursati* (p. 75)
   Seta 1-VII with 1 - 7 branches, usually 2 - 4, more than 5 branches very rare; seta 6-VII mesal to seta 9-VII; seta 1-P usually simple or bifid; skin darkly pigmented, with dark median spots on terga III - VII. *nigerrimus* (p. 65)

7. (3) **Seta 1-VI with 2 - 6 branches; seta 5-V with 30 - 45 branches; integument usually light to moderately pigmented. . . . *crawfordi* (p. 54)
   Seta 1-VI with 5 - 10 branches; seta 5-V with 12 - 30 branches; integument usually very darkly pigmented. . . . . *lesteri paraliae* (p. 61)

*Some specimens of *pursati* have distinct dark spots on the wing case, but these specimens will have very dense tuft-like seta 5-V with 45 or more branches and seta 1-VII with 6 - 13 branches (rarely less), while *sinensis* has only 1 - 5 branches on 1-VII.

**This couplet will work on about 90% of the specimens collected in Thailand, thus reared adults with associated skins are the best means of identification.

LARVAE

1. Seta 4-M small, with sinuate* spreading branches arising close together at base. . . . . *peditaeniatus* (p. 71)
   Seta 4-M with stiffer more erect or straight branches arising along central stem, or close together near base (*argyropus* and *nitidus*). . 2

2. (1) Seta 6-III usually with more than 20 branches; seta 6-I usually with more than 21 branches; frontal seta 5-C with 17 or more branches. *sinensis* (p. 45)
   Seta 6-III rarely with more than 20 branches; seta 6-I usually with less than 21 branches; frontal seta 5-C with 11 - 18 branches** 3

3. (2) Seta 8-C with 12 - 24 (rarely 11 on *nitidus*) branches. 4
   Seta 8-C with 5 - 11 branches. 7

4. (3) Seta 14-P with 3 - 5, usually 3 - 4 branches; seta 1-M with 26 - 38 branches, usually 28 or more. . . . . *pursati* (p. 75)
   Seta 14-P with 5 or more (rarely 5) branches; seta 1-M with less than 28 branches (rare specimens of *nitidus* with more). 5

5. (4) Seta 5-IV with 2 - 4 branches, usually 3; seta 5-III with 4 - 8 branches. *nigerrimus* (p. 65)
   Seta 5-IV seldom with less than 5 branches; seta 5-III with 7 - 17 branches. 6

6. (5) Seta 2-II with 8 - 14 branches; seta 5-V with 5 - 9 branches; seta 9-VI with 5 - 9 branches; pecten seldom with more than 6 long teeth; seta 1-X weak, rarely longer than saddle. . . . . *nitidus*, in part (p. 58)
   Seta 2-II with 6 - 9 branches; seta 5-V with 4 - 6 branches; seta 9-VI with 4 - 5 branches; pecten usually with 7 - 8 long teeth; saddle seta 1-X strong; longer than saddle. . . . . *argyropus* (p. 50)

7. (3) Seta 9-III with 10 - 16 branches; pecten seldom with more than 6 long teeth; seta 13-IV with 6 - 12 short branches, approximately 0.5 length of seta 10-IV. . . . . *nitidus*, in part (p. 58)
   Seta 9-III with less than 10 branches; pecten rarely with less than 7 long teeth; seta 13-IV with 4 - 9 long branches; approximately equal to or slightly less length of seta 10-IV. 8

*Seta 4-M may appear slightly sinuate on infrequent specimens of *argyropus* or *nitidus*; however, seta 8-C will have 11 - 24 branches (cf. *peditaeniatus* 4 - 9) and seta 9-C will have 6 - 16 (cf. *peditaeniatus* 3 - 7).

**Rare specimens of *lesteri paraliae* may key to *sinensis*, but seta 5-II on the former species has 6 - 10 branches while *sinensis* has 9 - 20 (seldom less than 11) branches.

8. (7) *Seta 5-III with 6 - 10 branches; seta 1-X strong, longer than saddle. *lesteri paraliae* (p. 61)

Seta 5-II seldom with less than 12 branches; seta 1-X usually weak and shorter than saddle. . . . . *crawfordi* (p. 54)

ANOPHELES (ANOPHELES) SINENSIS WIEDEMANN
(Figures 2, 8, 10, 11, 12)

Anopheles sinensis Wiedemann 1828: 547 (♂, ♀).
Anopheles plumiger Dönitz 1901: 37 (♂, ♀).
Anopheles jesoensis Tsuzuki 1902: 764 (♂).
Anopheles (Anopheles) hyrcanus var. *sinensis* of Edwards 1932: 41.
Anopheles (An.) sinensis Wiedemann, Reid 1953: 10 (♂*, ♀*, P*, L*, E*); Reid 1968: 85 (♂*, ♀*, P*, L*, E*); Harrison 1973a: 7 (lectotype).

Adult females can usually be recognized by: narrow apical tarsal bands, short basal dark mark on vein Cu, wing with wide pale apical fringe spot, remigium mostly pale scaled, humeral crossvein with scale patch or several scales, preapical dark mark on R_1 with few pale scales, apex of vein R_1 with dark scales and usually pale fringe spot at apex of vein Cu_2. Adult males have the above, but lack a basal pale band on palpal segment 3.[2] The pupae have the trumpet rim thin and uniform and have a distinct pattern of dark spots on the wing case. The larvae are more difficult to distinguish: seta 6-I and III usually have more branches than those of the other species; the spiracles are large; and setae 5, 6-C usually have more branches.

FEMALE (Figs. 2, 8, 10) *Head.* Vertex with pale erect scales above interocular area, dark erect scales laterally; frontal tuft with long pale setae; clypeus with tuft of dark scales on each side; pedicel with few small pale scales on external aspect, and pale scales on most basal flagellomeres; proboscis with dark scales, erect basally and appressed distally; labellum paler than labium; palpus usually with narrow apical and basal pale bands on segment 5, additional pale bands or spots at segmental joints 3 - 4 and 2 - 3, and a dorsomesal row of pale scales on segment 2. *Thorax.* Anterior promontory with long fine pale scales mesally, broader darker scales laterally; scutal integument light brown usually with dark brown median line extending back to prescutellar area, often with paired dark lateral lines on anterior dorsocentral bare areas, with dark eyespots, scutum sparsely covered with very fine seta-like curved silvery-yellow scales, and with longer stout golden setae in anterior promontory, acrostichal, dorsocentral, lateral prescutal, fossal, antealar and supraalar groups; scutellum with long golden setae and small fine curved pale scales; anterior pronotum with patch of dark erect scales on dorsocephalic aspect, setae caudally; pleural integument light brown or gray, usually with darker areas in form of upper and lower dark lines, may have several scales on lower sternopleuron; pleural setae: 4 - 10 propleural, 2 - 5 spiracular, 8 - 13 prealar, 5 - 6 upper and 5 - 9 lower sternopleural, 6 - 12 upper and 0 lower mesepimeral. *Wing.* Costa largely dark with subcostal and preapical pale spots and occasionally pale scales near humeral

*This couplet is valid for approximately 90% of the specimens collected in Thailand, thus reared adults with associated skins are the best means of positive identification.

crossvein (see taxonomic discussion); subcostal pale spot includes costa, tip of subcosta and R_1; preapical pale spot includes costa, R_1 and R_2; remigium usually pale on anterior margin, posterior margin with proximal and distal dark scales; humeral crossvein usually with 3 - 6 small dark scales, infrequently bare; base of vein R-R_1 with variable scaling, usually with distinct presector and sector pale areas, scattered pale scales between sector and subcostal pale spots and between subcostal and preapical pale spots; tip of R_1 with dark scales; R_S - R_{2+3} with basal dark mark, gradually paler to pale area just before fork; R_2 dark scaled except for pale spot equal to preapical pale spot on costa and R_1, tip dark scaled; R_3 dark scaled on base and tip; R_{4+5} largely pale, with apical and basal dark spots with scattered dark scales in between; M usually dark scaled on basal 0.5 or more, with pale area just before fork; M_{1+2} with small dark spots at base and tip, may have scattered dark scales in between; M_{3+4} as for M_{1+2}; Cu with small dark spot at extreme base followed by pale spot, then "basal" dark mark equal to or less length of most basal pale mark on Cu, and separated by own length or usually more from most basal dark spot on 1A; Cu pale scaled distal to basal dark mark; Cu_1 with dark basal and apical scales, in between usually with central vein scales pale and most lateral vein scales dark; Cu_2 pale scaled except for dark scaled tip; 1A pale scaled except small dark spot approximately midway along vein, and dark scaled tip; apical dark spot on 1A usually longer than apical dark spot on Cu_2; apical pale fringe spot extends from R_1 to slightly beyond R_{4+5}; caudal margin of wing usually with pale fringe spot adjacent to Cu_2; tertiary fringe scales paler than secondary and primary fringe scales except at pale fringe spots. *Halter*. Stem pale, knob dark scaled. *Legs*. Coxae with pale scales, midcoxa with 3 - 5 upper setae and upper and lower patches of pale scales. Foreleg: femur usually dark scaled dorsally and apically, with dirty yellow scales ventrally; tibia dark dorsally, paler ventrally; tarsomeres dark scaled except paler scales on venter of tarsomere 1 and narrow apical pale band approximately equal segment width on tarsomeres 1 - 3. Midleg: femur with dark brown scales on dorsoanterior aspect, dirty yellow scales on ventroposterior aspect; tibia with dark scales on dorsoanterior aspect, dirty yellow scales on ventroposterior aspect; tarsomeres as on foreleg except apical pale scales more in form of dorsoapical spots than true apical bands. Hindleg: femur dark scaled dorsally and apically, with yellow scales ventrally except at apex; tibia as for midleg, and also with few dorsoapical white scales; tarsomeres dark scaled except few yellow scales on venter of tarsomere 1 and small dorsoapical white scale patches on tarsomeres 1 - 4. *Abdomen*. Integument dark dorsally, paler ventrally, with long golden setae, devoid of scales except median tuft of erect dark scales near caudal margin of sternum VII.

MALE (Figs. 2, 10). Resembles female in wing and leg markings. *Head*. Second palpal segment with dorsomedian line of pale scales; 3rd palpal segment without basal pale band. *Genitalia*. Basimere with lateral and dorsal pale scales; inner parabasal spine with sharply hooked tip, outer spine straight, slender and longer than inner spine; mesal subapical spine long, slender and curved; tergum IX with long slender processes, tips slightly expanded; aedeagus with 3 - 6 pairs of leaflets, larger leaflets with several teeth toward the apex and with small basal denticles; ventral lobe of claspette with 2 - 3 setae as long as or longer than spines on dorsal lobe, and several smaller setae clustered at their bases; dorsal lobe of claspette with club formed from at least 3 spines on the inner half, while outer half contains a single spine which is bifid apically and adjacent to fused club.

PUPA (Fig. 11) *Cephalothorax*. Light to moderate pigmentation, wing case

with darkest pigmentation in form of distinct rows of round dark spots, infrequently with lighter pigmentation on veins or crossbars. *Trumpet.* With thin uniform rim, without secondary cleft or tragus. *Abdomen.* Terga III - VII without or with central dark spot; seta 5 with relatively few branches, 9 - 24 on segment V; 1-VII with 1 - 5 branches; 9-VIII, with well developed branches. *Paddle.* Refractile border about 0.65 paddle length; setae 1, 2-P single, or 1-P may be frayed.

LARVA (Fig. 12) *Head.* Seta 2-C simple, 3-C with 60 - 80 branches forming distinct tuft with branches difficult to count; 4-C with 2 - 8 branches; frontal setae, 5, 6-C with 16 - 24 and 16 - 21 branches respectively; 8-C with 7 - 14 branches; 9-C with 6 - 9 branches. *Antenna.* With spicules, largely on inner aspect; seta 1-A long, with 6 - 14 branches. *Thorax.* Seta 1-P without sclerotized base, simple or branched near tip; 2-P with prominent sclerotized base and 9 - 13 branches; 11-P with 3 - 6 short, stout branches; prothoracic pleural tubercle with long stout spine; 14-P with 7 - 12 branches; 4-M with 4 - 8 branches from a central stem, not sinuous; 3-T palmate, with small number of unpigmented branches, without filaments. *Abdomen.* Seta 1 partially developed and pale on segments I - II, well developed (palmate) and pigmented on III - VII, leaflets without well developed shoulders, but most with sharply pointed tips; 6-I with 21 - 28 branches, 6-III with 17 - 29 branches; 5-II with 9 - 20 branches; 9-III with 8 - 14 branches; 13-IV with 3 - 6 long slender branches from base; 5-VI with 6 - 11 branches; pecten with 7 - 9 long teeth and approximately double that number of small teeth; seta 1-X at least as long as saddle.

EGG. None were examined during this study. Reid (1968) reports that the eggs of *sinensis* have an unusually broad deck, making up about 0.33 the width of the egg; float ribs about 30 - 35. The egg illustrated by Ho et al. (1962) as *sinensis* in East China, has the wide deck, but shows only 29 ribs occupying somewhat less of the lateral aspect than indicated by Reid.

TYPE-DATA. A female lectotype was designated and described for *sinensis* by Harrison (1973a), and deposited in the Universitetets Zoologiske Museum, Copenhagen, Denmark. This specimen is in excellent condition and bears the following data on 2 labels: "Coll. Westerm." and "*Anopheles sinensis* Wied. China, Trentepohl." A female paralectotype, in good condition, is also deposited in the above museum. Two additional paralectotypes, a male and a female in very poor condition, are deposited in the Naturhistorisches Museum, Vienna, Austria. The 2 latter specimens were listed as the types for *sinensis* by Stone et al. (1959) and Reid (1968). The type-specimens of *plumiger* Dönitz, are located in the Zoologisches Museum, Humboldt Universität, Berlin, while the location of the type of *jesoensis* Tsuzuki, is unknown (Stone et al. 1959).

DISTRIBUTION (Fig. 11). This species can be collected nearly anywhere in Thailand except possibly in the most precipitous and heavily forested areas. It is particularly abundant in rice growing areas and rice is a major crop throughout Thailand. Consequently, the distribution map (Fig. 11) is actually one of potential distribution, rather than one based entirely on examined specimens. Scanlon et al. (1968) listed collections made from 24 provinces. Specimens (30♂, 74♀, 63 larvae and 106 larval and pupal skins) located in the USNM, were examined from the following provinces of THAILAND: Chanthaburi, Chiang Mai, Chiang Rai, Chon Buri, Lampang, Mae Hong Son, Nonthaburi, Phra Nakhon, Prachuap Khiri Khan and Tak. Aside from the provinces listed above and in Scanlon et al. (1968), specimens of *sinensis* were examined in Thailand in 1969 from 3 other provinces: Buriram, Lop Buri and Sara Buri.

Several hundred additional specimens located in the USNM and identified as

sinensis, were also examined and confirmed from: BURMA, CAMBODIA, CHINA (Canton, Yunnan), HONG KONG, INDIA (Assam), INDONESIA (Sumatra), MALAYSIA (Peninsular Malaysia), NORTH VIETNAM, JAPAN (Ryukyus), SINGAPORE, SOUTH VIETNAM and TAIWAN. Harrison (1973a) listed *sinensis* from Java in error.

TAXONOMIC DISCUSSION. This was one of the 1st *Anopheles* species reported from Thailand (Theobald 1910), and while there was early confusion concerning the name to be applied, most of the early records of *hyrcanus* group species from Thailand probably apply to this species. It was not until Reid's (1953) revision of the Southeast Asian *hyrcanus* group that it became possible to identify the group members and define their distribution with any degree of certainty.

Reid (1953) commented on the frequent presence of pale scales on the basal portion of the costa on specimens from China. Specimens in the USNM from Canton, Yunnan, Hong Kong, Taiwan and the Ryukyus show this feature. In addition, many exhibit a paler wing pattern. These specimens also exhibit more extensive pale scaling on the antennal flagellomeres. Specimens from North Vietnam, South Vietnam and Cambodia were darker, with fewer pale scales on the antennal flagellomeres, like the specimens from Thailand, Malaysia and Singapore. Too few specimens were available from Assam, Burma and Indonesia to indicate trends.

Immature stages from the Ryukyus, Taiwan and Hong Kong were checked and found to be similar to Thailand specimens. Although the pupal wing cases normally had less pigmentation, the distinct dark spots were still usually discernable.

After examining the specimens in the USNM and material in Thailand it is evident that confusion still exists regarding the identification of the adults and immatures of *sinensis*. This confusion is most often exemplified in the inclusion of several other species under the name *sinensis*, rather than the identification of *sinensis* under some other name. Species most often misidentified under *sinensis* are: *crawfordi* and *nigerrimus* as adults; *nigerrimus* and *nitidus* as pupae; and *crawfordi* and *nitidus* as larvae.

Confusion between *sinensis* and *nigerrimus* stems mainly from the highly variable hindtarsal banding found in adult *nigerrimus* (see p. 68), and a small degree of pigmentation overlap on the pupal wing case. However, the differences in pupal seta 5-V (*sinensis* 9 - 24 branches; *nigerrimus* 40 - 60 branches) are sufficiently different to separate these species. Confusion between the pupal stages of *sinensis* and *nitidus* is probably due to the occasional occurrence of very pale *sinensis*; however, seta 5-V is still the differentiating character. The larvae of these 2 species may rarely overlap, but the branches on head setae 5, 6-C, 6-III and the number of long pecten teeth should usually separate them. *Anopheles crawfordi* and *sinensis* adults are very similar and frequently confused. This problem is aggravated by variation in *sinensis*, but the characters presented in the key are still adequate for separating over 95% of the specimens encountered. Occasional larval specimens of *crawfordi* and *sinensis* are quite difficult to separate. When the key characters break down due to overlap, then the worker should check the number of branches on setae 5-C (*sinensis*, 16, normally 17 - 24; *crawfordi*, 13 - 16), 6-C (*sinensis*, 16, normally 17 - 21; *crawfordi*, 14 - 17), and seta 9-III (*sinensis*, 8 - 14; *crawfordi*, 5 - 11). Rare confusion may occur between *sinensis* and *lesteri paraliae* larvae; however, *paraliae* is always very darkly pigmented and has fewer branches on seta 5-II (6 - 10) than does *sinensis* (9 - 20). As a last resort there is one character that will differentiate *sinensis* larvae from nearly all others. This

character is most difficult to see and even more difficult to determine because it involves counting setal branches. Seta 15-C has 10 or more branches on *sinensis* larvae, while only rare specimens of *nigerrimus* ever reach this number and the other species have less than 10 branches.

One female from Chiang Mai was normal in all respects (including associated skins), except the preapical pale costal spot was missing on both wings. The absence of this spot left only one pale spot (subcostal) on the leading margin of the wing. Other *sinensis* collected with this specimen were all within the normal range of variation.

An. sinensis is a highly variable species. Variation is common in overall size, wing markings, larval chaetotaxy and the utilization of habitats. Apparently, *sinensis* exists in Thailand under near optimum ecological conditions, and thus exhibits the wide range of variations one would expect from a large gene pool.

BIOLOGY. This is one of the most abundant and widely distributed mosquitoes in Thailand. It is most characteristic of open agriculture lands (chiefly rice fields), but is not limited to this habitat. Immature stages have been collected from such varied habitats as: ground pools, pools beside a river, marshes, rice fields, stream margins, ditches, seepages, shallow ponds and sumps. All of these are normally fresh, shallow water habitats, usually with emergent vegetation (mostly grasses) and exposed to direct sunlight. No collections of this species have been made from brackish water, but large numbers were encountered along stream margins in Chiang Mai Province below hot springs which gave off a moderate sulphurous odor. In the Bangkok area, *sinensis* reaches peak seasonal abundance in October-November, when water reaches its highest level in the rice fields.

In mountainous regions *sinensis* should be considered a mosquito of the valleys, except in situations where extensive rice fields are at high elevations. Scanlon and Esah (1965) reported surveys in the Chiang Mai Valley area where *sinensis* was collected biting man at approximately 305 m, but not in the forested areas at higher elevations. During a 14 month period in 1965-1966, human biting collections made in small villages in an elevated, semiforested area in Kanchanaburi Province, yielded 9,303 mosquitoes, but no *sinensis* (Harinasuta et al. 1970). Wilkinson et al. (1970) reported on anthropophilic mosquitoes collected in a jungle camp in the Petchabun Mountains, and only recorded a single *sinensis* in 15 nights of collections. Its apparent low incidence at higher forested elevations is also supported by larval collection records. However, since *sinensis* is primarily a zoophilic species, low numbers or its absence in human biting collections can not be considered a true indication of population levels. In northern Thailand and the central valley, observations (SEATO Laboratory unpublished report) made for nearly 10 years indicate that *sinensis* is almost entirely zoophilic.

In comparative biting tests involving man and cows, almost none of the *sinensis* were attracted to man. Similar results have been reported by Reid (1968) from Malaysia. Moderate numbers of *sinensis* were collected at night in Lop Buri and Sara Buri Provinces by placing dry ice inside partially opened army bed nets and at one hour intervals closing the nets and collecting those mosquitoes attracted by the carbon dioxide. Apparently, *sinensis* is exophilic, for extensive resting collections in houses in Bangkok yielded almost no specimens (SEATO Laboratory unpublished report).

MEDICAL SIGNIFICANCE. Apparently *sinensis* is of little or no significance to human health in Thailand. The species is zoophilic, exophilic and furthermore, the areas of maximum *sinensis* populations in Thailand coincide primarily with areas of little or no malaria transmission. Iyengar (1953) reported

sinensis in south Thailand with microfilariae of *Brugia malayi*; however, it is uncertain which members of the group were involved in Iyengar's "*hyrcanus sinensis*" and "*hyrcanus nigerrimus*", as this study was prepared prior to Reid's (1953) revision of the group. Harinasuta et al. (1964) examined a small number of unspecified specimens of the *hyrcanus* group in southern Thailand, but found none infected. Reid et al. (1962) reported that natural infections found in members of this group (not *sinensis*) in Malaysia were animal filariae of the genus *Setaria*. During the same study *sinensis* was considered refractory to experimental infection with periodic *B. malayi* because only 3 of 99 infected adults developed mature larvae. Reid et al. (1962) also claimed that Hodgkin (1937, 1939) obtained similar results with *sinensis* infected with semi-periodic *B. malayi*. According to Ho et al. (1962) *sinensis* is a filaria vector of some importance in the Yangtze Valley area of China where *B. malayi* is prevalent, and that it is also responsible for low levels of malaria endemicity in the open plains, while *lesteri lesteri* is the main malaria vector in eastern China. The situation may be even more complicated in China for at least 3 other sibling species besides *lesteri lesteri* and *sinensis* have been called "*sinensis*" in the past (Ho et al. 1962). Regardless of the Chinese situation, there is no substantiated data available that incriminates *sinensis* as a vector of human pathogens in Thailand.

ANOPHELES (ANOPHELES) ARGYROPUS (SWELLENGREBEL)
(Figures 9, 13, 14, 15)

Myzorhynchus argyropus Swellengrebel 1914: 334 (♀*).
Anopheles hyrcanus var. *argyropus* of Christophers 1924: 30.
Anopheles (Anopheles) hyrcanus aberration *argyropus* of Edwards 1932: 41.
Anopheles hyrcanus typicus var. *pseudopicta* of Swellengrebel and Rodenwaldt 1932: 69 (not Grassi 1899).
Anopheles (Anopheles) argyropus Swellengrebel, Reid 1953: 36 (♂*, ♀*, P*, L*, E*).
Anopheles (Anopheles) argyropus (Swellengrebel), Reid 1968: 113 (♂*, ♀*, P*, L*, E*).

Adults may be recognized by a combination of extensive pale bands on the hindtarsi, long basal dark mark on vein Cu_2, remigium mostly dark scaled and a tuft of dark scales on the humeral crossvein. The male lacks a pale band at the base of palpal segment 3. The pupa is easily recognized by the parallel folds vertical to the trumpet rim, and seta 9-VIII (lateral spine) without branches or with few very fine branches. The larva can be recognized by the number of branches on setae 8-C, 14-P, 5-IV, the shape of tergal plate VIII and other key characters. Like *sinensis* except:

FEMALE (Figs. 9, 13) *Head.* Palpus dark, with 4 well defined pale bands, (sometimes only 3, when apical 2 bands confluent), and usually a few pale scales on inner surface of segment 2. *Thorax.* Scutal integument very dark, with darker prominent eye-spots, median and lateral dark lines and numerous golden setae; anterior promontory with narrow pale mesal scales and dark lateral scales, rest of scutum without scales; pleural setae; 3 - 7 propleural, 2 - 4 spiracular, 5 - 6 prealar, 2 - 4 upper and 4 - 6 lower sternopleural, 3 - 6 upper and 0 lower mesepimeral. *Wing.* Costa dark, except small subcostal and preapical pale spots; remigium with few pale scales; humeral crossvein with patch of dark scales; vein R with few pale scales between base and sector pale spot, often between sector and subcostal pale spots, no pale scales on

preapical dark mark; tip of R_1 dark scaled; subcostal pale spot often small, ill-defined, sometimes missing; R_S - R_{2+3} dark; R_{4+5} usually with few dark scales in median pale area; vein M dark except pale area just before fork; extreme base of Cu with small dark spot usually followed by short pale area and long "basal" dark mark, which approaches or reaches within its own length of upper dark mark on vein 1A; 1A usually with short upper and apical dark marks, infrequently these 2 marks fused and apical half of vein dark scaled; Cu_2 with apical dark mark longer than that on 1A; apical pale fringe spot variable, usually extending from R_1 to R_{4+5}, but may be shorter, between R_1 and R_3; posterior margin of wing without pale fringe spot at Cu_2. *Legs.* Midcoxa with 3 - 4 upper setae. Foreleg: femur dark scaled; tibia pale ventrally, may have very small apical pale spot. Midleg: femur dark scaled; tibia with venter pale scaled and apical pale spot; tarsomeres 1 - 3 with very narrow apical pale bands. Hindleg: tibia with distinct apical pale spot; tarsomere 1 with apical band; tarsomere 2 with longer apical band extending onto base of 3; tarsomere 3 with wide apical pale band extending well onto the base of 4; apical pale band of 4 extending well onto base of tarsomere 5; in some specimens tarsus may be entirely pale from middle of tarsomere 3 to the tip, usually however, at least a trace of dark median band on tarsomere 4.

MALE (Fig. 13). General markings as for the female. *Head.* Palpal segments 2 - 3 often with scattered, pale scales, base of segment 3 without pale band, segment 4 - 5 with pale bands, that on 5 occupying most of segment. *Genitalia.* Basimere with numerous pale scales ventrally, some darker scales laterally; tergum IX with long posterior processes, tips expanded; aedeagus with 2 pairs of leaflets (rarely 3), with small serrations; ventral lobe of claspette with 2 setae, mesal seta longer than club on dorsal lobe, and smaller lateral seta. Dorsal lobe of claspette with 3 spines which fuse apically to form club on inner half, and 2 spines on outer half adjacent to fused club.

PUPA (Fig. 14) *Cephalothorax.* Wing case with pattern of lines and spots, forming rectangles in some areas, spots not darker than other pigmentation; tip of antennal case dark. *Trumpet.* Rim thin and uniform, with parallel vertical wrinkles on sides. *Abdomen.* Terga III - VII with central dark spot; setae 1 and 5 densely branched on segments III - VI; seta 9-VIII spine-like or with few short, fine branches. *Paddle.* Refractile border long, about 0.8 - 0.9 paddle length; setae 1, 2-P usually single.

LARVA (Fig. 15) *Head.* Seta 3-C with 70 plus, crowded branches; 5, 6-C with 12 - 16 and 12 - 19 branches respectively; 8, 9-C with 13 - 22 and 9 - 16 branches respectively. *Thorax.* Seta 1-P usually with 2 - 3 fine apical branches; 2-P with 8 - 13 branches; 11-P with 5 - 6 stout branches from base; 14-P with 6 - 11 branches; 4-M with 6 - 12 branches from base, usually not sinuous; 3-T with flattened branches, not fully developed palmate. *Abdomen.* Seta 1 palmate, poorly developed on segments I - II, well developed and uniformly pigmented on segments III - VII, filaments uncolored; 2-II with 6 - 9 branches; 5-II with 9 - 15 branches; 6-I, III with 16 - 19 and 15 - 20 branches respectively; 9-III with 6 - 13 branches; 5-IV with 4 - 10 branches; 5-V with 4 - 6 branches; 5-VI with 5 - 6 branches; 9-VI with 4 - 5 branches; 13-IV with 7 - 10 short branches (cf. *sinensis*); tergal plate VIII sometimes roughly hexagonal instead of ovoid or roughly rectangular; pecten with 6 - 8 long teeth, usually 7; seta 1-X strong, longer than saddle; posterior tergal plates much darker than anterior tergal plates.

TYPE-DATA. The type-locality is Deli, Sumatra, INDONESIA. The type-specimen, a female, appears to have been lost and Reid (1953) designated plesiotypes (with larval and pupal skins) from MALAYSIA, which are in the BMNH.

DISTRIBUTION (Fig. 14). This species was infrequently collected, usually with other members of the *hyrcanus* group, from widely scattered provinces in Thailand. Specimens (4♂, 20♀, 2 larvae and 8 larval and pupal skins) in the USNM were seen from the following provinces of THAILAND: Chiang Mai, Chanthaburi, Chon Buri, Narathiwat, Pathum Thani, Phra Nakhon and Udorn. Besides the provinces listed by Scanlon et al. (1968) specimens were examined in 1969 in Thailand from Buriram and Sara Buri. The authors also examined 4♂, 27♀, 2 larvae and 12 larval and pupal skins of *argyropus* in the USNM from: CAMBODIA, INDIA (Assam), INDONESIA (Java and Sumatra) MALAYSIA (Peninsular Malaysia) and SOUTH VIETNAM. An additional 19♀ from CAMBODIA were found in the ORSTOM collections (Centre de ORSTOM, Bondy, France).

TAXONOMIC DISCUSSION. The accumulated differences in the adult and immature stages make this one of the easiest species of the *hyrcanus* group to recognize in Thailand. The overall impression is that it is more distantly related to *sinensis* than are the other members of the Southeast Asian *hyrcanus* group. Reid (1968) has suggested that it is in a connective position between the Southeast Asian *hyrcanus* group and the *coustani* species group of the Ethiopian region. The species in the latter group have the pupal trumpet with a series of vertical wrinkles, and most members have the hindtarsi pale distal to the apex of tarsomere 3 (Gillies and de Meillon 1968). None of the members of the *coustani* group occur east of Israel (Margalit and Tahori 1970) and southwestern Arabia, and *argyropus* has its westernmost distribution in Assam. We have recently examined specimens of *hyrcanus* (synonym = *pseudopictus* Grassi) females from Afghanistan. These resembled *argyropus* in the extent of pale markings on the hind tarsus, but had small numbers of dark scales in the pale areas and differed somewhat in wing pattern. Three specimens of *argyropus* from Java, obtained through the courtesy of the Instituut voor Tropische Hygiene, Amsterdam, were also examined. These bore the label "*pseudopicta* Grassi" and were presumably mentioned by Swellengrebel and Rodenwaldt (1932). These last 3 specimens had reduced subcostal pale spots (also seen on some Thai specimens) but were otherwise typical *argyropus*.

Reid (1953, 1968) said *argyropus* shows closest relationship to the southeast Asia *hyrcanus* group through *peditaeniatus*. This was justified by similarities in: the long refractile border on the pupal paddle; the spinelike seta 9-VIII on the pupa; broad hindtarsal bands on the adults; palpal scaling; and yellow-orange pale scales on the wings. He also pointed out at least 2 dissimilarities with larval *nigerrimus*: antennal shaft shape and the number of branches on seta 5-IV.

The authors feel that *argyropus* is more closely related to *nigerrimus* than to *peditaeniatus*. Studies of all 3 species over wide areas of their distributions (Reid 1963, 1968) and herein show that hindtarsal banding is highly variable. All 3 species exhibit essentially the same variation in palpal scaling and all can have yellow-orange scales on the wings. *Anopheles argyropus* is similar to *nigerrimus* in many ways: Adult - humeral crossvein with a patch of dark scales; remigium mostly dark scaled; midtarsi with narrow apical pale bands; 2 - 3 pairs of leaflets on male aedeagus; Pupa - trumpet without thickened, sawtooth areas (although *argyropus* does have vertical wrinkles); many branches on setae 1 and 5 on segments III - VI; Larva - many branches on setae 8, 9-C, seta 3-C with 70 or more branches, and lastly a common larval habitat, i.e., deep marshes and canals. *An. peditaeniatus* differs markedly from all the above: no scales on humeral crossvein, remigium mostly pale scaled; midtarsomere 3 with wide pale band, 4 - 7 pairs of leaflets on male aedeagus; trumpet with thickened sawtooth areas; setae 1 and 5 on pupal segments III - VI

with relatively few branches; larval seta 3-C with 40 - 70 branches, larval setae 8, 9-C with few branches, and a shallow larval habitat such as grassy ponds, swamps and rice fields. *An. argyropus* differs from *nigerrimus* by lacking a pale band at the base of 3rd palpal segment of male; absence of any pale scales on the base of the costa; having parallel vertical wrinkles on the pupal trumpet; and having a somewhat intermediate number of long pecten teeth (*nigerrimus*, 4 - 7; *argyropus*, 6 - 8; *peditaeniatus*, 7 - 9).

A few specimens of *peditaeniatus* examined from Thailand, verified by associated larval and pupal skins, had the hindtarsal bands nearly identical to those seen on *argyropus* with narrower than average bands. Similar specimens of *peditaeniatus* were also examined from Cambodia, South Vietnam and Malaysia. These 2 species should not be confused. The midtarsal banding is very distinct and there are also differences in the scales on the humeral crossvein, remigial scaling, pale scaling on the base of vein R and the preapical dark spot on vein R_1. The use of hind tarsal banding to separate these 2 species should be avoided.

Some confusion might arise over the identity of *argyropus* larvae because the branching of seta 4-M arises from the base and occasionally the branches are slightly sinuous like those of *peditaeniatus*. This problem can be resolved very quickly by counting the branches on setae 8, 9-C, those of *argyropus* have many more branches (see descriptions).

Two specimens of *argyropus* from Chiang Mai were found to have the hindtarsi entirely white distal to the middle of tarsomere 3, otherwise they were normal. Several other specimens from Thailand were examined which had only faint dark bands on hindtarsomere 4, and only the tip of hindtarsomere 5 dark scaled. Similar specimens with excessively pale hindtarsi were examined from Peninsular Malaysia, Indonesia (Java) and South Vietnam.

Additional variations noted on specimens of *argyropus* were: apical female palpal segment entirely pale; reduced subcostal spots on the costa; base of vein Cu dark scaled halfway to the fork; and apical 0.5 of vein 1A dark scaled. The latter variation was noted on several specimens from Thailand.

BIOLOGY. Adults of *argyropus* have been collected in small to moderate numbers in light traps in Bangkok during most months of the year. The largest numbers appeared in November - January, between the end of the monsoon rains and the cool season when surface waters were stable and at their greatest extent. Small numbers have been taken during human biting collections in Bangkok, Buriram, Chiang Mai, Chon Buri, Narathiwat, Pathum Thani, Sara Buri and Udon Thani. This species has also been collected in Chanthaburi Province in a Shannon trap with a light and men inside and in Sara Buri Province in a net trap baited with dry ice (carbon dioxide). Scanlon and Esah (1965) report that no *argyropus* were collected in heavily forested areas, and that far more were attracted to domestic animals than to man during their collections. In Thailand, immature stages have been collected from rice fields and deep seepage washes. Reid (1968) reported immatures collected in Malaysia from large deep swamps. Deep swamp and canal habitats need further examination in Thailand.

MEDICAL SIGNIFICANCE. As might be expected from the largely zoophilic habits, there is no evidence that *argyropus* is a vector of human pathogens anywhere in its range. Warren et al. (1963) evaluated Malayan *argyropus* as a vector of the simian malaria parasite, *Plasmodium cynomolgi bastianellii* Garnham, and found it almost refractory to infection. Harinasuta et al. (1970) dissected 12 *argyropus* in Kanchanaburi Province, Thailand, and found them negative for *Brugia* and *Dirofilaria* filariae.

ANOPHELES (ANOPHELES) CRAWFORDI REID
(Figures 9, 16, 17, 18)

Anopheles (Anopheles) crawfordi Reid 1953: 41 (♂*, ♀*, L, P, E*); Reid 1968: 102 (♂*, ♀*, P*, L*, E*).

Adults can usually be recognized by the narrow hindtarsal bands, wide apical pale wing fringe spot, pale scales on the coxae and male basimeres, a wing pattern consisting of rather short sharply defined dark spots on a generally pale field, and the tip of vein R_1 pale. The male lacks a pale band at the base of the 3rd palpal segment. Identification of the larva and pupa is much more difficult and the characters outlined in the keys and description must be consulted. This species is similar to *sinensis* except for:

FEMALE (Figs. 9, 16) *Head.* Palpus with sharply defined pale bands, some pale scales on segment 2, with few or none on segment 3 other than band. *Thorax.* Scutal integument basically grayish, without well developed dark lines, with very prominent eye spots; pleural setae: 2 - 5 propleural, 3 - 4 spiracular, 6 - 9 prealar, 3 - 5 upper and 3 - 5 lower sternopleural and 5 - 9 upper mesepimeral; occasionally 1 - 2 scales on latter area. *Wing.* Costa dark with usual subcostal and preapical pale spots, humeral area may have small humeral spot or 1 - 3 pale scales on one wing; humeral crossvein without scales; R with few pale scales on basal 0.33, with well developed sector pale spot; R_1 without pale scales on preapical dark area, with pale scales on tip; R_S-R_{2+3} with distinct dark basal mark, then pale to dark mark at fork; R_2 and R_3 largely pale; R_{4+5} with short basal and apical dark marks pale in between; vein M mostly pale, but with scattered dark scales near base; extreme base of Cu pale, or with several dark scales, followed by pale area, then short well defined dark mark which is separated by its own length or more from upper dark mark on vein 1A; Cu_1 and C_2 with very short apical dark marks; 1A with short upper dark mark, apical dark mark usually equal to or less than length of apical dark mark on Cu_2; pale apical fringe spot extending from R_2 to just beyond R_{4+5}; posterior margin without pale fringe spots. *Legs.* All coxae with pale scales; midcoxae with 3 - 4 upper setae. Foreleg: tibia without pale knee spot; tarsus with moderately wide apical pale bands on tarsomeres 1 - 3. Midleg: tarsus with apical pale bands on tarsomeres 1 - 4, those on tarsomeres 1 - 3 markedly narrower than those on foretarsus. Hindleg: tarsus like that of midtarsus, no basal banding.

MALE (Fig. 16) *Head.* Inner dorsal surface of palpal segments 2 & 3 may have prominent line of pale scales; palpal segment 3 without basal pale band (see taxonomic discussion); palpal segments 4 - 5 largely pale scaled. *Genitalia.* Basimeres with few pale scales; inner parabasal spine with sharply hooked tip; tergum IX with long posterior processes, tips slightly expanded; ventral lobe of claspette with 2 setae, mesal seta distinctly longer than lateral seta and spines on dorsal lobe; dorsal lobe of claspette with fused club on inner half formed from at least 3 separate stems; outer half of dorsal lobe with 2 flattened, leaflet-like spines adjacent to fused club; aedeagus with 4 - 7 pairs of leaflets, largest with well developed teeth at apex and along one margin, with basal denticles on the first 2 leaflets.

PUPA (Fig. 17) *Cephalothorax.* Integumental pigmentation variable, from light to heavy, usually with well marked pattern of dark lines forming squares or rectangular areas on wing case; antennal case usually with apex and most apical joint darkly pigmented. *Trumpet.* Pigmentation tan except darker

thickened areas on rim; rim with thickened areas of erect saw-like teeth; meatal cleft narrow. *Abdomen.* Terga III - VII with central dark spot; seta 1 with fewer branches than seta 5 on IV - VII; 1-VI with 2 - 6 branches; 5-V with 30 - 45 branches. *Paddle.* Refractile border approximately 0.55 - 0.65 of paddle length; 1-P with few apical branches.

LARVA (Fig. 18) *Head.* Seta 3-C with approximately 50 crowded branches; 5, 6-C with 13 - 16 and 14 - 17 branches respectively; 8, 9-C with 6 - 11 and 5 - 10 branches respectively. *Thorax.* Seta 1-P simple or with 2 - 3 short, thin branches near tip; 11-P with 4 - 6 stout branches from base; 14-P with 6 - 9 branches; 4-M with 4 - 8 branches from erect central stem; 3-T with slightly flattened and unpigmented branches. *Abdomen.* Seta 1 with slightly flattened, very lightly pigmented branches on segments I - II, well developed (palmate) and deeply pigmented on segments III - VII, pigment not extending onto filaments; 6-I and III with 16 - 21 and 15 - 21 branches respectively (rarely 20 - 21); 5-II with 10 - 18 branches; tergal plate VIII oval; pecten with 7 - 8 long teeth (infrequently 6 on one side); seta 1-X weak, usually shorter than saddle.

TYPE-DATA. The ♀ holotype and ♂ allotype, both with associated immature skins on slides, plus 1♂ and 3♀ paratypes are deposited in the BMNH. Reid (1953: 43) clearly says the type-locality is Kuala Lumpur; however, none of the above types are so labeled, although each has been identified by Reid and has an appropriately colored BMNH type-label on it. The ♀ is in excellent condition and has the following label data: (1st label) - "Selangor, 5th mile Kepong, 15-11-1950, J. A. Reid"; (2nd label) - "No 8445/11, larvae in swamp overgrown with vegetation"; (3rd label) - "*Anopheles (A.) crawfordi* Reid, Det. J. A. Reid"; (4th label) - round circular red label without writing; (5th label) - circular label with "holotype"; and (6th label) - "liason pelts in slide collection." The ♂ allotype is also in excellent condition with genitalia still intact, and has the following label data: (1st label) - "Selangor, 5 1/2 Kl. - Kepong, 28-3-1951, J. A. Reid"; (2nd label) - "No 454/62, larvae in swamp overgrown with vegetation"; (3rd label) - "*Anopheles (A.) crawfordi* Reid, Det. J. A. Reid"; (4th label) - round circular red label without writing; (5th label) - circular label with "Allotype ♂"; and (6th label) - "liason pelts in slide collection." The ♂ and 3♀ paratypes have the same data as the allotype except: all are numbered "No 454"; each has circular "paratype" label; and they lack the "liason pelt" label. The ♂ paratype is in excellent condition with genitalia intact, while the 3♀ paratypes have lost their heads.

DISTRIBUTION (Fig. 17). This species does not appear to have a continuous distribution throughout Thailand. It is most often encountered in the southern or southeastern parts of the country. Certain climatological factors may be partially or wholly responsible for the distribution of *crawfordi* (see biology section). The authors currently feel *crawfordi* will probably not be found in the dryer parts of the country, i.e., areas of western, northern and northeastern Thailand. Specimens (14♂, 26♀, 17 larvae and 41 larval and pupal skins) in the USNM were seen from the following provinces of THAILAND: Chanthaburi, Chon Buri, Narathiwat, Nakhon Ratchasima, Songkhla, Surat Thani, Trat and Yala. Besides these provinces and those listed by Scanlon et al. (1968), specimens were examined during 1969 in Thailand from Chumphon and Ranong. Also examined were 9♂, 24♀ and 10 larval and pupal skins of *crawfordi* in the USNM from CAMBODIA, INDIA (Assam), MALAYSIA (Peninsular Malaysia) and SOUTH VIETNAM. The type-specimens (2♂, 4♀ and 4 larval and pupal skins) from MALAYSIA were examined in the BMNH, and 7♀ from CAMBODIA were found in the ORSTOM collections. Additional literature records apply to

INDONESIA (Sumatra).

TAXONOMIC DISCUSSION. The adults have the general appearance of small specimens of *sinensis*, and can easily be misidentified as that species without careful examination. The sharp appearance of the wing spots on *crawfordi* is usually a good character, but may be difficult to see in older, rubbed specimens. The wing of *crawfordi* is quite similar to that of *nitidus*, but the extensive pale banding on the hindtarsus of *nitidus* is distinctive. There are no apparent differences in tarsal banding between *crawfordi* and *sinensis*, thus the taxonomist is left with wing characters and pleural chaetotaxy for characters. The pale tip on vein R_1 and the absence of pale scales on the preapical dark area on vein R_1 of *crawfordi* are the most useful characters in separating it from *sinensis*. Even these characters are not absolute, for rare specimens of *sinensis* were noted from Thailand which exhibited either the tip of R_1 pale, or R_1 with the preapical dark mark entirely dark scaled. Reid (1953) noted 6% (3/50) of the *crawfordi* he studied had dark scales on the tip of R_1. This was rarely encountered during the present study, and was always confined to only one wing. A pale fringe spot at Cu_2, 6 or more propleural setae and a long apical dark mark on 1A are all generally indicative of *sinensis*, but should be used with caution.

Specimens of *lesteri lesteri* from Hong Kong were also noted as very similar to *crawfordi*, but had the tip of R_1 dark scaled, preapical dark mark on R_1 with some pale scales, no fringe spot at Cu_2, a long apical dark mark on 1A and no pale scales on the midcoxae and male basimeres.

Of the 19 males of *crawfordi* examined from Thailand, Cambodia, Assam and Malaysia, none exhibited signs of a pale band on the base of the 3rd palpal segment. This would be expected as *crawfordi* is most closely related to *lesteri* and *peditaeniatus*, and males of this subgroup lack a pale band at the base of palpal segment 3. However, Reid (1953, 1968) noted that males of *crawfordi* sometimes exhibit a small pale band at the base of this segment. Since we have not seen this trait on *crawfordi* we have no explanation, unless this is a localized or infrequent variation of *crawfordi*.

As noted earlier (Reid 1953), occasional specimens exhibit either 2 - 3 pale scales or a distinct pale spot on the humeral area of the costa. This variation is usually confined to one wing and can be of value in identifying *crawfordi*, particularly the males. Males without a pale basal band on palpal segment 3, but with a pale humeral spot or pale scales in that area will most probably be *crawfordi*. No males of *lesteri paraliae*, *peditaeniatus* or *sinensis* from Thailand, have been found with pale scales on the base of the costa.

The pupal stage of *crawfordi* is very similar to that of *lesteri paraliae*. The thickened, saw-tooth like areas on the trumpet rim are exhibited only in these 2 species and *peditaeniatus*; however, the latter species is easily separable by the spine-like seta 9-VIII and a long refractile border on the paddle. Separation of *crawfordi* pupae from those of *lesteri paraliae* is very difficult. The pupa of *lesteri paraliae* is very darkly pigmented, but infrequently that of *crawfordi* is very dark. Seta 1-VI on Thailand specimens of *crawfordi* have 4 - 6 branches rather commonly and thus overlap with the 5 - 10 branches found on *l. paraliae*. The number of branches on seta 5-V (see key, p. 43) is the most reliable character for differentiation of these 2 species, but it is also a tedious character to check. The pupa of *crawfordi* should never be confused with that of *sinensis* or the remaining species for they all have a thin and uniform trumpet rim or one with vertical wrinkles (*argyropus*). Difficulty is also encountered in the identification of the larvae of *crawfordi*, for specimens have been found which have only 10 - 11 branches on abdominal seta 5-II and

this overlaps with 6 - 10 branches found on *l. paraliae*.

Persons working in areas where *crawfordi* and/or *lesteri paraliae* night be encountered, should conduct sample rearings to determine the species involved. The adults of these 2 species are readily separable, while the reliability of separating the immature stages is no more than 90%.

The examination of specimens from Thailand in comparison with specimens from Assam, Cambodia, Malaysia and South Vietnam, revealed little variation. One male and 2 females of 13 Assam adults exhibited a reduction in the apical fringe spot on the wing to a size comparable with that on *lesteri paraliae*. Otherwise, these specimens were typical *crawfordi*, and are thus considered variations of *crawfordi*. Reid (1953: 50) commented on a tendency in this species for a reduction in the apical fringe spot.

BIOLOGY. The numbers of *crawfordi* adults encountered during studies in Thailand were usually small and dependent on the worker's location. However, several local areas were encountered in southern and southeastern Thailand where *crawfordi* was abundant. These areas usually had tropical wet forest nearby, and always received abundant precipitation. Larval requirements indicate this is essentially a forest-swamp species. Larvae are found in clear water and nearly always in moderate to heavy shade. Confirmed larval habitats in Thailand include: seepage pools or springs, shallow-slow moving streams, stream pools, ground pools, large deep ground pools and sapphire mining pits, swamp pools and nipa palm swamps. Nearly all of these habitats contained floating leaves and/or emergent vegetation such as grass. No collections of *crawfordi* larvae have been made from rice fields in Thailand (cf. *sinensis*). In Malaysia, Reid (1968) reported this species from swamps with tall emergent grass, and specimens in the USNM from Malaysia were collected from, "overgrown swamp, grassy swamp, marshy depression and a drain." According to climatological maps (Ohman 1965) nearly all of the specimens in the USNM from Assam, Cambodia, Malaysia, Thailand and South Vietnam came from areas which receive 2,032 mm or more of rain per year, and most over 2,540 mm. Over half of Thailand receives less than 2,032 mm per year and these areas constitute the majority of the country under cultivation. The wetter remaining areas contain the majority of the tropical wet and rain forest reserves. Although the association of heavy precipitation and tropical wet forests with *crawfordi* are probably only 2 of the factors that determine its distribution this seems to be a definite correlation that should benefit future collectors.

Most larval collections of this species in Thailand were made below 100 m elevation, but one collection was made at 600 m from Khao Yai National Park in Nakhon Ratchasima. Adults have been collected in Thailand from a Shannon trap baited with man and light, biting man and biting buffalos. All the man biting collections were made outside houses.

MEDICAL SIGNIFICANCE. Identification problems in the *hyrcanus* group in the past have left few valid records for use in vector interpretations. Currently, there is no evidence *crawfordi* is involved in the transmission of human pathogens in Thailand. Reid et al. (1962) and Wharton, Laing and Cheong (1963) were able to infect *crawfordi* with *Brugia malayi* from human reservoirs, but decided the species was probably too zoophilic or not abundant enough to play an important vector role in filariasis areas in Malaysia. Confirmed records show that considerable numbers of *crawfordi* bit man in certain areas of both Chon Buri and Chumphon provinces; the latter is known to harbor an endemic focus of *Brugia malayi* (Harinasuta et al. 1964). The vector status in that area is still undetermined, and other potential vectors are present, i.e.

Anopheles campestris and *Mansonia* species.

Wharton et al. (1964) found that *crawfordi* was much more attracted to man than to monkeys at ground level, and only slightly attracted to monkeys on canopy platforms. During the same study *crawfordi* was found a poor laboratory host for *Plasmodium cynomolgi bastianellii*. These same authors did not find malaria parasites in wild collected *crawfordi*.

ANOPHELES (ANOPHELES) NITIDUS HARRISON, SCANLON AND REID
(Figures 8, 19, 20, 21)

Anopheles hyrcanus nigerrimus type C of Crawford 1938: 51 (P*).
Anopheles (Anopheles) indiensis of Reid 1953: 29 (♂*, ♀*, P*, L*, E*); Reid 1968: 98 (♂*, ♀*, P*, L*, E*); Rattanarithikul and Harrison 1973: 7 (L*).
Anopheles (Anopheles) nitidus Harrison, Scanlon and Reid 1973: 266.

Adults are easily recognized by the combination of: wide pale bands on the hindtarsus, a bright, sharply defined wing pattern like that seen on *crawfordi*, pale scales on the basal 0.33 of the costa and on the preapical dark mark on vein R_1 and a patch of dark scales on the humeral crossvein. Males have a basal pale band on palpal segment 3. The larvae and pupae are more difficult to separate and the characters given below as well as those in the keys are necessary for their identification. Like *sinensis* except:

FEMALE (Figs. 8, 19) *Head*. Palpus with 4 distinct pale bands, 2 basal bands are usually narrow and well defined, usually some pale scales on segment 2. *Thorax*. Scutal integument gray-brown, with faint median and lateral dark longitudinal lines; eye spots particularly well developed; pleural setae: 2 - 5 propleural, 2 - 4 spiracular, 7 - 10 prealar, 3 - 5 upper and 4 - 7 lower sternopleural and 5 - 9 upper mesepimeral. *Wing*. Costa with small subcostal and preapical pale spots, and with scattered pale scales on basal 0.33, often forming small humeral pale spot; remigium usually with a proximal and distal black spot separated by white scales, with white scales on anterior margin; humeral crossvein with patch of dark scales; vein R with few pale scales on basal 0.33, well developed sector pale spot and subcostal pale spot usually incomplete; R_1 with scattered pale scales between subcostal and preapical pale spots, tip rarely pale scaled; R_S-R_{2+3} with distinct basal mark then white scales until dark mark at fork; R_2 rarely completely dark scaled; R_{4+5} usually with few scattered dark scales on pale middle section; M with scattered dark scales on basal 0.33, then short dark marks thereafter; Cu sometimes with several dark scales at absolute base, then pale scales followed by short "basal" dark mark separated by at least its own length from upper dark mark on vein 1A; 1A with upper and apical dark marks short, approximately equal in length; apical dark mark on 1A may be longer or shorter than apical mark on Cu_2; apical pale fringe spot extending from R_2 to slightly below R_{4+5}; posterior wing margin usually with pale fringe spot at Cu_2. *Legs*. Coxae with pale scales, upper portion of midcoxa with 0 - 1 seta. Foreleg: femur dark scaled; tibia dark scaled above and pale ventrally; tarsomere 1 dark scaled above and pale ventrally, with short apical pale band; tarsomeres 2 - 3 dark scaled with apical pale bands, that on segment 2 may approach 0.5 segment length; tarsomeres 4 - 5 dark scaled. Midleg: femur dark dorsally, pale ventally except at apex; tibia with small basal pale band, dark dorsally, pale ventrally; tarsomere 1 - 3 dark scaled with short apical pale bands, that on segment 2 approximately 0.2 seg-

ment length. Hindleg: femur dark dorsally, pale ventrally except apex; tibia with small basal and apical pale bands, dark dorsally and pale ventrally nearly to apical pale band; tarsomeres 1 - 5 black except apical pale bands on tarsomeres 1 - 4 and basal pale bands on tarsomeres 4 - 5 (infrequently 3); widest hindtarsal band at juncture of tarsomeres 3 - 4, apical band of tarsomere 3 is approximately 0.25 tarsomere length and basal band on tarsomere 4 is 0.17 - 0.20 segment length; basal pale band on tarsomere 5 very rarely absent. *Abdomen.* Often few narrow scales on the posterior lateral corners of tergum VIII.

MALE (Fig. 19) *Head.* Palpus with pale scales on segment 2; segment 3 with distinct basal pale band and frequently with scattered pale scales; segments 4 - 5 with patches of pale scales. *Wing.* Costa nearly always with pale humeral spot, besides scattered pale scales on basal 0.33. *Genitalia.* Basimeres with numerous broad pale scales; ventral lobe of claspette with 2 setae, mesal seta distinctly longer than lateral seta and club on dorsal lobe; dorsal lobe of claspette with fused club on inner half formed from 2 - 3 stems, outer half of lobe contains 2 flattened leaflet-like spines adjacent to fused club; aedeagus with 2 - 3 pairs of leaflets, largest with teeth along one edge and sometimes with basal tooth.

PUPA (Fig. 20). Integument generally very lightly pigmented. *Cephalothorax.* Wing case may have light spots and lattice pattern; apical joint and tip of antennal case usually darkly pigmented. *Trumpet.* Rim uniform and thin without thickened areas or vertical wrinkles. *Abdomen.* Usually almost colorless; alveoli of setae such as seta 2 rarely surrounded by dark pigment; seta 1 and 5 on segments III - IV with numerous branches; 5-V with 30 or more branches; 9-II - VII lightly pigmented; 9-VIII with numerous branches. *Paddle.* Refractile border approximately 0.65 - 0.80 of paddle length; paddle base rarely with pigmentation.

LARVA (Fig. 21) *Head.* Seta 3-C with 70 or more branches; 5, 6-C with not more than 18 branches; 8, 9-C with 11 - 21 and 6 - 13 branches respectively. *Thorax.* Seta 1-P simple or with 2 - 3 thin branches near tip; 2-P with 11 - 19 branches; 11-P with 4 - 6 stout branches from base; 14-P with 5 - 11 branches; 1-M with 19 - 32 branches; 4-M with 6 - 10 branches which usually arise close together near base; 3-T with flattened unpigmented leaflets. *Abdomen.* Seta 1 with flattened unpigmented leaflets on segments I - II, and well developed (palmate) with darkly pigmented leaflets on segments III - VII, pigment not extending onto filaments; 2-II with 8 - 14 branches; 6-I, III with 16 - 22 and 15 - 20 branches respectively (rarely 20 or more); 9-III with 10 - 16 branches; 5-IV - V with 5 - 9 branches each; 9-VI with 5 - 9 branches; 13-IV with 6 - 12 short branches (cf. *sinensis*); tergal plate VIII elliptical, with posterior margin convex; pecten with 5 - 7 long teeth; seta 1-X usually weakly developed, shorter than saddle; posterior tergal plates with equivalent or more pigment than anterior tergal plates.

TYPE-DATA. The type-specimens for *nitidus* were selected from specimens collected in Selangor, Malaysia, where Reid (1953) did considerable work on what he called *indiensis*. The holotype ♀, deposited in the BMNH, is in excellent condition, has associated immature skins on a slide and has the following label data: (1st label) - "Selangor, 5th m. Klang Rd., 7-11-1950, J. A. Reid"; (2nd label) - "bred in laboratory from known mother", and rearing number "28/9"; and (3rd label) - is Reid's *indiensis* identification label. The ♂ allotype, with associated immature skins on a slide, is also in the BMNH and has the same label data as the holotype, except the rearing number is "28/10". Two ♂ and 5♀ paratypes from Selangor, Malaysia, are deposited in the USNM. One ♂ with genitalia intact, associated immature skins on a slide and rearing

number "28/8" is from the same collection as the holotype and allotype. One ♀ with associated immature skins on a slide and rearing number "454/68" is from "Kepong." One ♂ with genitalia intact and collection number "232" is from "Ampang Rd., K. L." Two ♀ with collection number "16984" are from "Sungei Tua." The 5 paratypes just noted were collected by Reid between 1941 - 1951, while the remaining 2♀ paratypes have collection number "804" and were collected in "Ulu Langat" in 1967 by personnel from the University of Malaysia.

DISTRIBUTION (Fig. 20). This species apparently has a discontinuous distribution in Thailand, much like that of *crawfordi*. One larva which conforms to *nitidus* was collected in Chiang Mai and in addition, several adults were collected in Mae Hong Son. This extends the range far north of the current distribution concept. It is possible that *nitidus* extends into northern Thailand via the wet forest on the Bilauk Taung Mountain range which separates Burma and Thailand, or it will be found in isolated pockets in the north. Elsewhere, in the central valley near Bangkok, the southeast and the peninsular region, *nitidus* can be locally abundant. Generally, it is a foothill species with larvae occurring up to approximately 300 m elevation, but usually lower. Specimens (11♂, 75♀, 35 larvae and 54 larval and pupal skins) in the USNM were seen from the following provinces of THAILAND: Chanthaburi, Chiang Mai, Chon Buri, Krabi, Nakhon Si Thammarat, Narathiwat, Phangnga, Phuket, Prachin Buri, Ranong, Rayong, Satun, Surat Thani, Trang, Trat and Yala. Additional specimens were examined during 1968 - 69 from Chumphon, Mae Hong Son, Nakhon Nayok and Sara Buri Provinces. In addition to the above, 23♂, 63♀, 3 larvae and 14 larval and pupal skins in the USNM were examined from: CAMBODIA, INDIA (Assam), INDONESIA (Sumatra), MALAYSIA (Peninsular Malaysia) and SOUTH VIETNAM. An additional 3♂, 16♀ and 4 larval and pupal skins in the BMNH were examined from: MALAYSIA (Peninsular and Sarawak), NORTH VIETNAM and THAILAND (Trang). Other specimens (1♂ and 11♀) from CAMBODIA were found in the ORSTOM collections.

TAXONOMIC DISCUSSION. This species was previously called *indiensis* until Harrison, Scanlon and Reid (1973) determined that *indiensis* sensu Reid (1953, 1968) does not occur in Madras, India, the type-locality of *indiensis* Theobald. Since the type of *indiensis* Theobald 1901, is lost or non-extant and no other specimens are known, *indiensis* Theobald was synonymized under *nigerrimus* Giles 1900, and *indiensis* of Reid was renamed *nitidus*. The sharp appearance of the wings, scutal eye spots, pale scales on the base of the costa, short basal dark mark on vein Cu and broad fore-and hindtarsal pale bands, make adult *nitidus* quite distinct. In addition, the pale band on the base of male palpal segment 3 should readily separate *nitidus* from *crawfordi* males (see taxonomic discussion under *crawfordi*). Male *nitidus* nearly always exhibit a pale humeral spot on the costa. Some females of *nitidus* and *nigerrimus* are difficult to separate, however, an abundance of pale scales on R_1 between the subcostal and preapical pale spots is usually indicative of *nitidus*. The wide foretarsal pale bands are also indicative of *nitidus*, as *peditaeniatus* is the only other species with comparable bands.

The immature stages of *nitidus* are more difficult to distinguish. The pupa is most often confused with that of *nigerrimus* and *pursati*, but can also be misidentified under *sinensis*. All these species have a thin uniform rim on the trumpet, but, *sinensis* can be separated from the others by fewer branches on seta 5-V. Beyond this point *nitidus* can be separated by the characters given in the key. Larvae most often confused with *nitidus* are *argyropus*, *nigerrimus*, *crawfordi* and *lesteri paraliae*. Fortunately, branching of seta 8-C will usually separate the 2 last named species from *nitidus*, if not, then the branching of seta

9-III is quite reliable. If this character is not convincing, then seta 13-IV on *nitidus* is tufted with 6 - 12 short branches, while this seta on *crawfordi* and *lesteri paraliae* has 3 - 9 long stout branches. Separation of *nitidus* larvae from *nigerrimus* is more difficult. Besides the key characters, seta 9-VI has: 5 - 9 (*nitidus*) and 2 - 4 (*nigerrimus*) branches. The characters used in the key to separate *argyropus* and *nitidus* overlap to some degree, but should differentiate 95% of Thailand specimens.

Little variation was noted in the adults of *nitidus*. The hindtarsal banding was much more consistant throughout this species range than that found for *argyropus*, *nigerrimus* and *peditaeniatus*. One frequent variation is the presence or absence of a distinct pale humeral spot on the costa. Although nearly always present on males, this character is less constant on females, but usually present on at least one wing and infrequently absent.

BIOLOGY. In Thailand this species is usually found in foothill, non-rice agricultural areas which have been cleared of forest in the recent past and still have some primary or secondary forests nearby. Although Reid (1968) listed larvae commonly found in rice fields in Malaysia, larvae were rarely found in this habitat in Thailand. Apparently cool still water, emergent and/or floating vegetation and partial shade are among the basic larval requirements. Confirmed larval habitats in Thailand include: swamps (including nipa palm swamp), jungle bog, seepage marsh, large mine pits, large rock pool, stream pool, ground pool, roadside ditch, rice field and elephant footprint. Nearly all of these had light to heavy shade and emergent and/or floating vegetation. Concentrations of green algae were mentioned in several collections. This habitat pattern may explain the apparent absence of *nitidus* in the immediate Bangkok area, however, short trips to foothill areas in the north (Sara Buri) or to the south (Chon Buri) will put the collector back into localized *nitidus* populations.

In localized foci *nitidus* may bite man in some numbers. At a newly cleared land settlement in Chon Buri Province, this species made up the largest component of the "*hyrcanus* group" specimens reported by Scanlon and Sandhinand (1965). Numerous adults have also been collected biting man in a roadside park in Sara Buri and in small villages near rubber plantations in Nakhon Si Thammarat. Aside from human biting collections, this species has also been collected biting domestic bovines, by light trap, Shannon traps baited with man and light and in CO_2 net traps baited with dry ice. Reid (1968) notes that *nitidus* (as *indiensis*) in Malaya appears to feed mostly on cattle. Currently, data from Thailand are insufficient for confirmation of a zoophilic feeding behavior.

MEDICAL SIGNIFICANCE. Malaria research in Malaya (Wharton et al. 1963, 1964) did not find natural malaria infections in wild caught *nitidus* (as *indiensis*). This research also showed few adult *nitidus* attracted to monkey baited traps. Furthermore, Warren et al. (1963) showed experimentally that *nitidus* (as *indiensis*) had an extremely low susceptibility to *Plasmodium cynomolgi bastianellii*. Reid et al. (1962) and Wharton, Laing and Cheong (1963) did not find human filarial infections in Malayan *nitidus* (as *indiensis*), although the former showed this species to be a low to moderate experimental vector of periodic *Brugia malayi*. Likewise, there are no data from Thailand which suggest *nitidus* is a natural vector of human pathogens.

ANOPHELES (ANOPHELES) LESTERI PARALIAE SANDOSHAM
(Figures 9, 22, 23, 24)

Anopheles (An.) hyrcanus subsp., near *sinensis* of Colless 1948: 86 (♂*, ♀*, L*).

Anopheles (An.) lesteri Malayan form of Reid 1953: 7, 39 (♂*, ♀*, P*, L*, E*).
Anopheles (An.) lesteri paraliae Sandosham 1959: 189 (♀, L); Reid 1963: 101; Reid 1968: 105 (♂*, ♀*, P*, L*, E*).

Adults have narrow hind tarsal bands (usually apical only), humeral crossvein without a scale patch, short apical pale wing fringe spot and a long dark mark on the base of vein Cu. Males lack a basal pale band on palpal segment 3. The pupal trumpet rim has thickened areas with a distinct sawtooth margin. The larvae are darkly pigmented, have reduced branching of seta 8-C and have 7 or more long pecten teeth. As for *sinensis* except:

FEMALE (Figs. 9, 22) *Head.* Palpus usually with all 4 pale bands distinct, apical 2 bands may fuse, infrequently a small number of pale scales on segment 2. *Thorax.* Integument of scutum color ash-gray, with 2 short submedian lines on anterior portion; eye spots present, not as distinct as in *crawfordi* and *nitidus*; pleural setae: 3 - 6 propleural, 2 - 4 spiracular, 5 - 8 prealar, 3 - 6 upper and 3 - 8 lower sternopleural and 5 - 11 upper mesepimeral. *Wing.* Costa with small subcostal and slightly larger preapical pale spots, no other pale scales present; remigium usually dark scaled or with narrow anterior row of pale scales; humeral crossvein without scale patch, rarely with 1 - 2 small scales; vein R nearly entirely dark scaled out to distinct sector spot, subcostal pale spot frequently incomplete or absent; R_1 completely dark scaled between subcostal spot, when present, and preapical pale spot, tip dark scaled; R_S-R_{2+3} usually entirely dark scaled to fork; R_2 rarely entirely dark scaled; R_3 with pale central portion; R_{4+5} largely pale in center, frequently with scattered dark scales on distal half; vein M dark scaled to fork or with pale area before fork; extreme base of Cu usually with few black scales followed by distinct pale scaled area or area with scattered pale scales, then long dark mark which approaches within its own length or less of upper dark mark on vein 1A; vein 1A with 2 distinct dark marks, upper mark short, apical mark may be longer than upper mark and is usually longer than apical dark mark on Cu_2; apical fringe spot very small, widest extension from R_1 to R_3, but usually from R_2 to R_3; no pale fringe spot on posterior wing margin. *Legs.* Midcoxa without pale scales or rarely 1 - 2, and with 3 - 5 upper setae. Foreleg: dark scaled except for narrow apical pale bands or dorsal patches on tarsomeres 1 - 3 and infrequently very narrow apical pale patch on 4; apical bands on tarsomeres 1 - 2 longest, usually complete ventrally, not more than 0.2 length of tarsomere; pale scales on tarsomeres 3 - 4 dorsal and lateral only, not connected ventrally. Midleg: dark scaled except for narrow apical pale bands on tarsomeres 1 - 4, bands usually incomplete, not connected ventrally. Hindleg: dark scaled except white scales dorsally on apex of tibia and complete, narrow apical pale bands on tarsomeres 1 - 4; base of tarsomeres 4 - 5 infrequently with small dorsal patch of pale scales.

MALE (Fig. 22) *Head.* Palpus with well developed line of pale scales on inner surface of segments 2 - 3, base of segment 3 without pale band, pale scales on segments 4 - 5 variable from entirely pale dorsally to pale basal and apical bands. *Wing.* Base of costa without pale scales. *Genitalia.* Basimeres without pale dorsal scales or rarely with 1 - 2 gray or black scales; ventral lobe of claspette with long mesal seta and shorter lateral seta; dorsal lobe of claspette with fused club on inner half formed from 3 - 4 stems, outer half of lobe with 2 flattened leaflet-like spines adjacent to fused club; aedeagus with 4 - 5 pairs of leaflets, largest with well developed teeth, even on base.

PUPA (Fig. 23). Integument darkly pigmented. *Cephalothorax.* Wing case brown with barred or rectangular pattern on veins; antennal case dark brown at

joints and tip. *Trumpet.* Darkly pigmented, with dark thickened areas bearing saw-toothed edge. *Abdomen.* Usually with dark spot on center of terga III - VII and several other smaller dark areas; area surrounding alveoli of setae, such as seta 2, always darkly pigmented; seta 9 lightly pigmented on all segments, with numerous branches on segment VIII; seta 1, 5 on IV - V with relatively few branches; 1-VI with 5 - 10 branches; 5-V with 12 - 30 branches; male genital lobe darkly pigmented on distal 0.5. *Paddle.* Base darkly pigmented; refractile border 0.50 - 0.65 paddle length; seta 1 simple or forked at tip.

LARVA (Fig. 24) *Head.* Darkly pigmented; seta 3-C with 43 - 70 branches; 5, 6-C with 10 - 16 and 13 - 15 branches respectively; 8, 9-C with 5 - 11 and 6 - 11 branches respectively; 15-C with 2 - 7 branches. *Thorax.* Seta 1-P simple or usually with 2 - 6 fine branches on distal half; 11-P with 3 - 6 stout branches from base; 14-P with 5 - 8 branches; 4-M with 3 - 8 branches from erect central stem; 3-T with flattened unpigmented leaflets. *Abdomen.* Seta 1 with flattened unpigmented leaflets on segments I - II, well developed (palmate) and darkly pigmented on III - VII, pigment not extending onto filaments; seta 6-I, III with 17 - 21 and 17 - 23 branches respectively; 5-II with 6 - 10 branches; 9-III with 5 - 10 branches; 13-IV with 4 - 9 long branches; pecten plate with 7 - 10 long teeth; seta 1-X strong, longer than saddle; anal papillae usually shorter than saddle.

TYPE-DATA. Sandosham (1959) apparently based the naming of this subspecies on Reid's (1953) description of *lesteri* "Malayan form", but did not designate a type even though Reid had deposited specimens of the "Malayan form" in the BMNH. Reid (1963) designated a female in the BMNH with associated pupal and larval skins, as lectotype for this subspecies. The lectotype is in excellent condition with only the right antenna missing, and has the following labels: "Selangor, Klang, 1940, J. A. Reid"; "No. 16715/11, larvae in"; "*Anopheles (A.) lesteri* Baisas & Hu, Det. J. A. Reid"; "Liason pelts in slide collection"; "lectotype" in Reid's handwriting; and a BMNH lectotype label.

DISTRIBUTION (Fig. 23). Scanlon et al. (1968) listed this subspecies from 9 provinces of Thailand; however, further examination of the specimens in the USNM revealed that the specimens identified as *lesteri paraliae* from Ayutthaya, Nonthaburi, Pathum Thani and Phra Nakhon were actually *pursati* and the single specimen on which the Chiang Mai record was based was a female *sinensis* with an unusually short apical fringe spot. Apparently *lesteri paraliae* has a low elevation-coastal distribution in Thailand, like that in Malaysia (Reid 1968). Specimens (19♂, 21♀, 30 larvae and 46 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Chumphon and Surat Thani. Additional specimens (13♂, 22♀, 10 larvae and 10 larval and pupal skins) in USNM were examined from: MALAYSIA (Peninsular Malaysia), SINGAPORE and SOUTH VIETNAM. Beside the lectotype female, 3♂, 5♀ and 2 pupal and larval skins in the BMNH were examined from: MALAYSIA and THAILAND (Trang). Additional literature records refer to BRUNEI (Colless 1948).

TAXONOMIC DISCUSSION. This is one of the easiest members of the group to identify in the adult stage. The very narrow tarsal bands, narrow apical fringe spot on the wing, extensive dark areas on the costa and vein R-R_1, long basal dark mark on vein Cu and absence of scales on the humeral crossvein, is a very distinct combination of characters. Even when the apical wing fringe is missing the above characters should be indicative. Apparently, *pursati* is the species most frequently confused with *lesteri paraliae*, particu-

larly since both have a narrow apical fringe spot on the wing and narrow tarsal bands. However, a mostly pale remigium, a patch of scales on the humeral crossvein, a short basal dark mark on vein Cu and the presence of pale scales on the midcoxa should readily identify *pursati*. Beside these characters, *pursati* is the smallest member of the group, while *lesteri paraliae* is usually nearly equivalent in size to *sinensis*. Males of the *nigerrimus* subgroup (including *pursati*) all exhibit a basal pale band on palpal segment 3, numerous pale scales on the basimeres and usually pale scales on the basal 0.33 of the costa. Male *lesteri paraliae* do not show these characters and thus, by elimination become the only remaining species with a narrow apical fringe spot on the wing.

Differentiation of the immature stages is more difficult, with only approximately 90% currently separable. The pupa can be readily identified as belonging to the *lesteri* subgroup on the basis of the thickened saw-tooth areas on the trumpet rim. Further separation, from *peditaeniatus*, is also simple on the basis of the paddle margin and seta 9-VIII, but final separation from *crawfordi* is frequently difficult. The larva of *lesteri paraliae* is frequently the most difficult stage to identify. Past confusion was most often noted between this species and *sinensis*, *nitidus* and *crawfordi*, and the reader should refer to the taxonomic discussions of those species for explanations and possible solutions. Several other points may be of value in identifying larvae of *lesteri paraliae*, but because of potential overlap, should be used with extreme caution: the head capsule is consistently darkly pigmented (brown-black); suggested distribution in Thailand is confined to coastal-low elevation regions; and the immature stages are apparently capable of tolerating high salt concentration; thus, *lesteri paraliae* may be the only species in the group found in brackish water.

Anopheles lesteri was described from the Philippines and southern China and is currently known from the Philippine islands of Leyte, Luzon, Mindanao, Mindoro, Negros and Samar, and from China (in part), Japan, South Korea and the Ryukyus (Okinawa). The latter record is based on specimens in the USNM and is of considerable interest since this subspecies has not been reported from Taiwan. The nominate subspecies differs from *paraliae* in the greater development of the apical fringe spot, the other stages currently being indistinguishable from *paraliae*. Because of geographic isolation and the great morphological similarity, Reid (1953) indicated that the narrow fringe form probably deserved subspecific rank, but did not formally propose this. Sandosham (1959) apparently based his name *paraliae* entirely on Reid's description but failed to designate a type, consequently, Reid (1963) later selected a lectotype and paratypes [sic] from material in the British Museum. Thus, the nomenclatorial status of the narrow fringe type of *lesteri* is solidly established. Its biological status is another matter.

As noted in the remarks on distribution, *lesteri paraliae* is confined to coastal areas of Malaysia (Peninsular Malaysia, Sabah and Sarawak) Brunei, South Vietnam and Thailand. Reid (1968) stated that areas of overlap between *lesteri* (sensu stricto) and *paraliae* had not been found, and this still appears to be true. The islands of Balabac and Palawan appear to form a definite link between North Borneo (Sabah) and the larger Philippine islands, therefore, one might expect to find intermediates there; however, *lesteri* has not been recorded from either island. Ho et al. (1962) reported one of the forms they studied to be equivalent to *lesteri lesteri*; however, Feng (1964) and Ma (1964, 1968b) felt that possibly none of the 5 species masquerading under the name *sinensis* in China during the past is actually *lesteri*. Harrison (1973a), after examining reared specimens with associated skins from the Philippines and southern China (Hong Kong), supported the contention (Baisas and Hu 1936; Ho et al.

1962) that *lesteri lesteri* occurs on both mainland China and the Philippines. The possiblity that the mainland segment of the nominate subspecies is geographically isolated from *lesteri paraliae* is very likely, but more specimens are needed from southern China, North Vietnam and South Vietnam for confirmation. As can be seen, many problems will have to be solved before we will understand the *lesteri* subgroup.

There is no doubt that *paraliae* from Malaysia, South Vietnam and Thailand represents a distinct taxonomic entity. For the moment it is probably best to continue regarding it as a subspecies of *lesteri*, at least until the Palawan fauna is examined in more detail. One cannot help, however, but suspect that *paraliae* is a good species restricted to the coastal areas of mainland Southeast Asia and Borneo.

BIOLOGY. All the records of *l. paraliae* from Thailand are from coastal areas and collected near sea level, except for a couple of collections up to 150 m elevation. Immatures are typically found in semi-permanent to permanent bodies of water with open sunlight to moderate shade. Floating and emergent vegetation is usually present. The water can be clear or stained and may be brackish, but should be cool; consequently, *l. paraliae* will not normally be found in rice fields. Immatures were collected in Thailand from: large marshy depression, open "swamp", nipa palm swamp, large ground pool and large rock pool. The immatures from Malaysia and Singapore came from: earth drain, marshy depression, drain w/"peaty" water, unused well and pond with *Eichornia* species.

Colless (1948) originally collected *l. paraliae* biting man in Brunei, and Macdonald et al. (1967) collected small numbers biting man in Sarawak. Reid (1961) and Reid et al. (1962) found *l. paraliae* strongly zoophilic and reluctant to enter houses in Malaya. In Thailand adults have been collected biting man, but in small numbers.

MEDICAL SIGNIFICANCE. There is no evidence that *paraliae* is a vector of human disease in Thailand. Reid et al. (1962) found *Dirofilaria* sp. and *Setaria* sp. in wild caught *paraliae*, and in experiments found it to be moderately receptive to *Brugia malayi*. Warren et al. (1963) showed experimentally that *paraliae* was much more susceptible to *Plasmodium cynomolgi bastianellii*, than other members of the *hyrcanus* group. Wharton et al. (1964) showed that *paraliae* would feed on monkeys in the forest canopy. Since malarial parasites have not been found in this subspecies, it is not considered a vector of malaria. More work is needed on *paraliae* in Thailand as little is known of its biting behavior. Its role in filariasis is unknown although it is found in areas (Surat Thani and Chumphon) where *Brugia malayi* occurs (Harinasuta et al. 1964).

The report by Ho et al. (1962) that the primary malaria vector in the Yangtze Valley of China is *lesteri lesteri* not *sinensis*, is most significant. They found *lesteri* markedly anthropophilic, entering houses readily. These observations are apparently the opposite of the behavior ascribed to *lesteri lesteri* in the Philippines. However, before its behavior can be understood much more work is needed on this species in both areas.

ANOPHELES (ANOPHELES) NIGERRIMUS GILES
(Figures 9, 25, 26, 27)

Anopheles nigerrimus Giles 1900: 162 (♀*).
Anopheles sinensis indiensis Theobald 1901: 145.

Anopheles bentleyi Bentley 1902: 15 (♀*).
Anopheles minutus Theobald 1903b: 91 (♀).
Anopheles (Anopheles) hyrcanus var. *nigerrimus* of Edwards 1932: 41 (in part).
Anopheles hyrcanus var. *williamsoni* Baisas and Hu 1936: 222 (P, L*).
Anopheles venhuisi Bonne-Wepster 1951: 284 (♂*, ♀*, P*, L*), (nom. nov. for *hyrcanus* var. X Venhuis 1939).
Anopheles (An.) nigerrimus Giles, Reid 1953: 24 (♂*, ♀*, P*, L*, E*); Reid 1963: 100; Reid 1968: 92 (♂*, ♀*, P*, L*, E*).

The adults are generally similar to *peditaeniatus* and *sinensis*, but have a darker appearance. The basal 0.33 of the costa usually has some pale scales, the humeral crossvein has a scale patch, the basal dark mark on vein Cu is long and hind tarsomeres 4 and/or 5 usually (78%) have a pale basal patch or band. The male has a pale basal band on palpal segment 3. The pupa is usually darkly pigmented with a thin uniform trumpet rim and setae 1 and 5 with numerous branches on most abdominal segments. The larva has 12 - 24 branches on seta 8-C and very few branches on seta 5-IV. Separation of both immature stages from those of other members of this group may infrequently prove difficult. Like *sinensis* except:

FEMALE (Figs. 9, 25) *Head.* Palpus with 4 distinct pale bands, infrequently apical and subapical pale bands confluent, usually a mesal patch of pale scales on segment 2. *Thorax.* Scutal integument dark gray, with poorly defined dark longitudinal stripes and eye spots; pleural setae: 4 - 10 propleural, 2 - 4 spiracular, 5 - 11 prealar, 3 - 4 upper and 4 - 7 lower sternopleural and 4 - 7 upper mesepimeral. *Wing.* Costa dark with subcostal and preapical pale spots, and usually several scattered pale scales slightly distal to humeral area; basal 0.33 of costa rarely with small humeral pale spot on one wing or completely dark scaled; remigium largely dark scaled; humeral crossvein with distinct patch of dark scales; vein R with few scattered pale scales on basal area and distinct sector spot; subcostal spot on R often divided or with an indefinite area of mixed pale and dark scales; R_1 usually without pale scales between subcostal and preapical pale spots, tip with dark scales; R_S-R_{2+3} usually dark nearly to fork; R_2 infrequently entirely dark scaled; R_{4+5} infrequently with scattered dark scales on middle portion; base of M dark, with pale area just before fork; extreme base of vein Cu dark scaled, usually followed by short pale area, then long dark mark at least the length of preceding pale mark (when present); long basal dark mark on Cu approaching within its own length or less of upper dark mark on vein 1A; apical dark mark on Cu_2 rarely as long as corresponding mark on 1A; vein 1A normally with 2 dark marks, infrequently these connect making apical 0.5 of vein entirely dark scaled; apical pale fringe spot long, from R_1 to beyond R_{4+5}; pale fringe spot at vein Cu_2 on approximately 50% of the specimens. *Legs.* Coxae with white scales, 1 - 3 upper midcoxal setae. Foreleg: Femur dark scaled; tibia dark scaled dorsally, pale ventrally; tarsomere 1 pale scaled ventrally; tarsomeres 1 - 3 with apical pale bands, that on segment 2 may approach 0.33 length of segment; tarsomeres 4 - 5 dark scaled. Midleg: Femur and tibia dark dorsally and pale ventrally, apex of tibia usually with few pale scales; tarsomere 1 frequently with venter pale scaled on basal 1/3 - 1/2; tarsomeres 1 - 3 with narrow apical pale bands; tarsomeres 4 - 5 dark scaled. Hindleg: Femur and tibia dark dorsally, pale ventrally, apex of tibia with distinct dorsal pale spot; tarsomeres 1 - 4 with apical pale bands; pale markings on base of tarsomeres 4 - 5 highly variable (see taxonomic discussion). *Abdomen.* Integument dark, usually with few dark scales on the posterolateral corners of

tergum VIII.

MALE (Fig. 25) *Head.* Palpus with pale scales mesally on segments 2 - 3 and distinct pale basal band on segment 3, segment 4 with distinct basal pale band, segment 5 nearly entirely pale scaled dorsally, except lateral edge. *Wing.* Essentially as on female, except wing may appear paler, and basal dark mark on Cu may be slightly shorter. *Genitalia.* Basimeres with numerous pale scales; ventral lobe of claspette with 2 setae, mesal seta distinctly longer than lateral seta and fused club on dorsal lobe; dorsal lobe of claspette with fused club on inner half formed from 2 - 3 stems, while outer half of lobe contains 2 flattened leaflet-like spines adjacent to fused club; aedeagus with 2 - 3 pairs of leaflets, largest may have teeth along one edge, no basal tooth apparent.

PUPA (Fig. 26) Generally darkly pigmented. *Cephalothorax.* Wing case usually with mottled pattern of dark pigmentation; leg case along anterior margin of wing sheath uniformly dark brown; outer half of antennal case darkly pigmented, with distinct dark marks at each joint. *Trumpet.* Darkly pigmented, without thickened saw-tooth areas on rim, but may have dark border area delineating thin, uniform rim. *Abdomen.* Seta 9 lightly pigmented on all segments, with many branches on segment VIII; area surrounding alveoli of abdominal setae, particularly seta 2, always darkly pigmented; terga III - VII usually with a cental dark spot, as well as other dark spots; setae 1 and 5 on III - V with numerous branches; 5-V with 30 or more branches; 1-VII with 1 - 7 branches, usually 2 - 4; 6-VII mesal to seta 9-VII; male genital lobe darkly pigmented on distal half. *Paddle.* Base darkly pigmented; refractile border approximately 60 - 70% of paddle length; 1-P simple or split near apex into 2 - 4 equal branches.

LARVA (Fig. 27) *Head.* Moderately pigmented; seta 3-C with 70 or more branches; 5, 6-C with 11 - 18 and 11 - 17 branches respectively; 8, 9-C with 12 - 24 and 8 - 14 branches respectively. *Thorax.* Seta 1-P simple or with 2 - 4 branches on distal half; 11-P with 4 - 8 stout branches from base; 14-P with 4 - 8 branches, usually 5 or more; 1-M with 21 - 28 branches; 4-M with 5 - 10 stiff, erect branches from central stem; 3-T with flattened unpigmented leaflets. *Abdomen.* Seta 1 with flattened unpigmented leaflets on I - II, well developed (palmate) and darkly pigmented leaflets on III - VII, pigment not extending onto filaments; seta 6-I, III with 15 - 20 and 12 - 20 branches respectively; setae 5-III - IV with 4 - 8 and 2 - 4 branches respectively; 9-VI with 2 - 4 branches; pecten plate with 4 - 7 long teeth; 1-X approximately equal to length of saddle.

TYPE-DATA. The holotype of *nigerrimus* is a female from Calcutta, India, located in the BMNH, and with the following label data: (1st label) - "type"; (2nd label) - "7-4-99, Calcutta, Dr. C. W. Daniels"; and (3rd label) - "*Anopheles nigerrimus* type G. M. Giles." The last label is hand penned, possibly by Giles. This specimen is in very poor condition, with the following parts missing: palps; antennae, except 5 basal flagellomeres on left side; right fore- and midlegs from trochanter on; tarsomeres of right hindleg; T_5 of left foreleg; T_3 - T_5 of left midleg; T_2 - T_5 of left hindleg; abdomen; right wing; and fringe on left wing. The thorax is split lengthwise on top, and nearly all setae or scales on the scutum are missing. The pleural areas are in fair shape. The following minor additions and corrections can be added to Reid's (1953) description of the holotype. The remigium has a line of pale scales on the anterior margin, humeral crossvein with only 2 dark scales, base of costa without pale scales; and only 2 - 3 pale scales on preapical dark mark of R_1. The problems involved in the identification of the type of *nigerrimus* and its synon-

yms were covered in depth by Reid (1953). Since then, *sinensis indiensis* Theobald 1901, has been reassigned (Harrison, Scanlon and Reid 1973) as a synonym of *nigerrimus*. Unfortunately, the types for *indiensis*, *bentleyi*, *williamsoni* and *venhuisi* remain lost or unknown. *Anopheles minutus* Theobald 1903b, with its type in the BMNH, has long been considered a synonym of *nigerrimus*; however, Reid (1968) lists it as such only for convenience and says it may represent a distinct species. We agree with both Reid's feelings and treatment of *minutus*, and thus, include it as a synonym of *nigerrimus*.

DISTRIBUTION (Fig. 26). This is one of the most widely distributed anophelines in Thailand. Scanlon et al. (1968) list collections from 18 provinces, but the examination of additional specimens indicates this species may be encountered anywhere in the country where suitable larval habitats are found. For this reason, the map is marked to show a potential distribution through the entire country. Specimens (10♂, 46♀, 15 larvae and 38 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Chiang Mai, Chon Buri, Lampang, Nakhon Sawan, Nonthaburi, Pathum Thani, Phra Nakhon, Phuket, Prachin Buri, Rat Buri, Rayong and Udon Thani. Additional specimens were examined in Thailand during 1968-70 from Buriram, Chumphon, Lop Buri, Nakhon Nayok and Sara Buri provinces. From elsewhere, 19♂, 87♀, 10 larvae and 17 larval and pupal skins in the USNM were examined from: BURMA, CAMBODIA, INDIA (Assam, Bihar and Punjab), INDONESIA (Java and Sumatra), MALAYSIA (Peninsular Malaysia), SOUTH VIETNAM and SRI LANKA. In the BMNH, 6♂ and 14♀ specimens (including holotype) were examined from BANGLADESH, BURMA, INDIA, MALAYSIA (Peninsular Malaysia and Sarawak), SOUTH VIETNAM and SRI LANKA. Another 1♂ and 25♀ specimens from CAMBODIA were found in the ORSTOM collections. Additional literature records refer to: BRUNEI (Colless 1948); CHINA, Hainan Island (Ho 1938b); many islands in INDONESIA (Bonne-Wepster and Swellengrebel 1953); and MALAYSIA, Sabah (Colless 1948). All previous records of *nigerrimus* in the Philippines refer to *lesteri*, *peditaeniatus* or *pseudosinensis*. The above records of *nigerrimus* from Brunei, Sabah and Sarawak are very interesting, since this species is apparently replaced in the Philippines by *pseudosinensis*. The adult description given by Colless (1948) for *nigerrimus* should probably apply to *peditaeniatus* instead, since the following *peditaeniatus*-like characters were described: (1) Costa dark except for subcostal and preapical pale spots; (2) liberal sprinkling of pale scales along almost entire length of vein 1(R-R_1); (3) humeral crossvein without scales; and (4) fringe spot at vein Cu_2 rare. (cf. *nigerrimus*). The larval description for *nigerrimus* given by Colless does not clarify this discrepancy, for characters applicable to both species were given (i.e., outer clypeal branches, and sutural branches).

The records of *hyrcanus nigerrimus* from Yunnan (Yao and Ling 1937) and Hainan Island (Ho 1938b), China, probably refer to *peditaeniatus* (Reid 1953).

TAXONOMIC DISCUSSION. There has been considerable confusion surrounding the status and identity of this species in Thailand and elsewhere in Southeast Asia. Much of this confusion was settled by Reid (1953), particularly for the Malayan populations. However, certain characters are highly variable and unless studied elsewhere, our understanding of *nigerrimus* will remain very limited. One of these variables is the extent of pale bands on the hindtarsomeres. Reid (1953) noted that approximately 5% of the Malay specimens lacked a basal pale band on tarsomere 4. Consequently, these specimens would have only apical (*sinensis*-like) hindtarsal pale bands. Like *peditaeniatus* (Reid 1953, 1963, 1968), the trend for reduction of the hindtarsal

bands on *nigerrimus* is much more evident in the Indian subregion. During 1970-71 Smithsonian Institution personnel in Sri Lanka collected a variety of aquatic insects. Among the mosquitoes were 46 *peditaeniatus* and 6 *nigerrimus* adults. All of the *nigerrimus* exhibited *sinensis*-type banding, i.e., no basal pale bands on hindtarsomeres 4 - 5. Some of the *peditaeniatus* also exhibited reduced banding equivalent to the *sinensis*-type, but the majority had a narrow pale band on the base of hindtarsomere 4. The *sinensis*-type hindtarsal banding was also predominant on the other USMN specimens of *nigerrimus* from India (Assam, Bihar), and Reid (1968) reported that a series of *nigerrimus* from Rangoon, Burma also exhibited reduced tarsal banding. In Thailand this one variable character is probably responsible for the majority of misidentifications noted among *nigerrimus*-*sinensis* during this study. Of 46 females available from Thailand, 42 had intact hindtarsi, permitting an analysis of this character from 9 provinces, and from the extreme north to the south. Three hindtarsal catagories were selected for notation: (1) tarsomeres 4 - 5 with pale basal band or patch; (2) only tarsomere 4 with a pale basal band or patch; and (3) tarsomeres without pale basal bands or patch, *sinensis*-type banding. Table 3 shows the frequency distribution of this variation.

TABLE 3. Hindtarsal variation on Thailand *Anopheles nigerrimus* females

	Tarsomere 4 and 5 with pale basal band or patch	Tarsomere 4 only with pale basal band or patch	Tarsomeres without pale basal scales
Number	14	20	8
Percent	33.3	47.6	19.1

Nearly 20% of the specimens exhibited *sinensis*-type hindtarsal banding and only 33% had basal pale scales on both hindtarsomeres 4 - 5. The 48% in the middle category may prove of value in separating certain specimens from *nitidus* and *peditaeniatus*, which in Thailand nearly always have pale scales on the base of both tarsomeres 4 - 5.

The distribution of these categories in Thailand appears to be random, however, the sample size of this study was much too small for accurate measurement of trends. Overall, there are indications that the hindtarsal banding on *nigerrimus* exhibits clinal tendencies between Sri Lanka-India and Malaysia. Studies on this variation in the Indonesian area would be most helpful.

A few *nigerrimus* with pale basal bands on both tarsomeres 4 - 5 had a pattern approaching that found on Thailand *peditaeniatus*; however, they can be separated quickly by the remigium, humeral crossvein, base of costa and vein R-R_1 characters.

Another variable noted on Thailand *nigerrimus* is the extent of dark scales on vein 1A. Several specimens were noted with the apical half of this vein dark scaled. The holotype from Calcutta has a similar vein 1A. This variation was also seen on 2 specimens from the above mentioned Rangoon, Burma collection (P. F. Mattingly, 11-1963; ♂192B, ♀131C), as previously noted by Reid (1968). This is a variable that occurs in this group on 3 species, *argyropus*, *nigerrimus* and *peditaeniatus*, and is observed most frequently on *argyropus*.

The presence or absence of a pale fringe spot of vein Cu_2 is another variable character. Reid (1953) noted 68% of the females he examined from Malaya had this pale spot. In Thailand the frequency of this spot was lower, it occurred on only 53% (23/44) of the females examined. Only 2% (1/44) of females examined from India had this spot.

Scattered pale scales were nearly always present on the base of the costa; however, several specimens were noted without such scales, or with only 1 - 2 pale scales.

BIOLOGY. This is a lowland, valley species which seems to prefer deep cool water for the immature stages. Scanlon and Esah (1965) found *nigerrimus* in the agricultural area of the Chiang Mai Valley, near and in the city, but not at various elevations on the nearby forested mountains. In Thailand immatures have been collected from: city moat (canal), large open marshes, large stream pools and a rice field. Immature specimens from Malaysia were collected in large swamps, ground pools, a small pond and rice field. In general, these immature collections were made in semi-open large bodies of water with some emergent or floating vegetation, under open sunlight to moderate shade and up to 300 m elevation. This should not be interpreted as implying any rice field. The authors feel this species is probably found in those fields where the water depth is sufficient to keep the water temperature fairly cool. Adults have been collected in Thailand resting in cattle sheds and houses, biting cattle, horses and man, in light traps and in net traps baited with dry ice. In Malaysia adult females have been collected biting man outside and inside houses and found resting in houses at night (Moorhouse 1965). Although *nigerrimus* does feed on man, its degree of attraction to various hosts is not understood and needs more investigation. Broad spectrum studies like Bruce-Chwatt et al. (1966) suggest *nigerrimus* is primarily zoophilic, however, more concentrated efforts are needed on such suspect species in malarious areas. Studies on host range and feeding preferences like that of Sullivan et al. (1971) on *Aedes albopictus* (Skuse), are urgently needed for comprehension of anopheline feeding behavior in malarious areas.

MEDICAL SIGNIFICANCE. Hodgkin (1956) reported *nigerrimus* as a vector of malaria parasites in Malaya. However, more recent studies by Warren et al. (1963), Wharton et al. (1964) and Moorhouse (1965) were unable to clarify this report because of limited specimens. There are also reports of malaria parasite transmission by *nigerrimus* in Indonesia, but these records require caution in interpretation due to possible confusion with other members of the species group. Reid (1968) considers *nigerrimus* a malarial pathogen vector of low status.

The capabilities of *nigerrimus* as a vector of filarial parasites also needs further study. There are a number of early reports of human filarial larvae found in "*nigerrimus*". Iyengar (1953) reported an infection rate of 3.7% for *hyrcanus* var. *nigerrimus* in investigations of *Brugia malayi* in southern Thailand, but Harinasuta et al. (1964, 1970) were unable to find infected members of this group in Thailand. Many of these early reports probably refer to animal filariae such as *Dirofilaria* spp. and *Setaria* spp. (Reid et al. 1962, Reid 1968). Experimentally, *nigerrimus* has shown a low susceptibility to infection with periodic *Brugia malayi* (Reid et al. 1962).

ANOPHELES (ANOPHELES) PEDITAENIATUS (LEICESTER)
(Figures 8, 28, 29, 30)

Myzorhynchus peditaeniatus Leicester 1908: 31 (♂, ♀, L).
Myzorhynchus sinensis var. *peditaeniatus* of James and Stanton 1912: 61.
Anopheles (Anopheles) hyrcanus var. *nigerrimus* of Edwards 1932: 41 (in part); Baisas and Hu 1936: 221 (P*, L*, E*).
Anopheles (An.) peditaeniatus Leicester, Reid 1953: 32 (♂*, ♀*, L*, P*, E*).
Anopheles (An.) peditaeniatus (Leicester), Stone, Knight and Starcke 1959: 25; Reid 1968: 109 (♂*, ♀*, L*, P*, E*).

All stages of this species are relatively easy to identify. In general the adults have broad pale bands on the fore-and hindlegs, the remigium is pale scaled, humeral crossvein without scales, a long basal dark mark on Cu_2 and vein R-R_1 with numerous pale scales. In addition to the above the male lacks a pale basal band on palpal segment 3. The pupa is distinct on the basis of the long refractile margin on the paddle and seta 9-VIII spine-like, with reduced branches. The larva is easily separated by seta 4-M having sinuous branches. Like *sinensis* except:

FEMALE (Figs. 8, 28) *Head.* Palpus with 4 distinct pale bands, infrequently apical and subapical pale bands confluent, usually with mesal patch of pale scales on segment 2 and sometimes 3. *Thorax.* Scutal integument gray-brown, with darker median and submedian lines, eyespots poorly defined; pleural setae: 2 - 6 propleural, 2 - 4 spiracular, 6 - 11 prealar, 2 - 5 upper and 4 - 6 lower sternopleural and 4 - 9 upper mesepimeral. *Wing.* Pale scales may have white, yellow or dirty pale appearance; costa dark scaled except small subcostal and preapical pale spots; remigium mostly pale scaled with anterior margin always pale, pale scales infrequently glossy white; humeral crossvein bare, rarely with 1 - 2 scales; basal 0.33 of R with numerous scattered pale scales, sector and subcostal pale spots frequently confluent, R_1 nearly always with numerous pale scales between subcostal and preapical pale spots, rarely sector and subcostal pale spots incomplete or missing; tip of vein R_1 dark scaled; R_S-R_{2+3} with mixed dark and pale, or mostly pale scales to fork; R_2 dark scaled except preapical pale spot; R_3 with pale middle section; R_{4+5} mostly pale scaled, with proximal and distal dark marks; vein M with base mostly dark or dirty pale scaled, with pale area preceeding fork; vein Cu with long basal dark mark, approaching within its own length or less of upper dark mark on 1A; vein 1A with upper and apical dark marks infrequently confluent; apical dark mark on 1A longer than that on vein Cu_2: apical pale fringe spot long, starting at or slightly above vein R_1 and extending to vein R_{4+5}; pale fringe spot at Cu_2 rare. *Legs.* Coxae with pale scales, upper midcoxa with 3 - 5 setae. Foreleg: Femur dark scaled; tibia dark dorsally, pale ventrally; tarsomeres 1 - 3 with broad apical pale bands and tarsomere 1 pale ventrally; pale bands on tarsomeres 2 and 3 may approach 0.5 or more tarsomere length; tarsomere 4 - 5 dark scaled. Midleg: Femur and tibia dark dorsally, pale ventrally, both may have few dorsal pale scales at apices; tarsomere 1 usually with few ventrobasal pale scales; tarsomeres 1 - 3 with fairly broad apical pale bands, that on tarsomere 3 may approach 0.5 tarsomere length; tarsomeres 4 - 5 dark scaled. Hindleg: Femur and tibia dark dorsally, pale ventrally, tibia with distinct pale apical band; tarsomeres 1 - 4 with apical pale bands; tarsomere 4 and usually 5 with basal pale bands (see taxonomic discussion).

MALE (Fig. 28) *Head.* Palpus usually with mesal line of pale scales on

segments 2 - 3, no basal pale band on segment 3, segments 4 - 5 with pale patches and bands. *Genitalia*. Basimeres with numerous pale scales; claspette with 2, infrequently 3 long setae on ventral lobe, mesal seta distinctly longer than lateral seta; dorsal lobe of claspette with fused club on inner half formed from 2 - 3 stems, outer half of lobe with 2 flattened leaflet-like spines adjacent to fused club; aedeagus with 4 - 7 pairs of leaflets, largest with large apical-subapical teeth and small basal teeth.

PUPA (Fig. 29). Integument generally with light to moderate pigmentation. *Cephalothorax*. Wing case with faint to moderate pattern of bars, lines or squares, no dark spots; antennal case with moderate pigmentation at joints, but no prominent dark spots. *Trumpet*. Moderately pigmented, with saw-tooth areas on rim, these areas rarely difficult to see. *Abdomen*. Seta 9 lightly pigmented on all segments, without, or with very fine branches on segment VIII; terga III - VII with or without dark central spot; setae in general with few branches; seta 0 on II - VIII well developed and branched; seta 1 with few branches on V - VII, usually 2 - 3; 5-V with 14 - 28 branches; male genital lobe without dark pigmentation on distal half. *Paddle*. Base without dark pigmentation, area of refractile border and marginal teeth long, approximately 80% of paddle length; 1-P usually simple.

LARVA (Fig. 30) *Head*. Tan to dark brown; seta 3-C with 40 - 70 branches; 5, 6-C with 13 - 18 and 11 - 20 branches respectively; 8, 9-C with 4 - 9 and 3 - 7 branches respectively. *Thorax*. 1-P simple or with 2 - 3 distal branches; 11-P with 3 - 7 stout branches from base; 14-P with 3 - 7 branches, usually 4 - 5; 4-M small, with 4 - 10 sinuous branches radiating from base; 3-T with long, flattened, unpigmented leaflets. *Abdomen*. Seta 1 with flattened unpigmented leaflets on I - II, well developed (palmate) and darkly pigmented leaflets on III - VII, pigment frequently extending beyond poorly developed shoulders onto filaments; 6-I, III with 18 - 25 and 16 - 22 branches respectively; 0 on II - VII with relatively long sinuous branches; 5 on III - V with 6 - 14, 3 - 5 and 4 - 7 branches respectively; pecten plate with 7 - 9 long teeth; 1-X approximately equal length of saddle.

TYPE-DATA. Three female syntypes are in the BMNH collection. These specimens were supposedly selected by James and Stanton (1912) from the collection of the Institute for Medical Research, Kuala Lumpur, after Leicester's death. According to James and Stanton (1912: 59) Leicester's type-specimens were lost enroute to the BMNH, indicating a type had been selected by Leicester for *peditaeniatus*. However, Leicester (1908: 33) does not mention selecting a type-specimen, but says, "Described from a large series bred from larvae." The specimens in this series are considered syntypes here, and include those selected and sent to the BMNH by James and Stanton. All 3 syntypes in the BMNH have an alphabetical code that suggests a rearing designation. The 1st syntype has the following label data: (1st label) - "D"; (2nd label) - "Cotype" on circular BMNH label with "*Myzorhynchus peditaeniatus* Leic." on the underside; and (3rd label) - "Fed. Malay States, Dr. G. F. Leicester, 1912-350." This specimen is in poor condition. The 2nd syntype is also in poor condition and has the following data: (1st label) on underside of cardboard minutin stage, "1 mile lake, Batu Rd, 26/4/04"; (2nd label) - "E"; (3rd label) - "Cotype" on circular BMNH label with "*Myzorhynchus peditaeniatus* Leic." on the underside; and (4th label) - "Kuala Lumpur, Fed. Malay States, Dr. G. F. Leicester, 1912-350." The 3rd syntype has its legs and abdomen glued flat to a cardboard stage and is in excellent condition. This specimen has the following label data: (1st label) - on underside of minutin stage, "Pupa fr., Jail Pool, Kuala Lumpur, 16/4/03"; (2nd label) - "F"; (3rd label) - "Cotype" on circular

BMNH label with "*Myzorhynchus peditaeniatus* Leic." on the underside; and (4th label) - "Kuala Lumpur, Fed. Malay States, Dr. G. F. Leicester, 1912-350." This last specimen fits the concept of *peditaeniatus* in almost every respect. Two males were also selected and sent to the BMNH by James and Stanton to represent *peditaeniatus*, however, both are actually *nitidus* as pointed out by Reid (1953, as *indiensis*).

DISTRIBUTION (Fig. 29). This species was collected from most areas in Thailand, except those heavily forested or at high elevations. It is a predominant species in agricultural areas, particularly those with rice fields, and will be found as abundant as *sinensis*, or more so, in many areas. Specimens (28♂, 138♀, 49 larvae and 100 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Ayutthaya, Chanthaburi, Chiang Mai, Chiang Rai, Chon Buri, Krabi, Lampang, Nakhon Si Thammarat, Nan, Narathiwat, Nonthaburi, Pathum Thani, Phra Nakhon, Prachin Buri, Prae, Rayong, Surat Thani, Trang, Udon Thani and Yala. During the period 1968-70 additional specimens were examined in Thailand from Chumphon, Lop Buri, Mae Hong Son, Nakhon Ratchasima and Sara Buri. These records coupled with those listed by Scanlon et al. (1968) indicate a distribution throughout most of Thailand. Consequently, the distribution map (Fig. 29) is shown as such, although certain forested or mountainous areas may be free of this mosquito. Specimens (169♂, 492♀, 30 larvae and 38 larval and pupal skins) in the USNM from outside Thailand were examined: BURMA, CAMBODIA, CHINA (Fukien, Kweichow and Yunnan), INDIA (Assam, Bengal, Bihar and Punjab), INDONESIA (Java and Sumatra), MALAYSIA (Peninsular Malaysia), NEPAL, PHILIPPINES, SOUTH VIETNAM, and SRI LANKA. Beside the 3 syntypes, numerous male and female specimens were examined in the BMNH from: BURMA, INDIA (Bihar, Central Provinces, Mysore), INDONESIA (Sulawesi, Sumatra), MALAYSIA, NEPAL, PHILIPPINES, SRI LANKA and THAILAND (Chiang Mai, Phra Nakhon). An additional 2♂ and 17♀ specimens from CAMBODIA were examined in the ORSTOM collections. Additional literature records refer to BORNEO and the Lesser Sunda Islands in INDONESIA. There are several specimens in the USNM from Fukien, Kweichow and Yunnan provinces, China, which fit the usual description of *peditaeniatus*, except the hindlegs have only narrow pale bands. However, since this variation is known for *peditaeniatus* from Assam and other parts of India (see taxonomic discussion) an extension up into southern China is logical. Feng (1964) in his work on the cryptic species called "*sinensis*" in Kweichow Province based his divisions on egg structures. He described the adult of his "medium decked egg type" and this description fits the specimens in the USMN except for one detail. Feng notes the hindlegs have only narrow apical pale bands on tarsomeres 1 - 4; however, 2 females from Fukien and one from Kweichow also have a very small patch of pale scales on the base of tarsomere 4. The one female from Yunnan Province has the hind tarsomeres like Feng's description. One male from Fukien was available for examination, and fits the current concept of *peditaeniatus*. Unfortunately, the abdomen was missing and the genitalia could not be checked. Considering the southern Chinese distribution of *peditaeniatus*, the species recorded as *hyrcanus* var. *nigerrimus* from Hainan Island by Ho (1938b) probably refers to this species (see *nigerrimus* distribution). No specimens resembling *peditaeniatus* have been seen or reported from the Hong Kong area, or from Taiwan. Overall, *peditaeniatus* probably has the widest distribution of any Southeast Asian member of the group, particularly since it is now recognized from southern China. *Anopheles sinensis* was previously considered the most widespread species, but it does not occur west of Assam, in the Philip-

pines, or east of Sumatra in Indonesia. The identity of Palaearctic *sinensis* is still unclear.

TAXONOMIC DISCUSSION. Nearly all the adults examined from Thailand were readily identifiable on the basis of the wing characters and the width of the hind tarsal banding. Specimens with a pale scaled remigium and bare humeral crossvein associated with a long basal dark mark on vein Cu and broad hindtarsal bands, should be recognized immediately as *peditaeniatus*. The use of the hindtarsal bands as the primary indicator of *peditaeniatus* should be discontinued, for the size of these bands is highly variable throughout its range. In India and Sri Lanka the most frequently encountered phenotype has only a small basal pale band or patch on tarsomere 4, beside the narrow apical pale bands. Less frequently this basal band or patch of pale scales disappears, particularly in northern India (Assam) and Nepal, leaving only narrow apical pale bands on hindtarsomeres 1 - 4. Both of these phenotypes are also present in southern China as discussed above under "distribution." In the Philippines, at the other end of its distribution, the most frequently encountered phenotype of *peditaeniatus* has 2 broad pale bands on the hindtarsi, which involve basal pale bands or patches on both tarsomeres 4 - 5. This latter phenotype is the one most commonly encountered in Indonesia, Malaysia and most of Thailand. In the northern parts of Thailand and South Vietnam the phenotype with pale scales on the base of only tarsomere 4 becomes more abundant. In the Chiang Mai area of Thailand this phenotype accounts for at least 50% of the specimens. Occasional specimens are found which have extremely wide pale bands on the hindtarsi. In these, the dark band on tarsomere 4 may be so narrow, that it approximates the banding found on the hindtarsi of *argyropus*. Fortunately, wing characters and midtarsal banding easily separate these species. The remigium on *peditaeniatus* is often entirely pale scaled, particularly in India and Sri Lanka where it may have a silvery-white appearance (Reid 1953); however, frequent specimens were encountered from Thailand and Malaysia which retained pale scales on the anterior margin, but had dark scales on the distal half of the hind margin. Another variable wing character rarely encountered, is the presence of a pale fringe spot on vein Cu_2. Occasional specimens of *peditaeniatus* are encountered with the distal half of vein 1A dark scaled, or nearly so.

The immature stages are as easy to distinguish as the adults. The pupa is readily identifiable by the long refractile margin on the paddle, the spine-like seta 9-VIII and the thickened saw-tooth like areas on the trumpet rim. The first 2 characters are shared with *argyropus*, which has vertical wrinkles on the outside wall of the trumpet pinna instead of the thickened saw-toothed areas. Infrequent specimens were noted where the saw-tooth like areas were not as obvious as usual, but high magnification confirmed their presence. Even without these 3 characters the pupa can be associated with *sinensis* and the *lesteri* subgroup on the basis of the number of branches of seta 1 and 5 on most of the segments. The only exception to this is the low number of branches found on these setae on *pseudosinensis* (*nigerrimus* subgroup) from the Philippines. The similarity of the long refractile border on the paddle and the spine-like seta 9-VIII on pupae of *argyropus* and *peditaeniatus* is apparently superficial, for other characters on the pupa are quite different (e.g., number of branches on abdominal setae 1 and 5). These latter characters plus adult and larval characters have been used to show that *argyropus* and *peditaeniatus* are not closely related (Harrison 1972). The larva is also distinct, and easily separated on the basis of the sinuous branches on seta 4-M and the low number of branches on setae 8, 9-C. Some specimens of *argyropus* and *nitidus* may

have slightly sinuous branches on seta 4-M, but these species have numerous branches on seta 8-C. The examination of specimens with reared, associated larval and pupal skins from Malaysia, Philippines, Sri Lanka and Thailand, including many from the Chiang Mai area of northern Thailand, revealed *peditaeniatus* is a highly variable species.

BIOLOGY. The largest number of immature collections of *peditaeniatus* in Thailand have probably come from rice fields. The larvae, however, are not restricted to this habitat, for they have been collected in the following additional sites: open and shaded ditches, marshes, seepage areas, ponds, large open "swamps," temporary puddles, flood pools, stream margin, stream pools, animal footprints, shallow well, holes in logs on a river and a 250 l clay water jar. Apparently, the most favorable larval requirements involve shallow water, warm water temperature, light or no shade and some vegetation, particularly emergent grasses. Immatures have been collected up to 540 m elevation in Thailand, while adults have been collected at 570 m in Sri Lanka. In Thailand adults have been collected in light traps, in Shannon traps baited with light and humans, in net traps utilizing dry ice, resting on trees, resting in animal sheds, biting humans outside and inside homes and biting cattle and buffalo. Very few adults were taken resting in houses in 3 years of collecting in Bangkok, but much larger numbers were taken in animal shelters and in light traps. Reid (1961) determined that Malayan *peditaeniatus* preferred a calf over 2 men by a 11:1 ratio. In similar studies in Chiang Mai and Bangkok, Thailand, the overwhelming proportion of *peditaeniatus* fed on cattle.

MEDICAL SIGNIFICANCE. The zoophilic habits of *peditaeniatus* greatly reduce the probability of its being a vector of human disease pathogens. Reid et al. (1962) and Wharton, Laing and Cheong (1963) found *peditaeniatus* to be a good experimental vector of periodic *Brugia malayi*, but the former concluded the proportion biting man in nature was too small to pose a problem. Harinasuta et al. (1964, 1970) did not find this species infected with filariae during studies in endemic *B. malayi* and *Wuchereria bancrofti* (Cobbold) areas in Thailand. Warren et al. (1963) determined experimentally that *peditaeniatus* has a very low susceptibility to *Plasmodium cynomolgi bastianellii*. Wharton et al. (1964) found no evidence of parasites in 146 wild caught peditaeniatus dissected during malaria studies in Malaya. It is possible that this species is involved in the transmission of animal parasites, particularly cervid filariae of the genus *Setaria* (Reid et al. 1962, Reid, 1968). If these parasites are serious pathogens in cattle, then *peditaeniatus* should probably be considered an economic pest in Thailand.

ANOPHELES (ANOPHELES) PURSATI LAVERAN
(Figures 8, 31, 32, 33)

Anopheles pursati Laveran 1902: 907 (♀).
Anopheles hyrcanus var. *nigerrimus* of Reid 1947: 89.
Anopheles (An.) species D_2 near *nigerrimus* of Reid 1953: 49.
Anopheles (An.) pursati Laveran, Reid 1963: 98 (♂*, ♀*, P*, L*, E*); Reid 1968: 96 (♂*, ♀*, P*, L*, E*).

A small species with narrow hindtarsal bands, a short apical fringe spot on the wing, pale scaled remigium, dark scale patch on the humeral crossvein, short basal dark mark on vein Cu and pale scales on the midcoxa.

Beside these characters the male possesses a pale basal band on palpal segment 3. The immature stages are very similar to *nigerrimus*, but can be separated by the characters presented here. As for *sinensis* except:

FEMALE (Figs. 8, 31) *Head.* Palpus with 4 distinct pale bands, apical band very small and on tip of last segment, preapical dark band wide and distinct. *Thorax.* Integument gray-brown with eye spots poorly defined; pleural setae; 2 - 5 propleural, 2 - 4 spiracular, 6 - 9 prealar, 2 - 3 upper and 3 - 4 lower sternopleural and 2 - 4 upper mesepimeral. *Wing.* Blurred color pattern; costa usually dark scaled except small subcostal and preapical pale spots, infrequently with small pale humeral spot; remigium wholly pale, or with anterior pale and posterior dark scaled; humeral crossvein with patch of dark scales; vein R dark scaled at extreme base, usually with few pale scales or distinct pale spot at presector area, then dark scales followed by distinct sector pale spot; subcostal pale spot on R usually extending basally for some distance towards sector spot; vein R_1 rarely with pale scales between subcostal and preapical pale spots, tip dark scaled; R_S-R_{2+3} dark scaled basally, pale before fork; R_2 and R_3 dark scaled except pale continuation from preapical pale spot on costa; R_{4+5} pale centrally, may have few scattered dark scales in pale area; vein M dark basally, pale prior to fork; vein Cu with pale scales at extreme base, that pale area as long as or longer than following basal dark mark; basal dark mark on Cu usually short, separated by more than its own length from upper dark mark on vein 1A, infrequently longer and approaching within its own length of upper dark mark on 1A; vein 1A with upper and apical dark marks approximately equal in length; apical dark mark on 1A approximately equal that on vein Cu_2; apical pale fringe spot short, extending at most from R_1 to R_3, often smaller, from R_2 to R_3; posterior margin of wing dark scaled, rarely with fringe spot at Cu_2. *Legs.* Coxae with pale scales, upper midcoxa with 1 - 2 setae. Foreleg: Femur dark scaled; tibia dark scaled dorsally, pale ventrally, may have small pale spot at apex; tarsomere 1 - 3 with narrow apical pale bands, tarsomere 1 pale ventrally; tarsomeres 4 - 5 dark scaled. Midleg: Femur dark scaled; tibia dark scaled except small basal and apical pale band or patch; tarsomeres 1 - 3 dark scaled with narrow apical pale bands; tarsomeres 4 - 5 dark scaled. Hindleg: Femur dark scaled; tibia dark scaled except small basal and apical pale band or patch; tarsomeres 1 - 4 dark scaled except narrow apical pale bands; tarsomere 5 dark scaled. *Abdomen.* Posterior angles of tergum VIII without scales.

MALE (Fig. 31) *Head.* Palpal segment 3 with distinct pale basal band, segments 2 - 3 may have mesal line of pale scales, segments 4 - 5 with pale bands and patches. *Wing.* Costa nearly always with small pale humeral spot; infrequently with pale fringe spot at Cu_2. *Genitalia.* Basimeres with numerous pale scales; claspette with 2 setae on ventral lobe, mesal seta much longer than lateral seta; dorsal lobe of claspette with fused club on inner half formed from 2 stems, outer half of lobe with 2 flattened leaflet-like spines adjacent to club; aedeagus with 2 - 3 pairs of leaflets, largest with small subapical denticle.

PUPA (Fig. 32). Integument generally lightly pigmented. *Cephalothorax.* Wing case usually with light tan pattern of squares and lines, may also have dark spots as on *sinensis* pupa; antennal case with or without pigment at joints. *Trumpet.* Lightly pigmented, without thickened saw-tooth areas on rim. *Abdomen.* Seta 9 lightly pigmented on all segments, 9-VIII with numerous branches; areas surrounding alveoli of setae pigmented, particularly seta 2; terga III - VII rarely with central dark spot; setae 1 and 5 with numerous branches on segments III - VI; 5-V with 45 or more branches; 1-VII with 3 - 13 branches, rarely less than 6; 6-VII cephalad of seta 9-VII; male genital lobe may have light

pigment on distal half. *Paddle.* Base may be pigmented; refractile border approximately 65 - 75% of paddle length; 1-P with 3 or more distal branches.

LARVA (Fig. 33). Generally light tan; 3-C with 45 or more branches; 5, 6-C with 11-16 and 12 - 18 branches respectively; 8, 9-C with 12 - 21 and 8 - 17 branches respectively. *Thorax.* 1-P usually simple, infrequently 2 - 3 distal branches; 11-P with 4 - 8 stout branches from base; 14-P with 3 - 5 branches, usually 3 - 4; 1-M with 26 - 38 branches, usually 28 or more; 4-M with 5 - 9 erect, stiff branches from central stem; 13-M with 6 - 9 branches; 3-T with flattened, unpigmented leaflets. *Abdomen.* Seta 1 with flattened, unpigmented leaflets on segments I - II, well developed (palmate) and pigmented leaflets on III - VII, pigment may extend onto filaments; 6-I, III with 11 - 20 and 12 - 17 branches respectively; 5-IV with 2 - 5 branches; posterior tergal plates conspicuously large on some specimens; pecten plate with 5 - 7 long teeth; seta 1-X slender, longer than saddle.

TYPE-DATA. The type-specimens, 2 females mounted in balsam on a microscope slide, are in the Pasteur Institute, Paris, where they were found by Reid (1947) after having been lost for over 40 years. The slide bearing the types contains the notation "*A. pensati*, Montagnes De Pensat, Cambodge, Févier 1902"; however, the original description clearly gives the locality as Pursat, or at least a mountainous wooded area west of that city. Reid (1953, 1963) redescribed *pursati* in detail and deposited specimens with skins from Malaysia in the BMNH. Based on an examination of the 2 *pursati* types we agree with Reid (1963) that his species D_2 near *nigerrimus* is equal to *pursati*.

DISTRIBUTION (Fig. 32). Specimens were taken from several widely scattered points in Thailand, conveying the impression that this species is widely distributed in the country, but uncommon. The majority of specimens examined came from the central valley, around and north of Bangkok. Reid (1963) reported specimens from the Thurman light trap collections in Chiang Mai, and 4 such specimens were located in the USNM. Specimens (14♂, 25♀ and 34 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Ayutthaya, Ang Thong, Chiang Mai, Nonthaburi, Pathum Thani, Phet Buri, Phra Nakhon, Surat Thani, Thon Buri and Udon Thani. Additional specimens were examined in Thailand during 1968-70 from Sara Buri Province. From elsewhere, 1♂, 2♀ and 6 larval and pupal skins in the USNM were examined from MALAYSIA (Peninsular Malaysia) and SOUTH VIETNAM. The last record is based on a female taken by light trap in 1967, from My Tho, in the delta province of Dinh Tuong. An additional 33♀ from CAMBODIA were examined in the ORSTOM collections. Reid's (1968) Malayan records and specimens are all from northern provinces. Apparently, *pursati*, is one of those species that is widely distributed in the monsoon areas of Indochina and Thailand, but does not extend further south than northern Peninsular Malaysia. Much additional collecting is needed for a better understanding of this species.

TAXONOMIC DISCUSSION. The small size of this species should always be considered, for only rare stunted members of the other species are found as small as *pursati*. In addition, the patch of dark scales on the humeral crossvein, narrow apical wing fringe spot, narrow hindtarsal bands, usually pale remigium and pale scales on the midcoxa make the adults of this species easily separable from the other species. The males are very distinct, for in addition to the above, they also have a pale band at the base of the 3rd palpal segment and a pale humeral spot of the costa. Some variation in adult wing characters was observed. The preapical pale spot on the costa is infrequently extremely small or even absent, a variation also noted on *sinensis*. The length of the basal dark mark on vein Cu is quite variable and consequently, should

not be used in Thailand for separating *pursati* from *lesteri paraliae*. Approximately 42% (10/24) of the adult females examined have this mark approaching within less than its own length of the upper dark mark on vein 1A. The Thai specimens differ from the Malayan specimens (Reid 1963, 1968) in this regard. This variation is apparently widespread in Thailand, and may be the cause for a number of *pursati* from the area around and north of Bangkok, having been previously misidentified as *lesteri paraliae*.

The pupa of *pursati* is very similar to those of *nitidus* and *nigerrimus*. All have the thin uniform trumpet rim and numerous branches on abdominal setae 1 and 5. In general *nitidus* has the least skin pigment, with *pursati* next followed by the rather darkly pigmented skin of *nigerrimus*. The numerous branches of seta 1-VII on *pursati* is usually diagnostic, and is somewhat like pupae in the *barbirostris* group. Persons using the position of seta 6-VII on either *nigerrimus* or *pursati*, must be certain that the skins are mounted as flat as possible; otherwise, the positions can be very distorted and misleading. Occasionally, pupal skins without associated larval skins or adults will be encountered which cannot be identified with certainty.

The larva is also very similar to those of *nitidus* and *nigerrimus*, but is usually distinct on the basis of setae 14-P and 1-M. Some *pursati* larvae have a larger posterior tergal plate on most abdominal segments than do other members of the complex, but additional specimens are needed to confirm this trend. Unfortunately, no whole larvae were available for examination during the study and the larval plate was necessarily drawn from skins.

BIOLOGY. Most adults examined were collected by light traps; however, a few females were taken biting man, cattle or buffalos in the area around and north of Bangkok. Reid (1963) also reported *pursati* biting man in Malaya. Specimens examined in Thailand during 1968-70 were collected resting in a clay water jar, biting cattle and man and 16 females were collected one night during a 2 hour period in a net trap baited with dry ice. Reid (1968) gives the larval habitat in Malaysia as deep cool pools, with *Pistia* spp. floating on the surface. The majority of specimens from Thailand were collected in the central valley which is essentially a rice plain, but also has many man made canals and ponds. Some varieties of rice grown in this area require 90 - 120 cm of water for a period of time. Such deep water habitats have been badly neglected in larval collections in Thailand and deserve more study. Immatures of *pursati* have been collected from: rice fields, ponds, ditches and a large ground pool. These habitats had abundant emergent and/or floating vegetation.

MEDICAL SIGNIFICANCE. This species is collected so infrequently that nothing is known about its adult behavior. *Anopheles pursati* probably is not a vector of human pathogens in Thailand.

ANOPHELES BARBIROSTRIS SPECIES GROUP
(*An. barbirostris* species group, Reid 1962)

Anopheles barbirostris Van der Wulp 1884.

GENERAL. Large dark mosquitoes. *Head*. Palpus dark with dense erect scales (see male description below); palpus approximately equal to length of proboscis; clypeus without scales; pedicel with dark and/or pale scales on upper and outer aspects; flagellomere 1 with dense patch of dark and pale scales. *Thorax*. Pleural area with white scale patches; lower mesepimeral setae frequently present. *Wing*. Basal half of costa with humeral pale spot and few

scattered pale scales; subcostal pale spot small; remigium and base of vein R with pale scales; veins R_S-R_{2+3} and M dark scaled to forks; tertiary fringe scales no paler than other fringe scales; with 1 - 2 apical pale fringe spots, frequently with pale fringe spot on posterior margin. *Legs*. Coxae with pale scales; femur, tibia and tarsus mostly dark, usually not speckled with pale scales; hindtarsus with narrow pale rings on some tarsomeres. *Abdomen*. Sterna usually with at least a few scattered pale scales.

FEMALE *Head*. Palpus completely dark scaled. *Abdomen*. Sternum VII with distinct tuft of dark scales.

MALE *Head*. Palpus often with several pale scales on apex of segments 4 - 5. *Abdomen*. Without scale tuft on sternum VII; dorsal surface of 8th segment with some pale scales. *Genitalia*. Basimeres with scales; aedeagus with 3 - 6 pairs of leaflets; 1st leaflet usually with distinct basal tooth; larger leaflets with fine teeth along both edges, approximately 0. 5 as long as aedeagus; claspette faintly bilobed; ventral lobe normally with 2 large spines arising from membraneous area, mesal spine longer than lateral spine; dorsal lobe with club-like structure composed of 4 - 5 separate basal stems that fuse distally.

PUPA *Cephalothorax*. Palpal case sexually dimorphic in most species, but not as distinct as in *hyrcanus* group; male palpal case with attenuated tip, that of female may be slightly attenuate, but not as long as male. *Trumpet*. Longest axis transverse to stem; rim without or with secondary cleft, or thickened ridge replacing secondary cleft, but without tragus. *Abdomen*. Terga without denticles on caudal margin; setae 1, 5 on IV - VII with many branches, central branch usually longer than other branches; seta 1-VII with more than 13 branches (except Philippine species).

LARVA *Head*. Seta 3-C usually with many stiff broom-like branches from base; seta 1-A large with numerous branches, usually reaching or exceeding tip of antenna. *Thorax*. Seta 1-P with 4 or more branches from near base. *Abdomen*. Seta 1 palmate on I - VII, well developed only on III - VII; 1-II usually pigmented (except *vanus* subgroup).

DISTRIBUTION. This group consists of 11 species and is limited to the Oriental region, except for *vanus* Walker, which has been recorded from the western tip of New Guinea (Reid 1968). Reid (1962) divided the complex into 2 subgroups on the basis of adult, larval and egg characters. These subgroups are:

- *barbirostris* subgroup -		- *vanus* subgroup -	
barbirostris	*franciscoi*	*ahomi*	*manalangi*
campestris	*hodgkini*	*barbumbrosus*	*vanus*
donaldi	*pollicaris*	*reidi*	

Members of both subgroups occur throughout nearly the entire distribution of the group. Distributions for most species are uncertain because of identification difficulties, particularly in Indonesia and the Indian subregion. The northernmost records in the west occur in Pakistan and Nepal, while in the east, members have been collected in Kwangtung, Szechwan and Yunnan provinces of China, and Hainan and Taiwan islands (Chow 1949). The center of distribution for the group appears to be Malaysia, but this may be a reflection of the large amount of work done by Reid (1962, 1968) in that country. At least 6 species, i.e., *barbirostris*, *barbumbrosus*, *campestris*, *donaldi*, *hodgkini* and *pollicaris*,

occur in Malaysia. To the east, *franciscoi* Reid, *manalangi* Mendoza and *vanus* Walker are recorded from the Philippines, and only *barbirostris*, *barbumbrosus* and *vanus* are recorded from the eastern Indonesian islands. The 6 species recognized from Malaysia are also found in Thailand, but *donaldi* and *pollicaris* are found only in extreme southern Thailand. Only 6 species are recorded northeast or west of a line drawn through the Isthmus of Kra on peninsular Thailand. Of these, *hodgkini* occurs up into central Thailand and probably also occurs in Burma and Cambodia for numerous specimens have been found in Thailand provinces immediately adjacent to these countries. *Anopheles ahomi* Chowdhury and *reidi* Harrison, (Harrison 1973b) are apparently confined to the Indian subregion. *Anopheles barbirostris*, *barbumbrosus* and *campestris* are the remaining 3 species on the mainland, and the first 2 are widely distributed from India to southeastern China and nearby islands. The distribution of the last species, *campestris*, is uncertain. Numerous adults examined from India and Sri Lanka had adult characters as described for *campestris*, but when available associated immature skins were examined they were clearly *barbirostris*. Such disjunct associations also occur in northern Thailand, where *campestris* apparently does not occur. Confirmed records of *campestris* are currently known only from Peninsular Malaysia and Thailand. Workers studying man biting "*barbirostris*" in India or Southeast Asia should definitely try to rear specimens so the distribution of *campestris*, a confirmed vector of malaria parasites in Malaysia, can be proven or disproven in other areas.

TAXONOMIC DISCUSSION. In Thailand, assignment of specimens to the *barbirostris* species group, particularly the females and larvae is quite simple using the characters provided in the keys. However, as noted in the keys and discussion, the determination of a particular specimen to a given species in the group may be very difficult, particularly if the specimen is not accompanied by additional reared life stages.

As in the *hyrcanus* group, recognition of this species group was facilitated by the accumulation of a mass of biological and disease transmission data by workers in Malaya which led Reid (1962) to search for morphological differences. The differences he detected are even finer than those used to separate members of the *hyrcanus* species group. Furthermore, these meticulous differences persist for the most part in areas outside of Malaysia and reinforce Reid's (1962, 1968) position that these represent valid species. The numerous specimens examined from Thailand have widened the ranges of variation for a number of characters, and in rare cases eliminated the value of a given character, but the species parameters established by Reid remain stable.

The *barbirostris* species group is most closely related to the *bancrofti* species group, which has its center of distribution in the Australian region. Both groups exhibit: wings with areas of mixed black and white scales; pale fringe spots on the posterior margin of the wing; shaggy all black palps on females; clypeus without scales; a tuft of black scales on sternum VII, often with white scales on other sterna; narrow pale bands on hindtarsi; larval seta 1-P branching from the base; larval palmate setae fully developed; and larval seta 3-C usually bushy. In Southeast Asia, members of the *barbirostris* group show more affinities to the *hyrcanus* group than to the *albotaeniatus* or *umbrosus* groups (see taxonomic discussion under *hyrcanus* species group).

BIOLOGY. Members of this group occupy a moderately wide range of larval habitats usually associated with still water. Only *barbirostris* and *campestris* larvae are normally found closely associated with human habitation in such habitats as rice fields, ditches and open temporary ground pools. The remaining species are forest dwelling species with the larvae found in

shaded stream pools, ground pools or swamps. The adults of *barbirostris* and *barbumbrosus* appear to feed largely on domestic and other large animals, while *campestris* is normally more anthropophilic. Very little is known of the feeding habits of *donaldi*, *hodgkini* and *pollicaris*, although *donaldi* is a proven vector of human malaria pathogens in Malaysia.

MEDICAL SIGNIFICANCE. Currently, there is no evidence that any member of this group serves as a vector of human pathogens in Thailand, although *barbirostris*, *campestris* and *donaldi* have been incriminated as vectors of malarial and/or filarial parasites in other Southeast Asian countries. For additional remarks on this subject see the discussions under the respective species.

KEYS. The following keys are based primarily on those of Reid (1968), with changes to accommodate the Thai fauna. As will be noted, many of the characters used do not offer clear cut options, particularly in the adult and larval keys; consequently, a significant portion of larvae and adults will not be identifiable unless they are accompanied by additional reared life stages. The pupal stage is by far the most reliable stage for species determinations, thus workers requiring precise identifications should bear this in mind when undertaking studies in Thailand.

KEYS TO THE SPECIES OF THE *AN. BARBIROSTRIS* GROUP IN THAILAND

ADULTS

1. Apex of wing with lower pale fringe spot extending at least from vein R_{4+5} to M_1; no white scales on the abdominal sterna. *barbumbrosus* (p. 102)

   Apex of wing with lower pale fringe spot narrow, at vein R_{4+5} only; abdominal sterna with at least a few white scales on the midventral line (*hodgkini* frequently without these scales). 2

2(1). Apex of wing with only 2 narrow pale fringe spots, no pale fringe scales at R_2; midtarsi usually without apical pale bands or patches. . . 3

   Apex of wing with 3 pale fringe spots and middle spot at R_2, or with only 2 pale fringe spots, but upper spot wide with pale scales down to include R_2; midtarsomeres 1 - 2 usually with narrow apical pale bands or patches. 4

3(2). White scales on abdominal sterna not confined to median tufts and a row on each lateral margin, many scattered between these. *campestris** (p. 89)

   White scales on abdominal sterna mostly confined to median tufts and a row on lateral margins, a few scattered scales may occur between median tufts and lateral margins. . . . . *barbirostris** (p. 83)

*This character is only 80-85% reliable, see taxonomic discussion under *barbirostris* and *campestris* for further explanation. Also see couplet 4.

4(2). First foretarsal pale band short, half or less as long as tarsomere 5 (infrequent *hodgkini* males have a longer band), rarely crossing joint onto tarsomere 2; median pale scales on abdominal sterna II-VI usually 0 - 20; central and south Thailand. . . . . *hodgkini** (p. 97)

First foretarsal pale band long, more than half as long as tarsomere 5, usually crossing joint onto tarsomere 2; median pale scales on sterna II-VI more than 20; extreme southern Thailand. 5

5(4). First foretarsal pale band longer than tarsomere 5, with 0.33 of band on base of tarsomere 2; 2nd foretarsal pale band also crossing joint, with 0.25 - 0.33 of band on base of tarsomere 3; costa may have some pale scales on preapical dark mark. . . . . *pollicaris* (p. 100)

First foretarsal pale band seldom longer than tarsomere 5, with 0.25 or less of band on base of tarsomere 2; 2nd foretarsal pale band rarely crossing onto base of tarsomere 3; costa without pale scales on preapical dark mark. . . . . *donaldi* (p. 94)

PUPAE

1. Trumpets without secondary cleft or seam. 2

Trumpets with secondary cleft or seam. 3

2(1). Seta 0-VII with 2 - 5 branches, rarely 2; abdominal seta 9 yellow or tan; extreme southern Thailand only. . . . . *pollicaris* (p. 100)

Seta 0-VII with 1 - 3 branches, rarely 3; abdominal seta 9 very dark brown, rarely yellow or tan; central and south Thailand. *hodgkini* (p. 97)

3(1). Trumpet without secondary cleft but with thickened seam; abdominal seta 9 nearly black; seta 9-VII, 6 - 8 times as long as thick; sums of branches on both setae 5-III less than 30. *barbumbrosus* (p. 102)

Trumpet with secondary cleft, without seam; abdominal setae 9 yellow to light brown; seta 9-VII shorter, 4 - 6 times as long as thick; sums of branches on both setae 5-III 30 or more. 4

4(3). Sum of branches of both setae 2-VI is 17 - 58. . *campestris*** (p. 89)

This sum is 6 - 18** 5

5(4). Sum of branches on both setae 2-III is 11 - 19; found throughout Thailand. . . . . *barbirostris* (p. 83)

This sum is 8 - 11; extreme southern Thailand only. . *donaldi* (p. 94)

LARVAE

1. Median dorsal valve of spiracular apparatus with caudal, thumb-like, stigmal process; seta 9-C with 10 - 17 branches. *pollicaris* (p. 100)

Median dorsal valve with small clear caudal knob, but no stigmal process; seta 9-C with 5 - 11 branches. 2

*Approximately 15% of *barbirostris* males found throughout Thailand have this phenotype.

**Slight overlap occurs in these counts between *barbirostris* and *campestris*, see discussion under *barbirostris*.

2(1). Seta 3-C with 12 - 36 thin attenuated branches, usually lax and spread out. . . . . *barbumbrosus* (p. 102)
Seta 3-C with thick branches, usually stiff and crowded together (broom-like), and usually more numerous (19 - 95). 3*

3(2). Seta 3-C with 19 - 44 branches, rarely more than 40; sum of branches on both setae 5-III plus those on both setae 13-IV usually total 25 - 38. *hodgkini* (p. 97)
Seta 3-C with 30 - 95 branches, rarely less than 40; sum of branches on both setae 5-III plus those on both setae 13-IV rarely more than 24. 4

4(3). Difference between the sum of branches on both setae 13-III and that of both setae 5-VII is 0 - 10. . . . . *barbirostris* (p. 83)
This difference is 9 - 23. 5

5(4). Sum of branches on both setae 13-I is 27 - 45. . . . *campestris* (p. 89)
This sum is 18 - 27. . . . . *donaldi* (p. 94)

ANOPHELES (ANOPHELES) BARBIROSTRIS VAN DER WULP
(Figures 34, 35, 36)

Anopheles barbirostris Van der Wulp 1884: 248 (♀).
Anopheles martini Laveran 1902: 907 (♀).
Myzorhynchus barbirostris Van der Wulp, Theobald 1903b: 86 (♀, L*).
Anopheles (Anopheles) barbirostris of Edwards 1932: 40 (in part); Reid 1947: 89 (in part).
Anopheles (Anopheles) vanus of Bonne-Wepster and Swellengrebel 1953: 209; Reid 1962: 14 (= *barbirostris*).
Anopheles (Anopheles) vanus of Wattal, Kalra and Gopal 1962: 65; Reid 1968: 129 (= *barbirostris*).
Anopheles (Anopheles) barbirostris Van der Wulp, Reid 1962: 7 (♂, ♀*, P*, L, E*); Reid 1968: 122 (♂*, ♀*, P*, L*, E*).

Females are usually recognizable by: the absence of an accessory pale wing fringe spot at vein R_2; a narrow pale fringe spot confined to R_{4+5}; an abundance of pale scales on vein Cu; few pale scales on the abdominal sterna; and narrow apical pale bands on the foretarsi. The pupa has a secondary cleft on the trumpet, numerous branches on setae 1, 5, on III - VII, few branches on seta 2-VII and yellow to light brown setae 9. The larva rarely has less than 40 stiff broom-like branches on seta 3-C, a well developed and pigmented palmate seta 1 on segment II and does not possess a stigmal process on the spiracular apparatus.

FEMALE (Fig. 34) *Head.* Vertex with broad dark brown scales except white scales just above interocular space; interocular space with long, mostly dark setae and narrow white scales approximately 0.25 - 0.33 length of setae; palpus dark with erect scales, giving very shaggy appearance; proboscis dark,

*The remaining species, *hodgkini*, *barbirostris*, *campestris* and *donaldi* are not always identifiable in the larval stage without other associated stages.

with erect scales except near apex; forefemur/proboscis ratio with 0.83 - 0.92 range and 0.87 mean; pedicel with scales on upper-outer aspects; flagellomere 1 with dense patch of scales, remaining flagellomeres without scales. *Thorax*. Integument dark gray, with darker longitudinal lines; eye spots not clearly delineated; anterior promontory with moderate to narrow erect pale scales, mixed with darker scales laterally; entire scutum except eye spots, covered with short fine pale scales and long dark setae; scutellum with long dark setae; anterior pronotum with prominent patch of dark scales on dorsocephalic aspect; pleural setae: 2 - 5 propleural, 4 - 7 spiracular, 10 - 14 prealar, 6 - 11 upper and 3 - 6 lower sternopleural, 11 - 16 upper and 0 - 3 lower mesepimeral; small pale scales usually associated with the propleural, sternopleural and mesepimeral setae. *Wing*. Costa with small humeral pale spot, at least ventrally, and usually scattered pale scales between humeral area and small subcostal pale spot, remainder of costa dark to preapical pale area; remigium dark scaled proximally and distally, usually with median pale scales; humeral crossvein with distinct patch of dark scales; base of vein R mostly dark scaled, with scattered pale scales out to poorly defined sector pale mark; R_1 mostly dark scaled, frequently few pale scales at subcostal area and on dark preapical area, tip of vein pale; R_S-R_{2+3} dark scaled to fork; R_2 dark scaled except pale area on distal 0.33, tip usually dark or slightly dark, at least on underside of wing; R_3 usually with approximately half of scales pale, but may be dark scaled like R_2; R_{4+5} with mixed dark and pale scales, infrequently median 0.80 pale scaled; M dark scaled to fork; M_{1+2} with base and apex dark scaled, variable amount of dark and pale scales in between; M_{3+4} with base and apex dark scaled, mostly pale scaled in between; Cu with distinct short dark mark near base separated by its own length or more from upper dark mark on vein 1A, remainder of vein out to apical dark mark on Cu_2 with more than half of scales pale, rarely over half dark; Cu fork normally without distinct dark mark; Cu_1 normally with short dark mark at mediocubital crossvein, few scattered dark scales out to short apical dark mark; Cu_2 with preapical dark mark longer than apical dark mark on Cu_1; apex of Cu_2 usually with small pale scale patch; 1A normally with 2 short dark marks on distal half, proximal half may have scattered dark scales; apical pale fringe spot narrow, at R_{4+5} only, rarely with accessory pale fringe spot at vein R_2 (see male description); posterior margin of wing usually with narrow pale fringe spot at apex of Cu_2. *Halter*. Stem pale scaled, knob dark scaled. *Legs*. All coxae with white scales; upper midcoxa with 1 - 3 stout dark and 2 - 3 fine pale setae. Foreleg: Femur swollen basally, dark scaled except few pale scales on base at joint with trochanter and few internal and external pale scales at apex; tibia dark scaled dorsally, paler ventrally, often few white internal and external scales at apex; tarsomere 1 dark dorsally, paler ventrally, with apical white band half the length of tarsomere 5 or shorter; tarsomere 2 dark scaled except for apical pale band, pale band on tarsomere 2 narrower than that on tarsomere 1; tarsomeres 3 - 5 entirely dark scaled, or tarsomere 3 rarely with very narrow dorsoapical pale patch. Midleg: Femur dark scaled dorsally, paler ventrally, with few white scales on base and distinct internal and external white scale patches at apex; tibia dark scaled dorsally, paler ventrally, with few white scales at apex of segment; tarsomeres 1 - 5 entirely dark scaled, or infrequently with apices of tarsomeres 1 - 2 with very small dorsal patch of light scales. Hindleg: Femur with few white scales at apex, basal 0.33 of segment gray, darkening into black scales near apex; tibia with narrow white basal band, dark scaled dorsally except distinct dorsoapical white scale patch, paler scaled ventrally except at apex; tarsomeres dark scaled, except narrow apical white bands on tarsomeres

1 - 4 and narrow basal white bands or patches on tarsomeres 3 - 5. *Abdomen.* Integument dark dorsally, paler ventrally, most sterna with silvery basal spot on each side of midline; sterna II - VII with a median patch of pale scales, usually few pale scales forming lateral row along lateral margins, and infrequent scattered pale scales in between lateral rows and median patch (see taxonomic discussion); often few dark scales on sternum VI, in addition to prominent tuft on VII.

MALE (Fig. 34) *Head.* Palpus usually completely dark scaled, may have faint apical pale bands on segments 4 - 5. *Wing.* Generally paler than that of female; veins R_S-R_{2+3} and M entirely dark scaled to forks; often with accessory pale fringe spot at vein R_2. *Abdomen.* Dorsal surface of 8th segment usually with small patch of narrow pale scales on median area, usually changing to dark scales apically. *Genitalia.* Basimeres usually with few basal pale scales on dorsomesal aspect, many dark scales laterally and apically; ventral lobe of claspette small and ill-defined, with 2 setae arising just off sclerotized section, on clear membranous area; mesal seta of ventral lobe longer than lateral seta and fused club on dorsal lobe; club on dorsal lobe composed of 4 - 5 separate basal stems which fuse distally into single structure; aedeagus with 4 - 6 pairs of leaflets approximately half the length of aedeagus, largest pair of leaflets with blunt basal tooth and fine teeth along both edges on distal 0.50 - 0.66, remaining large leaflets also with teeth on one or both edges.

PUPA (Fig. 35). Integument usually with tan to light brown pigmentation. *Cephalothorax.* Wing case with mottled pattern of dark spots, lines or bars; outer half of antennal case darker than inner half, with distinct dark rings at joints and dark tip. *Trumpet.* Darkly pigmented, with thin uniform rim and deep secondary cleft. *Abdomen.* Seta 9 with approximately same amount of pigment as integument, not dark brown or black; 9-VII, 5 - 6 times as long as wide; 9-VIII with few fine branches; setae 1, 5 on III - VII strongly developed with many branches (15 - 55), frequently twisted or matted, often with a central branch or stem which projects beyond main tuft; seta 8-II present or absent; seta 0-VI, VII usually with 2 - 4 branches; seta 2-III with 6 or more branches, rarely less; seta 2-VI with 3 - 9 branches, rarely more (see taxonomic discussion). *Paddle.* Base darkly pigmented, also small pigmented spot at apex; refractile margin approximately 0.75 of paddle length; seta 1-P usually simple, may be split into 2 - 3 branches near apex.

LARVA (Fig. 36). Whole larvae dark. *Head.* Dark brown, antennae usually paler with numerous spines; setae 2-C simple and close together, rarely bifid; seta 3-C with 32 - 65 stiff, broom-like branches, rarely less than 40; seta 4-C with 2 - 5 branches; seta 6, 7-C with 8 - 14 and 8 - 18 branches respectively; seta 8, 9-C with 7 - 11 and 6 - 9 branches respectively. *Thorax.* Seta 1-P with 4 - 11 branches from near base; 11-P with 2 - 4 short stout, equal-length branches from base; 14-M with 12 - 21 branches; 3-T with flattened pale leaflets, some showing slight filament development. *Abdomen.* Seta 1 with flattened, unpigmented leaflets on segment I and rarely II; 1, on II - VII normally darkly pigmented and well developed; seta 13-I with 7 - 17 branches; 2-II with 5 - 7 branches; 5-III with 5 - 10 branches; 13-III with 3 - 12 branches, 13-IV with 3 - 5 branches; 5-VII with 4 - 8 branches; and 9-VII with 1 - 4 branches; pecten with 9 - 12 long teeth, usually 9 - 10; seta 1-X approximately equal to length of saddle.

TYPE-DATA. According to Reid (1962) the type of *barbirostris* is located in the Leyden Museum. This female was collected on Mount Ardjoeno in eastern Java. The condition of this female was described in some detail by Reid, who pointed out the difficulty of correctly identifying this specimen to *barbi-*

rostris. Reid felt the apparent absence of *campestris* on Java, coupled with the hilly inland collection site, made the identity of this female as *barbirostris* safe. The type-material of the synonym *martini* is composed of 2 females mounted on separate glass slides, and located in the Pasteur Institut, Paris. These 2 slides have identical labels: "*A. martini*, Montagnes des Pensat, Cambodge, Fevrier 1902." We concur with Reid (1962) that the condition of these specimens mounted in Canada balsam prohibits their positive identification. Reid assigned this name as a synonym of barbirostris, because *barbirostris* is normally a hill and mountainous species while *campestris* is a coastal plain species. Our observations on the distribution of *barbirostris* and *campestris*, and the examination of the *martini* types, support Reid's assignment of *martini* as a synonym of *barbirostris*.

DISTRIBUTION (Fig. 35). This species is very abundant and widely distributed in Thailand. It is likely to be found anywhere in Thailand where a thorough search is made, except at higher elevations or in dense primary forest. In certain areas of Thailand, *barbirostris* may be uncommon. This is particularly true just north of Bangkok in the rice plains along the Chao Phrya River, where *campestris* is the predominant member of the *barbirostris* group. Specimens (326♂, 451♀, 412 larvae and 1,211 larval and pupal skins) in the USNM were examined from the following provinces of Thailand: Chanthaburi, Chiang Mai, Chiang Rai, Chon Buri, Kanchanaburi, Khon Kaen, Krabi, Lampang, Lampoon, Nakhon Ratchasima, Nakhon Si Thammarat, Nan, Narathiwat, Pathum Thani, Phangnga, Phet Buri, Phrae, Phuket, Prachin Buri, Prachuap Khiri Khan, Ranong, Rat Buri, Satun, Songkhla, Surat Thani, Trang, Trat, Udon Thani and Yala. Additional specimens (68♂, 166♀, 23 larvae and 65 larval and pupal skins) in the USNM were examined from: BURMA, CAMBODIA, INDIA (Assam, West Bengal), INDONESIA (Sumatra), LAOS, MALAYSIA (Peninsular), PORTUGUESE TIMOR, SRI LANKA and VIETNAM (North and South). Additional literature references indicate *barbirostris* occurs through the Indonesian chain as far east as the Moluccas. Reid (1968) claims this species does not occur on Borneo, but several specimens in the USNM from Sabah key to *barbirostris* in the larval and pupal stages, while the adults are intermediate between *barbirostris* and *donaldi*. All previous records of *barbirostris* from the Philippines apply to *franciscoi*, *manalangi* or *vanus* (Reid 1962). *Anopheles barbirostris* is distributed from Pakistan in the west to Hainan Island, Kwangtung Province, China in the east, and south down the Indochina Peninsula, through Indonesia to the islands of Sulawesi and the Mollucas. According to Chow (1949), this species has been recorded as far north in China as Szechwan and Yunnan provinces, but these records need confirmation because of confusion between *barbirostris* and *barbumbrosus* (Reid 1962).

TAXONOMIC DISCUSSION. Our current interpretation of *barbirostris* and the other members of the group in Southeast Asia is due primarily to the efforts of Reid (1962, 1968). However, a number of problems still exist. Reid (1968) discussed some of these and pointed specifically to *campestris*-like adults with immature skins of *barbirostris* from the east coast of Peninsular Malaysia, Chiang Mai, Thailand and Rangoon, Burma. He also observed several females from Malaysia and southern Thailand, which had a pale accessory wing fringe spot like *donaldi* adults, but had *barbirostris* immature skins. Reid summarized his view on these problems as follows: "This tendency, under certain circumstances, for some adults of *barbirostris* to resemble those of *campestris* or *donaldi*, means that identifications based on adults alone should not be regarded as reliable until confirmed by examination of the early stages, particularly the pupae (and for *donaldi* the eggs). Once the species present in an area

are known, identification of adults without early stages may be perfectly reliable." During the present study specimens with such overlapping variation were not infrequent. In northern Thailand, frequent adults with dark wings and numerous pale scales on the sterna were encountered, yet all proved to be *barbirostris* when the immature skins were examined. Such disjunct associations commonly occur in reared specimens from India (West Bengal) and Sri Lanka. Nearly all the *barbirostris* examined from central and southern Thailand, where *campestris* also occurs, have pale wings and relatively few pale sternal scales. These characters would be most valuable if they were distinct from those on *campestris* as Reid described from Peninsular Malaysia, but that is not always true in Thailand (see *campestris*, taxonomic discussion). In general, the wing characters previously used to separate *barbirostris* from *campestris* are not valid in Thailand. The abundance of pale sternal scales seems significant only in areas where both species occur, and sympatry can be accurately determined only by the examination of immature skins.

Rare females of *barbirostris* exhibiting an accessory pale fringe spot on the wing, can be confused with *hodgkini*, but should not be confused with *donaldi* or *pollicaris* because these last 2 species have broad foretarsal pale bands and both are apparently found only in extreme southern Thailand. To add to the confusion, approximately 15% of *barbirostris* males from all over Thailand, but particularly from the peninsular area, exhibit an accessory pale fringe spot on the wing and can be confused with *hodgkini*. Sometimes this accessory spot is not clearly defined and is confluent with the preapical fringe spot, consequently the upper spot is wide with pale scales down to include vein R_2. On one aberrant female all pale fringe spots were missing, making identification possible only through associated immature skins.

Specimens of *barbirostris* adults should be easily separated from *barbumbrosus*, because adults of the latter have the lower apical pale fringe spot on the wing extending down at least to vein M_{1+2}, and the abdominal sterna of *barbumbrosus* lack pale scales.

The pupa of *barbirostris* is the stage with the most reliable characters for identification and unfortunately, the stage that is most often overlooked. Those studies or persons requiring precise identifications should plan their programs to include rearing immatures. Otherwise, specimens should be identified only to the group level, i.e., *barbirostris* group. *Anopheles barbirostris* pupae can rarely be confused with the other members of the group. The pupae of *barbumbrosus*, *hodgkini* and *pollicaris* possess basic trumpet structural differences from *barbirostris*. The pupae of *campestris* and *donaldi* (Malaysian specimens) are similar to *barbirostris*, but the characters presented in the key should separate 95 - 97% of these species. Of 778 *barbirostris* pupae from Thailand, only 3 had the sum of setae 2-VI branches equal to or more than 17, and all 3 had sums of 18. This range (6 - 18) overlaps slightly with that of *campestris* (17 - 58), which only rarely has sums of less than 20.

The identification of *barbirostris* larvae in Thailand is extremely difficult. Only *barbumbrosus* with a non-rigid, few-branched seta 3-C and *pollicaris* with a stigmal process, can be separated from *barbirostris* with consistency. The larvae of the remaining species all possess characters which overlap with those of *barbirostris*. The larva of *donaldi* has not been collected in Thailand, but Malaysian specimens are very similar to *barbirostris*. The larva of *campestris* is usually distinct from that of *barbirostris*, but the characters used to determine this are difficult to use. Larvae of the remaining species, *hodgkini*, are frequently collected with *barbirostris* and often cannot be distinguished from them.

BIOLOGY. In general, *barbirostris* might be called a foothill mosquito. In Thailand, immature collections have been made from sea level up to 500 m in elevation, while adults were collected biting man (Scanlon and Esah 1965) at elevations between 750 - 1400 m. Apparently, *barbirostris* is well suited for life in most areas of Thailand, and utilizes a large variety of oviposition sites. Immature stages have been collected from river margins, river pools, stream margins, stream pools, flowing ditches, stagnant ditches, moats, lakes, permanent ground pools, temporary ground pools, flood pools, rice fields, wells, canals, marshes, fish pools, rock pools, grassy ponds, seepage springs, buffalo and elephant footprints and a nipa palm swamp. A large majority of these habitats also had emergent, floating and/or submergent vegetation. Usually the habitats where *barbirostris* immatures are found are located in open sunlight to light-moderate shade. Immatures of this species have rarely been collected in heavy shade, which may account for its absence in primary forest. Tolerance for high pollution levels has also been noted. Larvae have been collected from sewage ditches, and ground pools with heavy concentrations of buffalo dung and urine.

Adult *barbirostris* are generally zoophilic and can cause severe pest problems for cattle and buffalo owners. This species will bite man, but not on a large scale except in situations where the normal host animals are absent. Reid (1961) found Malayan *barbirostris* were attracted to a calf 17 times more frequently than to 2 men. More recently, Reuben (1971) found Indian "*barbirostris*" were attracted to a bullock 38 times as frequently as to 2 men. Adults from Thailand have been collected: biting man and bovines, resting outside, resting in animal sheds, resting in houses, in light traps, in man baited traps, in Shannon traps, in malaise traps and in a carbon dioxide net trap baited with dry ice.

MEDICAL SIGNIFICANCE. This species has been incriminated several times as a vector of malaria parasites; however, since the recognition of a sibling group (Reid 1962), at least 2 of these reports have been corrected. The "*barbirostris*" reported as a malaria vector from the west side of the Malay peninsula and that from Borneo are now recognized as *campestris* and *donaldi*, respectively. Unfortunately, the other reports, from Sumatra and Sulawesi, have not been clarified. In fact, it is not clear which species occur on these islands. Griffith (1955) reported malarial oocysts from a single *barbirostris* from Chiang Mai Province, but the identity of the mosquito is now suspect in light of Reid (1962). Since then no further malarial infections have been found in members of this group from Thailand. Experimentally, *barbirostris* showed a very low susceptibility to *Plasmodium cynomolgi bastianellii* (Warren et al. 1963). In view of the zoophilic habits of this species, coupled with a definite exophagic-exophilic behavior, there is little potential for *barbirostris* in Thailand being a vector of malaria pathogens.

The capabilities of *barbirostris* as a vector of filarial parasites deserves consideration. Apparently, *barbirostris* in Peninsular Malaysia is not susceptible to *Wuchereria bancrofti* infections (Wharton 1960), in fact, all the members of this group have a low susceptibility to this parasite (Reid 1962). On the other hand, several members are involved in the transmission of *Brugia malayi* and studies in Malaya by Reid et al. (1962), Wharton (1962) and Wharton, Laing and Cheong (1963) have shown that *barbirostris* is a good experimental vector of the periodic form, but a relatively poor vector of the subperiodic (semiperiodic) form of this parasite. Iyengar (1953) reported *barbirostris* from southern Thailand infected with *B. malayi*, however, this report came prior to the recognition of the other sibling members of the group.

Reid (1962, 1968) suggests that *barbirostris* is probably not involved in the transmission of *B. malayi* in Malaya due to its zoophilic habits. The same should probably apply to Thailand.

The role of *barbirostris* in the transmission of animal parasites such as *Setaria* and *Dirofilaria* needs serious study. Some of the early records of human filaria infections in *barbirostris*, may be due to misidentified animal filariae. Several zoophilic members of the *hyrcanus* group are known vectors of animal filariae and the same is probably true of some of the zoophilic members of the *barbirostris* group, particularly a species like *barbirostris* which feeds on bovines. Harinasuta et al. (1970) found specimens identified as *barbumbrosus* and *campestris* from Kanchanaburi Province, Thailand positive for *Dirofilaria* larvae.

ANOPHELES (ANOPHELES) CAMPESTRIS REID
(Figures 37, 38, 39)

Anopheles (Anopheles) campestris Reid 1962: 15 (♂*, ♀*, P, L*, E); Reid 1968: 129 (♂*, ♀*, P, L*, E).

Adults are not normally distinct from those of *barbirostris*, but they often have darker wings and more pale scales on the abdominal sterna. The pupa is the best stage for identification, and is nearly always separable by numerous setal branches. The larva is very much like *barbirostris* except for more numerous branches of some setae. This species is like *barbirostris* except for:

FEMALE (Fig. 37) *Head.* Forefemur/proboscis ratio with range of 0.75 - 0.86 and 0.83 mean. *Thorax.* Pleural setae: 2 - 6 propleural, 4 - 9 spiracular, 8 - 12 prealar, 5 - 9 upper and 3 - 5 lower sternopleural and 9 - 16 upper and 0 - 2 lower mesepimeral. *Wing.* Often darker than wing of *barbirostris*; vein Cu-Cu_2 frequently with more dark than pale scales (caution-see taxonomic discussion); tip of wing frequently with pale stripe extending from preapical pale costal spot back to M_{1+2}; tip of wing without accessory pale fringe spot adjacent to tip of vein R_2. *Legs.* Foretarsomere 3 usually without apical pale band; midtarsomeres usually without pale bands. *Abdomen.* With numerous pale scales on sterna II - VII, particularly in median patches and lateral rows; pale scales scattered between median sternal patches and lateral rows also numerous; sternum VI rarely with dark scales on caudal margin.

MALE (Fig. 37). Like female, generally with more dark scales on wing; without accessory pale fringe spot adjacent to tip of vein R_2; distal half of dorsal surface of 8th abdominal segment usually with central patch of dark scales and pale scales on lateral aspects. *Genitalia.* Aedeagus with 3 - 6 pairs of leaflets.

PUPA (Fig. 38). Like *barbirostris* except setae 0 and 2 have more branches on most segments; 0 on VI - VII usually with 4 - 6 branches; 2-III with 8 or more branches; 2-VI with 6 - 29 branches (see taxonomic discussion).

LARVA (Fig. 39) *Head.* Seta 3-C with 60 or more stiff, broom-like branches; 8, 9-C with 6 - 9 and 6 - 11 branches respectively. *Thorax.* Seta 11-P with 3 - 7 branches; 14-M with 20 - 28 branches. *Abdomen.* Seta 13-I with 12 - 27 branches; 5-III with 5 - 8 branches; 13-III with 8 - 21 branches; 13-IV with 3 - 7 branches; 9-VII with 2 - 5 branches.

TYPE-DATA. The ♀ holotype, ♂ allotype and 1♂ and 2♀ paratypes, with larval and pupal skins (except ♂ paratype) are in excellent condition and are

located in the BMNH. The holotype and allotype have the respective rearing numbers "L.H. 75/10" and "L.H. 75/2" and are from, "Rantau Panjang, Klang, Selangor, Malaya." Two of the paratypes (♂ and ♀) are from Selangor, Malaya, and the ♀ has a rearing number, "L.H. 81/7." The remaining paratype (♀) is from Perak, Malaya, and has a rearing number, "073/21."

DISTRIBUTION (Fig. 38). The actual distribution of *campestris* in Thailand is still unknown; however, the confirmed (associated immature skins) distribution depicted on Fig. 38 hints this species is common in the Chao Phrya River basin and the coastal areas of the country. Apparently, *campestris* is confined to areas of low elevation in Thailand, as Reid (1962) found in Malaya. The northern or northeastern limits of its range are currently not known. In the northeast (Korat Plateau), *campestris* definitely occurs in the vicinity of Khon Kaen, where *barbirostris* and *barbumbrosus* were also collected. The Korat Plateau, although 125 m in elevation, has extensive flat rice plains which appear to be one of the primary habitats for *campestris*. Further west, *campestris* has not been found north of Ayutthaya. Fairly frequent adults with a *campestris*-like habitus have been collected in Chiang Mai and Lampang, but associated immature skins show these are actually *barbirostris*.

Locally, *campestris* can be extremely abundant, and the predominant member of the group. This is particularly true in Ayutthaya, Nonthaburi and Pathum Thani, just north of Bangkok.

In other areas it may share certain habitats with *barbirostris*, and be much less common. Normally, such mixed populations are not the rule. Specimens (137♂, 179♀, 175 larvae and 386 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Ayutthaya, Chanthaburi, Chon Buri, Khon Kaen, Nakhon Si Thammarat, Nonthaburi, Pathum Thani, Prachin Buri, Phra Nakhon, and Songkhla. Additional specimens (4♂, 6♀ and 12 larval and pupal skins) were examined in the USNM and BMNH (type-series) from MALAYSIA (Peninsular Malaysia). Reid (1962, 1968) discussed the possibilities of *campestris* occurring in India, Burma, and the Indo-China region. Although specimens from some of these countries or regions were examined and found to have a *campestris*-like habitus, all having associated immature skins proved to be *barbirostris*. Consequently, confirmed records of *campestris* are still known only from Malaysia and Thailand.

TAXONOMIC DISCUSSION. As early as 1942, 2 types of *barbirostris* were recognized in Malaya (Reid 1942). The dark-winged type was recognized by Reid (1962) as a distinct species, *campestris*, not only on morphological differences, but also on behavior traits and vector capabilities quite distinct from those of *barbirostris*. Of the species of the *barbirostris* group found in Thailand, *campestris* is one of the most difficult to recognize, yet because of its known vector-disease pathogen associations in Malaysia, it is the most important member of the group to identify. Reid (1962, 1968) found *campestris* in Peninsular Malaysia with relatively stable characters and easily separable from *barbirostris*; however, this is not the case in Thailand. In Pathum Thani and Ayutthaya, north of Bangkok, *campestris* is extremely abundant and quite variable. While 134 confirmed females from these areas had extensive pale scaling on the abdominal sterna as is normal for *campestris*, nearly 50% of these exhibited pale scaling on Cu-Cu_2 and other wing veins as is normally found on *barbirostris*. Specimens from these areas with these combinations of characters have caused much confusion for past identifiers. Now it is clear that the wing characters used by Reid to separate Malayan *campestris* and *barbirostris* are not valid in Thailand. Not only do many Thai *campestris* have light wings, but in areas where *campestris* does not occur some specimens of *bar-*

birostris exhibit dark wings.

The pattern of pale scales on the abdominal sterna used by Reid to separate Malayan *barbirostris* and *campestris* is valid in some, but not all areas of Thailand. These valid areas seem to be those where both species occur or meet. The pale sternal scale pattern on Thai *campestris* is nearly stable and like that depicted for Malayan *campestris*. On the other hand, while *barbirostris* usually exhibits few pale sternal scales in areas where it is found with or near *campestris*, it often exhibits extensive pale sternal scaling in areas where *campestris* does not occur. Consequently, the only areas where these 2 species may be separated by an adult character with any degree of accuracy are areas where they both occur. However, such areas of sympatry must first be determined by examining the immature skins of individually reared specimens.

The number of branches on pupal seta 2 on the abdominal segments is highly variable, particularly when using the summation method; however, of 249 pupal skins on which the sum of the branches on both setae 2-VI were counted, only 6 skins had counts of less than 20 branches. These counts are 19(1), 18(2), 17(2) and 13(1). Since *barbirostris* has a range up to 18 branches, there is a slight overlap, but these 2 species should still be separable by this character on a 95 - 97% level. Several dark winged adults with extensive pale sternal scaling and immature skins were available from the rice fields of the Chiang Mai Valley. Two of these had the sum of seta 2-VI on the pupal skin with 18 branches. Since we could not determine whether these represented the lower range of *campestris* or upper range of *barbirostris*, and since there were so few specimens we have tentatively identified these as *barbirostris*. The Chiang Mai Valley is extensive, flat, at approximately 300 m elevation and used primarily for rice cultivation. Further work is definitely needed in this valley to determine if *campestris* is present.

Two *campestris* pupal skins with aberrant characters were observed. One had only slight notches for trumpet secondary clefts. The other had the chaetotaxy on the left side of abdominal segment VI normal, while on the right side setae 2 - 3 and their alveoli were missing, while seta 1 was represented twice.

The larval chaetotaxy of *campestris* is more variable than that of the pupa and overlaps with characters used to separate *barbirostris*. Consequently, the larval stage is less reliable than the pupal stage for separating these 2 species. Larval skins of *campestris* are best used to confirm pupal identifications.

BIOLOGY. As expressed by the name *campestris* (of fields, of plains), this species is typically found on flat coastal or rice plain areas. Immatures have been collected in Thailand from 1 - 200 m elevation. Larval habitat requirements are uncertain; however, clear still fresh water, some emergent, floating or other vegetation, and light-moderate shade are usually present. Only 2 collections were made in Thailand in which the water was possibly brackish. Immature stages have been collected in Thailand from rice fields, marshes, sumps, canals, ponds, wells, large and small pits, ditches, hoofprints, stream margin pools, ground pools, flood pools, a nipa palm swamp and fresh standing water in a large stump.

Adult behavior of *campestris* has been investigated during a number of studies in Malaysia. Reid (1942), during laboratory feeding experiments on malaria and filariasis patients, found that 60% of the dark-winged *barbirostris* (*campestris*) fed on man to only 26% of the light-winged *barbirostris*. In 1961, Reid continued attractiveness studies and showed that when 2 men were compared with one calf, 77% of the *campestris* selected the men, compared to only

6% of the *barbirostris*. When 2 men were compared with 2 goats this study showed 85% of the *campestris* attracted to the men. Reid and Weitz (1961) conducted a blood meal identification (precipitin) study on 27 *campestris* found resting outdoors and showed 17 (63%) had fed on man, 8 on monkeys and 2 undetermined. Wharton et al. (1964) followed this by comparing man and monkey baited net traps at ground level and found 92% of the *campestris* came to the man baited trap. No *campestris* came to a monkey baited trap in the canopy. Because of these studies, *campestris* is listed by Reid (1968) as highly anthropophilic and ranked as the 3rd species of *Anopheles* in Southeast Asia most attracted to man. *Anopheles campestris* is also highly endophagic. Moorhouse and Wharton (1965) showed this species biting man indoors at a ratio of 4.4 : 1 over man outdoors. Of the *campestris* collected during this study (6 nights), 85% were caught fairly evenly distributed between 2000 - 0200 hours. This study also showed *campestris* is endophilic when pyrethrum knockdown catches revealed 51 *campestris* resting in 15 of 27 houses between 1600 - 1730 hours. The real significance of these anthropophilic, endophagic and endophilic traits was demonstrated by Moorhouse (1965) during a malaria eradication pilot project in Malaysia. This house spraying project completely eliminated *campestris* in the project area, while *barbirostris* populations in the project area were unaffected. Outside the project area, *campestris* population levels remained unchanged. Another useful *campestris* behavior trait has been detected. Moorhouse and Wharton (1965) found in comparing man biting and man baited net trap collections that over twice as many *campestris* were captured by the net trap method. Reid (1968) carried this work one step further and determined in 178 nights of comparing catches between man in huts with window traps and man baited net traps outside, that 69% (1,300/1,897) were collected in the outside net traps. This information is significant, particularly for studies such as vector-dissection surveys, where the number of specimens collected is important.

Adult behavior of *campestris* in Thailand is extremely difficult to interpret because of overlapping adult characters and the possibility of mixed collections. The behavior data accrued in the Malayan studies may also apply to Thai *campestris*, but this needs confirmation. The only study reported to date from Thailand where pure (or nearly so) *campestris* populations occur, is that of Gould et al. (1965). This vector-dissection study was conducted in Pathum Thani, and 961 *campestris* were collected on human bait between 1900 - 2400 hours (D. J. Gould, personal communication). Specific mention was made that of the 6 anophelines studied, *campestris* was the only species most frequently collected indoors. These data indicate that Thai *campestris* at least from this area, are anthropophilic and endophagic.

MEDICAL SIGNIFICANCE. To date, *campestris* has not been incriminated as a vector of human pathogens in Thailand; however, this is very possible in view of its vector capabilities just across the border in northern Malaya. Hodgkins' (1956) studies in western Peninsular Malaysia quite convincingly incriminated the dark-winged type of *barbirostris* (*campestris*) as a vector of human malaria parasites. This study plus all the malaria dissection studies involving *barbirostris* group members in Malaya prior to 1962 are tabulated in Reid (1962). Later studies, Moorhouse and Wharton (1965) and Moorhouse (1965) present further data to incriminate *campestris* as a vector of human malaria pathogens in the lowland-coastal areas of western Peninsular Malaysia. Reid (1962) noted that where *campestris* is the vector of human malaria parasites there is a tendency for *Plasmodium vivax* (Grassi and Feletti) to be the predominant parasite. Although some evidence was presented to explain

this tendency, further confirmative studies are needed. Reid and Weitz (1961) determined that some wild *campestris* feed on monkeys, and suggested that *campestris* may also be involved in the transmission of simian malaria. However, Warren et al. (1963) showed in a laboratory experiment that *campestris* had a very low level of susceptibility to infection with *Plasmodium cynomolgi bastianellii*. Furthermore, Wharton et al. (1964) did not find simian malaria parasites in wild caught *campestris*, in an area where there was active transmission of these parasites.

Only 2 vector-malaria dissection studies have been conducted in Thailand where we feel confident the specimens referred to are *campestris*. The 1st reported by Reid (1962), refers to a study conducted in Nonthaburi by Dr. Udaya Sandhinand in 1960 when over 2,000 "*barbirostris*" were dissected. The 2nd is the study conducted by Gould et al. (1965) in Pathum Thani, where 961 *campestris* were dissected. Neither study revealed malaria parasites in *campestris*. Griffith's (1955) report of a single malaria infection in *barbirostris* from Chiang Mai may actually refer to *campestris*, although we currently do not consider *campestris* to occur in the Chiang Mai Valley. It is entirely possible that *campestris* did occur in Chiang Mai in the past and has since been eliminated by the house spraying conducted by the Thai malaria eradication program since the late 1940's. The feasibility of total elimination (eradication) of *campestris* from an area was demonstrated by Moorhouse (1965).

The status of *campestris* as a vector of filarial parasites is now well established, but early work in Malaya was contradictory and created considerable confusion until the 2 forms of *Brugia malayi* (Wilson et al. 1958) and the sibling species in the *barbirostris* group (Reid 1962) were recognized. Studies conducted in Malaya prior to 1962 are summarized by Reid (1962). Studies conducted by Wharton (1962) in the laboratory show *campestris* is a very efficient vector of periodic *B. malayi*, a poor vector of subperiodic *B. malayi*, an efficient vector of *B. pahangi* and refractory to infections with *Wuchereria bancrofti*. Reid et al. (1962) found 19/3,573 or 0.53% of wild caught specimens from a northwest Malayan study area infected with 3rd stage (mature) larvae. During this study Reid fed *campestris* upon an infected volunteer from Kedah State. Most of these specimens (22/24 or 88%) had mature *B. malayi* larvae. *Anopheles campestris* is now considered one of the major vectors of periodic *B. malayi* in western and northwestern Peninsular Malaysia.

Iyengar (1953) conducted the first major filariasis survey in southern Thailand and reported 42 of 358 "*barbirostris*" positive for *B. malayi* larvae. These "*barbirostris*" were collected resting in houses during morning hours, and thus may have been *campestris*, which is endophilic. Nair and Chayabejara (1961) reported that the periodicity of the *B. malayi* in southern Thailand was strictly nocturnal with peak peripheral microfilaremia between 2100 - 0500 hours. This periodicity is very similar to the peak period of man-biting activity exhibited by Malaysian *campestris* (Moorhouse and Wharton 1965). Harinasuta et al. (1964) attempted to incriminate the mosquito vector(s) of *B. malayi* in southern Thailand by outdoor man-biting collections between 1800 - 2000 hours. The selection of this time period favored the collection of *Mansonia* species that can transmit periodic *B. malayi*, and reduced the possibility of collecting infected specimens of the more nocturnal and endophilic *campestris*. In fact, *Mansonia uniformis* (Theobald), was found positive (0.6%), while none of the anophelines were positive. Since *campestris* is highly endophilic, the indoor spray program used by Harinasuta et al. was probably very effective; however, such results are not evident because only outdoor man-biting densities were monitored. Harinasuta et al. (1970) also reported *Dirofilaria*

sp. larvae in *campestris* from a study near the Burma border in Kanchanaburi, however, this determination is suspect due to overlapping adult variation and the absence of any confirmed *campestris* from that province. Large numbers of confirmed *barbirostris* group members have been examined from Kanchanaburi, but all were *barbirostris*, *barbumbrosus* or *hodgkini*.

The possibility of *campestris* being or having been a vector of malarial or filarial pathogens in Thailand is very real. Hopefully, *campestris* no longer presents a disease vector threat because of the long term malaria eradication house spraying program. However, if future foci of human malaria or filarial diseases are located in Thailand where *campestris* is also abundant, an immediate house spraying program seems to offer the best means of control. Apparently, *campestris* represents one of the few vectors in the world that has behavorial traits that permit rapid elimination by chemical control methods.

ANOPHELES (ANOPHELES) DONALDI REID
(Figures 40, 41, 42)

Anopheles (An.) barbirostris of Colless 1948: 80 (♂*, ♀*, L*).
Anopheles (An.) donaldi Reid 1962: 17 (♂*, ♀*, P, L, E*); Reid 1968: 132 (♂*, ♀*, P, L, E*).

Besides the egg, the adult is the easiest stage of *donaldi* to recognize. Usually the presence of broader foretarsal pale bands, an accessory pale wing fringe spot at R_2, narrow pale bands on the midtarsi and fairly numerous pale abdominal sternal scales are indicative of *donaldi*. However, other species can also exhibit these characters, so identifications should be confirmed by examining as many stages as possible, particularly the egg. This species is like *barbirostris* except for:

FEMALE (Fig. 40) *Thorax*. Pleural setae: 3 - 7 propleural, 5 - 8 spiracular, 12 - 16 prealar, 5 - 8 upper and 3 - 4 lower sternopleural, 11 - 16 upper and 0 - 4 lower mesepimeral. *Wing*. Usually paler, pale areas usually more continuous with fewer scattered dark scales; tip of R_2 rarely with dark scales on upper or under surface; tip of wing with accessory pale fringe spot adjacent to R_2. *Legs*. Upper midcoxa with 2 - 5 setae; foretarsomeres usually with broader pale bands (see taxonomic discussion); 1st band 0.5 - 1.0 length of tarsomere 5, usually extending as narrow band onto base of tarsomere 2; 2nd band 0.5 or less length of tarsomere 5, sometimes extending as faint band onto base of tarsomere 3; 3rd band usually present as very narrow band, or distinct dorsal pale spot on apex of tarsomere 3; tarsomere 4 - 5 dark scaled. Midtarsomeres 1 - 3 usually with narrow apical pale bands or small dorsoapical pale spots. *Abdomen*. Sterna usually with slightly more pale scales than found on *barbirostris*.

MALE (Fig. 40) *Head*. Palpus with distinct narrow pale bands at apex of segments 3 - 4. *Legs*. First foretarsal band often longer than length of tarsomere 5. *Wing*. Generally paler than that of female, with accessory pale fringe spot infrequently confluent with preapical pale fringe spot; consequently, upper pale fringe spot is wide with pale scales down to include R_3. *Abdomen*. Sterna with pale scales generally confined to median area; dorsal surface of 8th segment with median patch of pale scales. *Genitalia*. Aedeagus with 3 - 4 pairs of leaflets.

PUPA (Fig. 41). Nearly identical to *barbirostris* except abdominal seta 2 has fewer branches on segments III, VI; sum of branches of seta 2-III is 8 -

11 (11 - 19 *barbirostris*), and 2-VI is 5 - 11 (7 - 18 *barbirostris*).

LARVA (Fig. 42). According to Reid (1968), "Not always distinguishable from *barbirostris*. Frontal hairs 6 and 7 on the head with slightly more branches, 10 - 17 and 15 - 20; the difference is accentuated a little by summing the branches on all four hairs giving a total of 50 - 75 (*barbirostris* 39 - 62). Abdominal hair 13, III with rather more branches (8 - 14) and 5, VII averaging slightly fewer (4 - 6), with the result that there is a larger difference between the sums for the pairs 13, III and 5, VII, this difference is 10 - 17 (*barbirostris* 0 - 10). Other sums of the branches on pairs of hairs are as follow: 5, VII 8 - 11 (*barbirostris* 10 - 15), 13, I 18 - 27 (*campestris* 27 - 45), 13, II 20 - 29, 13, III 19 - 26 (*barbirostris* 10 - 24), 13, IV 6 - 8 (*hodgkini* 10 - 18); for the two pairs 5, VII + 13, I, 26 - 38 (*campestris* 40 - 57)."

TYPE-DATA. The ♀ holotype, ♂ allotype and 1♂ and 2♀ paratypes, with larval and pupal skins (except paratype #01856) are located in the BMNH. The holotype, allotype, 1♂ and 1♀ paratype are numbered "0421/31; 0421/33; 0410/47; and 0434/14" respectively and are from "Puchong, Selangor, Malaya." The other ♀ paratype is numbered "01856" and is from, "Ulu Lui, Ulu Langat, Malaya." The ♂ genitalia of the paratype has been mounted on a slide, while that of the allotype is still intact.

DISTRIBUTION (Fig. 41). In Thailand, *donaldi* is apparently uncommon and found only in the extreme southern portion. Reid (1968) says that *donaldi* is locally common in central and southern Peninsular Malaysia, is the most common member of the group in Borneo and may be present in Sumatra and Java. No new distributional data has come to light since Reid's work. A single female in the USNM was examined from Narathiwat Province, THAILAND. An additional 4♂, 13♀ and 4 larval and pupal skins in the USNM were examined from MALAYSIA. The type-specimens (2♂, 3♀ and 8 larval and pupal skins) in the BMNH from MALAYSIA (Peninsular Malaysia) were also examined.

TAXONOMIC DISCUSSION. This species, like *campestris*, is extremely close to *barbirostris* and specimens of *donaldi* frequently cannot be identified without other associated stages for verification. Originally, *donaldi* was detected by distinctive egg characters. Although we have not dealt with eggs in this study, egg characters appear the best means of separating *donaldi* from *barbirostris*; therefore, the following extract from Reid (1968) is included, "Length 0.48 mm., somewhat shorter than that of *barbirostris*. Differs distinctly in usually having the deck divided into an area at each end, or if not divided then narrowed towards the middle; also the floats are relatively longer, about 3/4 as long as the egg, and the tail end is less upturned and pointed. Float ribs about 28-34." The egg of *barbirostris* has a single deck slightly more than 0.1 as wide as the egg width, floats about 0.67 the egg length and 28 - 44 ribs in the floats. Since only one specimen is available from Thailand and only a few available from Malaysia, little variation was observed. Although the foretarsal pale bands are long on the Thailand female, the bands do not cross over onto the bases of tarsomeres 2 - 3. The foretarsal pale bands also appear shorter like *barbirostris*, on the specimens from East Malaysia, while those from Peninsular Malaysia and the Thailand specimen are as described. Reid (1968) noted that the pupal and larval characters used to separate *donaldi* and *barbirostris* in Peninsular Malaysia were less reliable in East Malaysia where *barbirostris* is apparently absent. Finding characters that are distinct where these 2 species are found together, and then break down when only one species is present in an area, is identical to the situation found with *barbirostris* and *campestris* in both Malaysia and Thailand.

The variation noted by Reid (1968) regarding the accessory pale fringe spot,

particularly on males, is essentially identical with that found in about 15% of the *barbirostris* males from peninsular Thailand (see *barbirostris*, taxonomic discussion). With the previously described character trends in mind, it would be interesting to determine if this *donaldi*-like character on *barbirostris* is another character breakdown where only one species occurs.

Reid (1962) noted males usually have more pronounced pale palpal bands than males of *barbirostris*; however, we were unable to detect any difference in the size of these bands.

BIOLOGY. In Borneo where *donaldi* seems most common, Colless (1948, as *barbirostris*) notes the larvae were common in most ground water habitats with some vegetation and not exposed to direct sunlight, or deep shade as in jungle pools. He listed rice fields, overgrown drains and open sedge swamps as the most favored habitats. Reid (1962) said that in Malaya, *donaldi* has to compete with *barbirostris* and tends to be more local and is found in more shady breeding sites, such as river swamps or the edge of the forest in more inland hilly areas. Moorhouse (1965) found *donaldi* larvae in Selangor, Malaysia, at the edge of "swamp-forest" under moderate shade and in lightly shaded sedge "swamps." Adults of *donaldi* have been collected by a number of techniques, including: resting, biting human bait inside and outside houses, biting cattle, resting near poultry, pigs and cattle, and in net traps using human bait (Reid 1962; Moorhouse and Wharton 1965; Macdonald et al. 1967). Adult behavior has proven somewhat unusual for a member of the *barbirostris* group. Like some members of the *umbrosus* group, *donaldi* actively bites in shaded forest during the day, then enters settlements and houses at night to bite. Reid (1968) suggests *donaldi* is less zoophilic than *barbirostris*, but confusion exists about this aspect of *donaldi* behavior (Reid 1962). Reports indicate that *donaldi* readily enters houses at night to bite, however, tests in Malaya (Moorhouse and Wharton 1965) show a slight preference for biting outside. Although *donaldi* bites in houses at night, it does not remain in the houses during the day as does *campestris*, but apparently returns to the shaded forest (Moorhouse and Wharton 1965). In summation, *donaldi* is reported to: readily bite man, but show a preference for cattle; enter houses to bite at night, but show a preference to bite outside; leave houses before daylight; and bites in the shaded forest during daylight hours.

MEDICAL SIGNIFICANCE. The role *donaldi* plays in the transmission of human pathogens in Malaysia is becoming increasingly evident. This species is clearly a vector of periodic *Brugia malayi* in the inland hills areas of Peninsular Malaysia and is probably a vector of this parasite in Borneo (Reid 1968). Peninsular Malaysian *donaldi* were found to have a very low level of susceptibility to *Wuchereria bancrofti* (Wharton et al. 1963), however, de Zulueta (1957) considered *donaldi* a vector of this parasite in Borneo.

The role of *donaldi* in the transmission of malaria parasites is still unclear. Reid (1962) summarized the few records of *donaldi* found naturally infected with malaria parasites in Borneo. However, in 1968 he suggested these parasites were possibly not of human origin because Wharton, Eyles et al. (1963), Moorhouse (1965) and Moorhouse and Wharton (1965) found oocysts in Peninsular Malaysian *donaldi*, resembling the mousedeer malaria, *Plasmodium traguli* Garnham and Edeson. The 2 studies by Moorhouse also reported finding primate-like oocysts in *donaldi*, but these infections could not be correlated with any human malaria in the study areas. Moorhouse (1965) noted that in previous experimental susceptibility studies *donaldi* from Peninsular Malaysia failed to transmit *Plasmodium falciparum* (Welch) and was a poor host for *P. traguli* parasites. Furthermore, Warren et al. (1963) and Bennett et al. (1966)

have shown Peninsular Malaysian *donaldi* to be refractory to strains of *P. cynomolgi*, one of the common primate malaria parasites in Malaysia. Despite these confusing reports and in the absence of any confirmed human malaria parasites having been found in Peninsular Malaysian *donaldi*, Reid (1968) still lists *donaldi* as a minor vector of human malaria parasites in Malaysia. Field and laboratory studies by Hardin, Santa Maria and Liaw (1973) now lend support to this contention. These authors found 7 of 4,303 wild caught *donaldi* from Sarawak positive for sporozoites, and found laboratory reared *donaldi* highly susceptible to both *P. falciparum* and *vivax* infections. These infected mosquitoes were also able to transmit both parasite species to a susceptible human volunteer. A comparison of these results with those achieved using Peninsular Malaysian *donaldi* would suggest that the strain of *donaldi* in East Malaysia (at least Sarawak) is much more receptive to infection with malaria parasites. This suggestion is one means of clarifying the confusion surrounding the malaria vector capabilities of *donaldi*, however, further research is needed. Regardless of the vector capabilities of *donaldi* in Malaysia, it is apparently too scarce in Thailand to serve as a vector of human pathogens.

ANOPHELES (ANOPHELES) HODGKINI REID
(Figures 43, 44, 45)

Anopheles (An.) hodgkini Reid 1962: 20 (♂, ♀*, P*, L*, E*); Moorhouse 1965: 113 (♀); Reid 1968: 134 (♂, ♀*, P*, L*, E*).

Best recognized in the adult and pupal stages. Adult females have an accessory pale wing fringe spot at vein R_2 and a narrow apical pale fringe spot confined to R_{4+5}, few to no pale scales on the abdominal sterna, and narrow pale tarsal bands like those of *barbirostris*. The pupa can be identified by the absence of a secondary trumpet cleft or fold and the presence of relatively short, dark brown setae 9. This species is like *barbirostris* except for:

FEMALE (Fig. 43) *Thorax*. Pleural setae: 3 - 5 propleural, 5 - 8 spiracular, 7 - 12 prealar, 3 - 7 upper and 3 - 4 lower sternopleural, 6 - 11 upper and 0 - 4 lower mesepimeral. *Wing*. Paler than *barbirostris*; tip of R_2 rarely with dark scales on the upper or under surface; tip of wing with accessory pale fringe spot adjacent to R_2. *Legs*. Upper midcoxa with 2 - 3 setae; midtarsomeres 1 - 3 usually with narrow apical pale bands or small dorsoapical pale spots. *Abdomen*. Sterna with fewer pale scales than found on *barbirostris*; lateral and diagonal sternal pale scales absent, only median groups remain, with 0 - 5 scales per segment; sterna may not have pale scales (see taxonomic discussion), but sternum VII usually with 2 - 4 anterior pale scales.

MALE (Fig. 43) *Head*. Palpus with distinct narrow pale bands at apex of segments 3 - 4. *Wing*. Generally paler than that of female, with accessory pale fringe spot adjacent to R_2; accessory pale fringe spot often confluent with preapical pale fringe spot, consequently, upper pale fringe spot is wide with pale scales down to include R_3. *Legs*. First and 2nd foretarsal pale bands 2 - 3 times as long as broad, that on tarsomere 1 frequently half or more as long as tarsomere 5, seldom crossing onto base of next tarsomere. *Abdomen*. Dorsal surface of 8th segment with median patch of mixed pale and dark scales. *Genitalia*. Aedeagus with 4 - 6 pairs of leaflets.

PUPA (Fig. 44) *Cephalothorax*. Trumpet without secondary cleft or fold, with shallow emargination or, infrequently with small darkened indentation at normal site of secondary cleft. *Abdomen*. Seta 0-VII with 1 - 2 branches,

rarely 3 and then only on one side; setae 9 dark brown, rarely yellow or tan; seta 1 and particularly 5 on segments IV - VII with branches more densely clumped than on *barbirostris*.

LARVA (Fig. 45). Not always distinguishable from *barbirostris* and occasionally *barbumbrosus*. *Head.* Seta 3-C with 19 - 44 branches usually stiff and broom-like, rarely non-rigid or more than 40. *Thorax.* Seta 13-P with 9 - 15 branches (7 - 9 *barbumbrosus*); 14-M with 8 - 14 branches (12 - 21 *barbirostris*: 20 - 28 *campestris*). *Abdomen.* Seta 2-I with 6 - 7 branches (3 - 6 *barbumbrosus*); 2-II with 7 - 12 branches, rarely 5 - 6 (5 - 7 *barbirostris* and *campestris*); sum of branches for both setae 13-IV is 10 - 18 (6 - 9 on *barbirostris* and *donaldi*); seta 9-VII with 4 - 7 branches (1 - 4 *barbirostris*: 2 - 5 *campestris*).

TYPE-DATA. The ♀ holotype, ♂ allotype and 2♀ paratypes, with associated larval and pupal skins (except paratype #0195) are located in the BMNH. The holotype is numbered "0150/7" and comes from "16th mile Gombak, Selangor, Malaya, Feb. 1957, J. A. Reid." The allotype has the same data, but is numbered "0150/1". The 2 paratypes are from "11 mile, Ulu Gombak Rd., April 1957", in Selangor, Malaya, and are numbered "0195 and 0195/1" respectively. All 4 specimens are in excellent condition. The wing-tip fringe scales have been knocked off the holotype, and the allotype genitalia has been mounted on a slide.

DISTRIBUTION (Fig. 44). In Thailand *hodgkini* is a forest mosquito, although it is infrequently found in shaded plantations and villages. Typically, it is found in either secondary or primary forest. There seems to be some correlation of *hodgkini* with the distribution of tropical wet forests in Thailand; however, this needs further study. Currently, *hodgkini* is found in peninsular Thailand and up to about 15° N latitude in central Thailand. The most northern collections were made in Khao Yai National Park (Nakhon Ratchasima) and in the Khwae Noi River valley (Kanchanaburi). This species is encountered most commonly in the southern peninsular provinces; however, it is also abundant on Ko Chang (Trat), an island off the southeast coast next to Cambodia. Specimens (66♂, 59♀, 122 larvae and 156 larval and pupal skins) in the USMN were examined from the following provinces of THAILAND: Kanchanaburi, Krabi, Nakhon Ratchasima, Phangnga, Phuket, Prachin Buri, Ranong, Satun, Songkhla, Trang and Trat. Additional specimens were examined from MALAYSIA in the USNM (2♂, 7♀ and 8 larval and pupal skins) and in the BMNH (1♂, 3♀ and 6 larval and pupal skins - type-series), while 4♂ and 8♀ specimens from CAMBODIA were examined in the ORSTOM collections.

TAXONOMIC DISCUSSION. *Anopheles hodgkini* is usually encountered in forested areas, and should not be difficult to identify because the only other forest species in this group are *barbumbrosus*, *donaldi* and *pollicaris*. Since the last 2 species are rare and only occur in the extreme southern provinces of Thailand, *hodgkini* is most commonly associated with *barbumbrosus*, from which it is easily separated by the apical pale fringe spots on the wing and normally a few pale scales on the abdominal sterna. The pupa of *hodgkini* differs from that of *barbumbrosus* by the absence of a secondary fold on the trumpet. If *hodgkini* and *donaldi* were found together, the best differentiating character besides small foretarsal differences, would be the pupal trumpet. *An. donaldi* has a deep secondary cleft, which is absent on *hodgkini* pupae. The use of the foretarsal bands would become a primary character in separating *pollicaris* and *hodgkini*, while the key characters are best for separating the pupae (see taxonomic discussion under *pollicaris*). The presence of a thumb-like stigmal process on *pollicaris* larvae will always separate the larvae of

these 2 species. Along forest edges and in cultivated plantations, *hodgkini* will occasionally be found with *barbirostris*. In such situations the pupal trumpet provides the best differentiating character, for like *donaldi*, *barbirostris* has a deep secondary cleft that is absent on *hodgkini* pupae.

Adults of *hodgkini* occasionally exhibit character variations which may influence their identification. Reid (1962) indicated that *hodgkini* females always possessed a few pale scales on the abdominal sterna, or at least on sternum VII; however, Moorhouse (1965) found many *hodgkini* without pale sternal scales. A minority of Thai *hodgkini* are also without pale sternal scales, but the majority usually exhibit at least 1 - 2 such scales on sternum VII. The occurrence of the accessory pale fringe spot at vein R_2 is also slightly variable. Three confirmed *hodgkini* females were found that lacked this spot on both wings, and were only separable from *barbirostris* by associated pupal skins. Infrequent female *hodgkini* may have the preapical and accessory pale fringe spots confluent. Approximately 30% of the male *hodgkini* show a confluence of these 2 spots.

Pupal characters also exhibit a few variations. Rare specimens of *hodgkini* were noted which had a small dark indentation at the spot on the trumpet where a secondary cleft or fold occurs on other species. Occasional specimens have a seta 0-VII with 3 branches, but only on one, never both of these setae. The pigmentation of seta 9 was a very useful secondary character for identifying *hodgkini* pupae. These setae were dark brown to black on over 95% of the specimens examined, while the same setae on *barbirostris*, *campestris*, *donaldi* and *pollicaris* are nearly always pale yellow or tan. Such dark setae are also found on *barbumbrosus* pupae, but those of the latter on segment VII have a length 6 - 8 times the width, while on *hodgkini* they are only 4 - 5 times the width. Dark setae 9 are very prevalent in the *vanus* subgroup of the *barbirostris* group. Both *manalangi* and *vanus* usually exhibit dark setae, although *vanus* is less consistent than *manalangi*. *Anopheles franciscoi*, the only member of the *barbirostris* subgroup in the Philippines, has yellow to tan setae like the other subgroup members (except *hodgkini*).

Larvae of *hodgkini* have few (19 - 44) branches on seta 3-C, another character similar to the *vanus* subgroup. When these branches rarely exceed 40, then the pupal stage is the best way of separating *hodgkini* from *barbirostris* larvae. *Anopheles barbumbrosus* larvae can occasionally be confused with those of *hodgkini*, because the former has seta 3-C with 12 - 36 branches and infrequently they are more rigid than normal. One *hodgkini* larva was found with an anomalous, bifid seta 2-C. Seta 1-II (palmate) on *hodgkini* is often pale like those found on *barbumbrosus* and other *vanus* subgroup members. Members of the *barbirostris* subgroup (including *franciscoi*) have seta 1-II darkly pigmented (except for *hodgkini*).

As can be seen from the above discussion *hodgkini* has a number of immature characters that imply a close relationship to the *vanus* subgroup. On the other hand, the pale fringe spots on the wing and pale abdominal sterna scales found on adult *hodgkini* coupled with egg characters (Reid 1962), imply a relationship with the *barbirostris* subgroup. Apparently *hodgkini* occupies a somewhat intermediate position between these 2 subgroups.

BIOLOGY. As indicated in the distribution section, *hodgkini* is essentially a forest species in Thailand. Much more is known about the biology of the immature stages of this species than the adults. Immature stages have been collected in Thailand from 5 - 750 m elevation. The larvae apparently require clear (often stained), cool, moderate to heavily shaded water. Floating leaves are often encountered in the larval habitats. Immatures have been collected in

Thailand from large marshes, large pond, ditch, canals, ground pools, flood pools, rock pools, stream pools, stream margin, large seepage springs, large shallow wells, elephant footprints and a large mining pit. The most frequently encountered habitats with this species were rock pools and stream pools, particularly in dried up stream beds.

Adult *hodgkini* are rarely collected. Reid (1962) says that small numbers of this species were taken in a human bait trap by Macdonald and Traub (1960). One female in the USNM was collected by Bishop Museum personnel in Trang Province in 1964, but with no mention of the bait used. SEATO Medical Research Laboratory personnel have spent thousands of man hours making anopheline biting collections on both animal and human bait over the last 12 years, and adult *hodgkini* have not been collected. Many of these collections were made in or adjacent to forested areas on peninsular Thailand.

MEDICAL SIGNIFICANCE. No information is available that incriminates *hodgkini* as a vector of human pathogens. Attempts to infect *hodgkini* with *Plasmodium cynomolgi* Mayer have involved too few mosquitoes to allow conclusions as to their susceptibility (Warren et al. 1963; Bennett et al. 1966). The lack of information on adult behavior and biting responses after many years of collecting efforts in Thailand and Malaysia seems to rule out any direct involvement of *hodgkini* in the transmission of human pathogens.

ANOPHELES (ANOPHELES) POLLICARIS REID
(Figures 46, 47, 48)

Anopheles (An.) pollicaris Reid 1962: 24 (♂, ♀*, P, L*, E*); Reid 1968: 136 (♂, ♀*, P, L*, E*).

This species is fairly easily recognized, particularly in the adult female and larval stages. Adult females have wide foretarsal pale bands, an accessory pale fringe spot adjacent to wing vein R_2 and often have scattered pale scales on the costa in the preapical dark area. The larva is typical of the group, except it has a unique thumb-like stigmal process. The pupa is fairly easily separated from the majority of the group members by the absence of a secondary cleft in the trumpet. Essentially this species is like *barbirostris* except for:

FEMALE (Fig. 46) *Thorax.* Pleural setae: 1 - 4 propleural, 5 - 8 spiracular, 9 - 13 prealar, 3 - 5 upper and 3 - 4 lower sternopleural, 6 - 10 upper and 0 - 3 lower mesepimeral; and 2 - 6 lower sternopleural white scales (*barbirostris* 5 - 10); 8 - 17 lower mesepimeral white scales (*barbirostris* 2 - 12). *Wing.* Preapical dark mark on costa often with scattered pale scales; tip of R_2 often dark scaled; accessory pale fringe spot adjacent to vein R_2. *Legs.* Upper midcoxa with 2 - 3 setae; foretarsi with broad pale bands; 1st pale band on apex of tarsomere 1 and base of tarsomere 2 approximately 4 - 7 times as long as wide, usually as long as or longer than length of tarsomere 5 and with 0.33 of band on base of tarsomere 2; 2nd pale band on apex of tarsomere 2 and base of tarsomere 3, length approximately 2 - 4 times width, with 0.25 - 0.33 of band on base of tarsomere 3; 3rd pale band small only on apex of tarsomere 3. Midtarsomeres 1 - 2 with narrow apical pale bands or small dorsoapical pale spots. *Abdomen.* Sterna with no lateral or diagonal pale scales; median pale scales from 5 - 17 on sterna II - VI; caudal margin of sternum VI may have several central black scales.

MALE (Fig. 46) *Head.* Palpus with distinct narrow pale bands at segmental

joints 3 - 4 and 4 - 5. *Wing.* Generally paler than female. *Legs.* Foretarsal pale bands usually longer than those on female, 1st band approximately equal to length of foretarsomere 3; tarsomere 3 without apical pale band. *Abdomen.* Dorsal surface of 8th segment with scales on median area, pale scales basally, black scales apically. *Genitalia.* Aedeagus with 4 - 5 pairs of leaflets; 3 largest leaflets on each side have small denticulate edge, 2nd leaflet usually with most extensive denticles.

PUPA (Fig. 47) *Cephalothorax.* Trumpet without secondary cleft or fold. *Abdomen.* Seta 0-VII with 2 - 5 branches; seta 9 yellow or tan, 4 - 6 times as long as wide.

LARVA (Fig. 48) *Head.* Seta 9-C with 10 - 17 branches (other members of complex, 5 - 11). *Abdomen.* Median dorsal valve with thumb-like stigmal process; seta 1 on III - VII (palmates) large, dark, with tips pale; 1-II darkly pigmented.

TYPE-DATA. The ♀ holotype, ♂ allotype and 2♀ paratypes, with associated larval and pupal skins (except paratype #961) are located in the BMNH. All 4 specimens are in excellent condition and come from the same locality in Selangor, Malaya. The holotype, allotype and one ♀ paratype are labeled: "16th mile, Ulu Gombak, 13-5-1957, J. A. Reid." These 3 specimens each possess a number for associated reared skins, they are: holotype - "0196/11; allotype - "0196/4"; and paratype - "0196/6". The other ♀ paratype numbered "961", has the following data: "16 mi. Ulu Gombak, Bare leg catch-forest." The allotype genitalia were clipped and mounted on a slide for this study. This slide bears the following SEAMP label; "SEAMP Acc. No. 334, ♂ prep. 73/112," and is deposited with the allotype in the BMNH.

DISTRIBUTION. This is another species which enters Thailand only along the southern border where a Malayan type climate and vegetation are common. Specimens (2♂, 2♀, 3 larvae and 6 larval and pupal skins) in the USNM were examined from Satun and Songkhla provinces, THAILAND. Additional specimens from Malaysia were examined in the USNM (5♂, 4♀ and 15 larval and pupal skins), and in the BMNH (1♂, 3♀ and 6 larval and pupal skins - type-series). Apparently *pollicaris* is a true Malayan species for it has not been found outside of Malaysia except for southern Thailand.

TAXONOMIC DISCUSSION. Adults of this species are most similar to *donaldi* and *hodgkini*, but can be separated from these by the broad foretarsal pale bands which cross onto the bases of the next tarsomeres, and pale scales on the preapical dark area of the costa (when present). This latter character was noted by Reid (1963) on about 50% of the Malayan specimens, but was not present on the Thai specimens examined here. The holotype of *pollicaris* does not possess these pale costal scales, but the 2♀ paratypes in the BMNH exhibit this character. No variation was noted regarding the accessory pale fringe spot adjacent to the tip of wing vein R_2, but this may be due to the few specimens available for study. Males should not be confused with any other members of the group, because of the very wide foretarsal bands. The pupa of *pollicaris* is easily separated from all the other Thailand members of the group (except *hodgkini*) by the absence of a secondary cleft or fold in the trumpet. Pupal separation of *pollicaris* from *hodgkini* is more difficult, and in the past has been based entirely on the degree of branching on seta 0-VII. Unfortunately, this character is not completely reliable in Thailand or Malaysia, for *hodgkini* occasionally has 3 branches on 0-VII and *pollicaris* infrequently has 2 branches on 0-VII. Another character has been found which is about 97 - 98% reliable, this involves the color of seta 9. Setae 9 on *pollicaris* are yellow or tan, while those on *hodgkini* are nearly always dark brown or

black. By using both the seta 0 and seta 9 characters the pupae of *pollicaris* and *hodgkini* can be separated more reliably. The larva of *pollicaris* can be separated from the other species in the complex by 2 characters, i.e., the number of branches on seta 9-C and the presence of a thumb-like stigmal process. The latter is by far the better character, but since this process is unpigmented, at times it is virtually impossible to see. When this process is hard to see, the specimen(s) are easily confused with *barbirostris* larvae, unless the seta 9-C character is used.

BIOLOGY. Very little is known about the biology and behavior of this species, particularly in the adult stage. It appears to be a forest species in Thailand as it is in Malaysia. The 5 Thailand collections consist of immatures taken from temporary pools and stream pools along stream courses. These sites were under light to heavy shade (3 of 5 moderate) and at elevations up to 190 m. These pools contained floating leaves and the water was usually clear, although in one case polluted due to stagnation. In all cases the stream courses were located in secondary or primary forest. Other species found as larvae in these pools were: *An. montanus, An. roperi, Uranotaenia* spp., *Culex* spp., and in one pool *Aedes (Aedimorphus)* spp., *Aedes (Muscidus)* sp. and *An. balabacensis* Baisas. Nothing was discovered about adult behavior from the Thailand collections and apparently very little is known from Malaysia. Reid (1968) points out small numbers have been collected in the forest biting man. In fact, one ♀ paratype in the BMNH was collected by this method.

MEDICAL SIGNIFICANCE. Currently, *pollicaris* is considered an uncommon forest species that is not involved in the transmission of human disease pathogens.

ANOPHELES (ANOPHELES) BARBUMBROSUS STRICKLAND AND CHOWDHURY
(Figures 49, 50, 51)

Myzorhynchus barbirostris var. *pallidus* Swellengrebel 1919: 8 (♂*); Swellengrebel and Swellengrebel-de Graaf 1919: 21 (L*); Swellengrebel and Swellengrebel-de Graaf 1920b: 82 (L*).

Anopheles barbumbrosus Strickland and Chowdhury 1927: 18 (nom. nov. for *barbirostris* var. *pallidus* Swellengrebel, non *pallidus* Theobald 1901) (L*).

Anopheles (Anopheles) barbumbrosus of Edwards 1932: 40 (in part); Christophers 1933: 157 (♂*); Bonne-Wepster and Swellengrebel 1953: 212 (♂*, ♀*, L*).

Anopheles (Anopheles) barbumbrosus Strickland and Chowdhury, Reid 1962: 29 (♂*, ♀*, P*, L*); Reid 1968: 138 (♂*, ♀*, P*, L*).

This species is the only member of the *vanus* subgroup of the *barbirostris* group that occurs in Thailand. The adults, pupal and larval stages possess distinctive characters that make it the most easily recognized member of the *barbirostris* group found in Thailand. This species is like *barbirostris* except for:

FEMALE (Fig. 49) *Thorax.* Pleural setae: 3 - 7 propleural, 4 - 7 spiracular, 11 - 16 prealar, 5 - 9 upper and 4 - 6 lower sternopleural, 5 - 12 upper and 0 lower mesepimeral; propleuron without pale scales, lower mesepimeron with pale scales. *Wing.* Normally with humeral pale spot on costa and scales on humeral crossvein; accessory pale fringe spot adjacent to vein R_2; lower apical pale fringe spot wide and distinct, extending at least from R_{4+5}

to M_{1+2}; usually with pale fringe spot at Cu_2. *Legs*. Upper midcoxa with 3 - 4 setae. Foreleg: Femur with distinct pale spot on inner and outer aspect near apex; foretarsi dark scaled except small dorsoapical pale spot on tarsomeres 1 and 2. Midleg: Femur with long distinct pale spot on inner and outer aspect near apex; midtarsi dark scaled except very small dorsoapical pale spot on tarsomeres 1 and 2. Hindleg: Tibia with distinct basal and apical pale bands; tarsomeres 1 - 4 with narrow apical pale bands; tarsomeres 3 - 5 with basal pale bands, increasing in size distally; basal pale band on T_5 equal or wider than apical pale band on tarsomere 4. *Abdomen*. Without scales, except sternum VII with median tuft of dark scales near caudal margin; sternum VII rarely with 1 - 2 dirty white scales cephalad of dark scale tuft.

MALE (Fig. 49) *Head*. Palpus with very narrow pale band at segmental joints 3 - 4 and 4 - 5. *Wing*. Paler than that of female, with distinct humeral pale spot on costa. *Abdomen*. Dorsal surface of segment 8 without scales. *Genitalia*. Basimeres with pale dorsal and dark lateral scales; tergum IX with short lateral lobes; aedeagus with 2 - 6 pairs of leaflets; largest pair of leaflets usually with small indistinct basal tooth, infrequently this tooth is larger; distal half of largest pair of leaflets distinctly curved, sometimes with a large lateral denticle near beginning of curve; usually only one pair of large leaflets and these have variable amounts of small lateral denticles, remaining leaflets usually small.

PUPA (Fig. 50) *Cephalothorax*. Trumpet with very small indentation associated with long seam or fold. *Abdomen*. Setae 1 and 5 on V - VII with many branches and tufted; sum of branches on both setae 5-III less than 30; 9 on III - VIII dark brown or usually black, 9-VII, 6 - 8 times as long as wide, 9-VIII usually with few lateral branches, infrequently almost spinelike.

LARVA (Fig. 51) *Head*. Antenna nearly always pale, even when remainder of head is dark; seta 1-A often shorter, not reaching tip of antenna; 3-C with 12 - 36 thin attenuated branches, usually non-rigid and spread out. *Thorax*. Seta 11-P usually stout and split at base into 2 stout branches; 13-P with 7 - 9 branches. *Abdomen*. Seta 2-I with 3 - 6 branches; 1-II nearly always unpigmented or faintly pigmented, rarely heavily pigmented; pecten plate with 9 - 12 pecten teeth, usually 10 - 12.

TYPE-DATA. No types designated. The name *pallidus* Swellengrebel, was based on males reared from larvae collected in Mandailing, Sumatra and the island of Nusa Kambangan (= Noesa Kembangan), South Java. Strickland and Chowdhury (1927) failed to designate a type for this species when they changed the name from *pallidus* Swellengrebel (not *pallidus* Theobald 1901) to *barbumbrosus*. One ♂ is in the BMNH from Nusa Kambangan, the type-locality. Possibly this is one of Swellengrebel's original specimens, but due to the lack of adequate characters to separate the adults of this species from those of *An. vanus*, it is best left as is until the fauna of Java and Sumatra become better known.

DISTRIBUTION (Fig. 50). This is another member of the *barbirostris* group which should be considered a forest species. The distribution map does not show *barbumbrosus* as occurring throughout Thailand, however, this species should be expected anywhere in Thailand where primary or secondary forest exists. Actually the range of *barbumbrosus* in Thailand is probably being reduced by the depletion of the forests. There are no specimens available to show that *barbumbrosus* has ever occurred in the broad rice plains north of Bangkok. Only a few specimens are available from the Korat Plateau, which also has broad rice plains, and these all come from mountainous or hilly areas of the plateau. These findings suggest that besides forests, mountain

or hill streams and pools, clear cool water is another basic requirement. It will be interesting to note the distribution of this species in Thailand in future surveys. Specimens (121♂, 158♀, 304 larvae and 383 larval and pupal skins) deposited in the USNM were examined from the following provinces of THAILAND: Chanthaburi, Chiang Mai, Chiang Rai, Chon Buri, Chumphon, Kanchanaburi, Khon Kaen, Krabi, Lampang, Mae Hong Son, Nakhon Nayok, Nakhon Ratchasima, Nan, Narathiwat, Phangnga, Phrae, Prachin Buri, Ranong, Songkhla and Yala. Other specimens (3♂, 13♀, 28 larvae and 4 larval and pupal skins) in the USNM were examined from INDONESIA (Java), MALAYSIA (Peninsular), SRI LANKA (see taxonomic discussion) and TAIWAN. Two ♂ and 6♀ from CAMBODIA were found in the ORSTOM collections. Additional literature references record this species from INDIA, NEPAL, INDONESIA (Sumatra) and SOUTH VIETNAM.

TAXONOMIC DISCUSSION. Adults of *barbumbrosus* are distinct and easy to recognize in Thailand. Both sexes possess a lower apical pale fringe spot on the wing which extends at least from R_{4+5} to M_{1+2}. This spot is not found on other Thai members of the *barbirostris* group. Pale scales are not found on the abdominal sterna, except a rare 1 - 2 pale scales on sternum VII. All the other members of this group possess at least a few pale scales on the abdominal sterna except *hodgkini* which infrequently has no sternal pale scales. The distal curve on the largest pair of aedeagal leaflets is also usually sufficient to identify rubbed males of *barbumbrosus*.

Wattal et al. (1962) were the first to record *barbumbrosus* from India and Reid (1962) was the first to record it from Nepal and Sri Lanka. Reid (1962) noted the adults from Nepal and Sri Lanka lacked the accessory pale fringe spot normally found adjacent to wing vein R_2 on *barbumbrosus*. Adults (1♂, 8♀) recently collected in Sri Lanka by Smithsonian Institution personnel confirm this observation. Besides the absence of the accessory fringe spot, these adults only have narrow apical pale bands on hindtarsomeres 1 - 4, while *barbumbrosus* from Thailand also has basal bands on tarsomeres 3 - 5 in addition to the apical bands. Too few immatures are available from Sri Lanka for valid comparison but those available key to *barbumbrosus*. Possibly the reduction in tarsal banding is associated with the clinal band reduction in India and Sri Lanka previously discussed under *nigerrimus* and *peditaeniatus*. The status of *barbumbrosus* in the Indian subregion needs further study.

The pupa is quite distinct, and should not be confused with the other members of the group that occur in Thailand. Besides having a secondary seam on the trumpet rather than a deep cleft, or no cleft, *barbumbrosus* pupae also have fewer branches on seta 5-III and have seta 9 darkly pigmented and quite long on segment VII. *Anopheles hodgkini* is the only species that could cause confusion, for it also possesses darkly pigmented seta 9, but these are not as long as those on *barbumbrosus*. Besides, *hodgkini* pupae do not have a secondary cleft or seam on the trumpet and have more branches on seta 5-III.

Larvae of *barbumbrosus* can usually be identified by the few non-rigid branches on seta 3-C, and the pale palmate seta 1-II. These characters do vary slightly however, and specimens will occasionally be found with the branches on 3-C stiffer than normal, or with seta 1-II lightly to moderately pigmented. Specimens with these variations can easily be confused with *hodgkini*, which normally has 19 - 44 stiff branches on seta 3-C and seta 1-II often pale. In such situations the number of branches on setae 13-P and 2-I may be of help, but it is better to rear the specimens and identify cast pupal skins and adults.

Several other variations were observed. Occasional females and more

frequently males (5 - 10%) will exhibit a broad pale upper fringe spot on the wing. This broad spot is due to an extension and joining of the pale preapical spot and the accessory pale spot at R_2.

Spine-like pupal seta 9-VIII with very few lateral branches were observed frequently. Specimens from Chiang Mai, Kanchanaburi and Lampang seemed to possess this variation more frequently than specimens from other areas.

Anomalies were also observed on several larvae. At least 3 larvae from Lampang were noted with seta 2-C separated by at least 2 widths of a 2-C alveolus, rather than one width which is normal. One larva from Lampang was observed with both 2-C forked at midpoint, while another larva from Chiang Mai had an extra 3-C on the right side.

BIOLOGY. Over 95% of the immature collections of *barbumbrosus* have come from primary or secondary wet, deciduous or evergreen forests, or dense bamboo groves. Only a few collections have been made at the forest edge or outside a forest. Immature collections have been made from 75 - 1,065 m in elevation, usually in moderate to heavy shade, and normally in cool clear water sources that contain dead leaves and/or limbs. Approximately 60% of the larval collections came from stream pools, rock pools, flood pools or stream margins. However, *barbumbrosus* larvae have also been collected in the following habitats: a small pond-marsh on a mountain, stump hole in ground, pit, rock hole, ground pools, puddles, swamp margin, shallow well, seepage spring, rice field with abundant emergent vegetation, wheel tracks, elephant footprints, hoof prints, large open bamboo internode laying on the ground, tree hole in a fallen tree, water pot and a water jug.

Very little is known about the biology and behavior of adults of this species. Scanlon and Esah (1965) reported *barbumbrosus* females collected biting man at an elevation between 760 - 1,370 m in northern Thailand. Harinasuta et al. (1970) reported 11 females collected by the human bait method in Kanchanaburi Province. Apparently, these are the only confirmed records of *barbumbrosus* biting man. One female was captured in a light trap in Chiang Mai, but other trapping methods have been unproductive.

MEDICAL SIGNIFICANCE. Although seldom encountered, this is a common forest species in Thailand, at least more common than in Malaysia (Reid 1968). Even so, we still have no information that indicates *barbumbrosus* is involved in the transmission of human pathogens. Recently Harinasuta et al. (1970) reported 1 of 9 dissected females infected with a *Dirofilaria* larva.

ANOPHELES UMBROSUS SPECIES GROUP
(*An. umbrosus* species group, Reid 1950)

Myzorhynchus umbrosus (Theobald) 1903b.

GENERAL. Moderately large and dark. *Head.* Palpus entirely black or brown scaled (except *separatus*), with basal scales usually more dense and erect; palpus equal to or shorter than length of proboscis; clypeus bare; 1st antennal flagellomere only with patch of dark scales; interocular space with tuft of long yellow or tan setae and short white scales (except *separatus*); vertex with erect scales only. *Thorax.* Pleuron without white scale patches and lower mesepimeral setae; propleuron without scales; scutum with center ashy gray and sides dark brown on most species. *Wing.* Basal half of costa without scattered pale scales; subcostal pale spot small, infrequently absent; preapical pale spot small; humeral crossvein with dense patch of black scales; remigium

usually dark scaled; basal 0.33 of vein R entirely dark scaled; base of Cu usually dark scaled; veins R_S-$R2+3$ and/or M with pale scales just before forks; tertiary fringe scales dark (except *separatus*); posterior margin of wing without pale fringe spot; tip of wing with 1 - 2 small pale fringe spots (*brevirostris*, with a nearly unicolorous dark brown wing, is an exception). *Legs*. Coxae with few dark or pale scales; upper midcoxa without scales; femora, tibiae and tarsomeres mostly dark scaled; tarsomeres may have narrow to moderate pale bands. *Abdomen*. No scales on the terga or sterna (see male description).

FEMALE *Head*. Antenna with reduced whorled setae; pedicel with small dark scales on upper and outer aspects.

MALE *Head*. Antenna with long dense whorled setae; pedicel very large, without scales. *Abdomen*. Dorsal surface of 8th segment without scales (except *roperi* and *separatus*). *Genitalia*. Basimeres with at least dark scales (except *brevipalpis*); aedeagus with leaflets (except *hunteri*), which may have fine lateral denticles; claspette bi-or trilobed, with at least one stout mesal seta on ventral lobe; dorsal lobe with club-like structure composed of several separate basal stems that fuse distally to form single club.

PUPA *Cephalothorax*. Palpal sheath not exhibiting consistently separable sexual dimorphic characters; male palpus appearing slightly more attenuated than that of female. *Trumpet*. Longest axis transverse to stem, but less so than in *hyrcanus* and *barbirostris* groups; rim of trumpet usually without secondary cleft, but with long, often complex, tragus. *Abdomen*. Terga with denticles on caudal margins (except *baezai* and *samarensis*); seta 1-VII with 5 or fewer branches; seta 5-VII with not more than 13 branches.

LARVA *Head*. Seta 2-C frequently branched near tip; seta 3-C with not more than 25 branches, usually 5 - 20. *Abdomen*. Without palmate setae or with 2 to 3 pairs of palmate setae instead of the usual 5 - 6 pairs.

DISTRIBUTION. There are currently 12 species recognized in this group: *baezai*, *brevipalpis*, *brevirostris* Reid, *collessi* Reid, *hunteri* (Strickland), *letifer*, *roperi*, *samarensis* Rozeboom, *separatus*, *similissimus* Strickland and Chowdhury, *umbrosus* and *whartoni*. Their distributions extend from Assam where *roperi* and *umbrosus* are known, to the Philippines where *baezai* and *samarensis* occur, and Guam where *baezai* was recently recorded (Basio and Reisen 1971). The group definitely has its center of distribution in Malaysia-Indonesia, for 11 of 12 described species occur in Malaysia (Reid 1950, 1963, 1968). The distribution of this group seems to have a definite correlation with the distribution of tropical wet forests. Accordingly, members of this group are rarely, if ever, collected in areas where annual rainfall levels are low and the year is divided into very distinct wet and dry seasons. This correlation is very evident in Thailand, where there are 6 members of the group: *baezai*, *letifer*, *roperi*, *separatus*, *umbrosus* and *whartoni*. The only areas where these species are found in Thailand is in the southern peninsula and/or the southeast corner near Cambodia. Both areas have the heaviest rainfall in Thailand and tropical wet forests.

TAXONOMIC DISCUSSION. This group is less homogeneous and more artificial than the *hyrcanus* and *barbirostris* groups. Although several assembleges of species in the group are obviously sibling clusters, the group as a whole cannot be called a sibling group. The *letifer* subgroup (Reid 1968) includes *collessi*, *letifer*, *roperi* and *whartoni*. These species are so similar that some stages are still unseparable, and those that can be separated are distinguished by minute differences. *Anopheles baezai* and *samarensis* are also very closely related. The former has a Philippine synonym, *gateri* Baisas, which should also be considered when these 2 species are reviewed.

Anopheles hunteri and *separatus* are separable only on poorly known male genitalia and larval characters. *Anopheles brevirostris* and *umbrosus* have a number of similarities and are probably more closely related to each other than to the other members of the group. Nevertheless, they are easily differentiated in all stages known. The egg of *brevirostris* is unknown. One of the remaining 2 species, *brevipalpis*, is distinct and the other, *similissimus*, is very poorly known.

The relationship of the *umbrosus* group to the other species groups in Southeast Asia has been discussed earlier under the taxonomic discussions of the *albotaeniatus*, *hyrcanus* and *barbirostris* groups. The closest relationship seems to lie with several members of the *albotaeniatus* group, however, species such as *separatus* and *hunteri* also point to a relationship with the *hyrcanus* group. The outcome of phylogenetic interpretations is entirely dependent on the life stage(s) that the worker feels has the most significant characters (Reid 1950). Reid (1950, 1963, 1968) selected the larval and pupal stages as the main indicators of affinities, and for convenience, we concur with this selection.

Six of the 12 known species are not known from Thailand. *Anopheles samarensis* is known only from the Philippines, and is supposedly separable from *baezai* by pale banding on the adult tarsomeres, the size of the tragus on the pupal trumpet and fewer branches on larval seta 3-C (Rozeboom 1951). There are Philippine specimens in the USNM of the above stages which exhibit degrees of development of these characters intermediate between *baezai* and *samarensis*. This suggests that *baezai*, its synonym *gateri* and *samarensis* need to be reexamined to determine if these are overlapping characters of 2 species or highly variable characters of a single species. *Anopheles similissimus* is currently differentiated only on the basis of larval characters reported in the literature. No specimens are available, but the species is listed from several areas of Peninsular Malaysia (Reid 1968). The larva, if accurately described, is most unique in having seta 3-C with numerous branches as in the *hyrcanus* group and seta 1 on the abdominal segments filamentous as in the *umbrosus* group. The single female reported was listed as indistinguishable from *umbrosus*. *Anopheles hunteri*, from Peninsular Malaysia and the Indonesian islands of Bintan and South Natuna, is also imperfectly known. This species as pointed out above, is very similar to *separatus*. The male of *hunteri* is quite unique in the *umbrosus* group because it does not have aedeagal leaflets. The larva is distinct from that of *separatus* by having fewer branches on setae 3-C (6 - 10) and 1-A (less than 20). *An. brevipalpis* was described from what is now Sabah. It has since been recorded from Peninsular Malaysia and Sumatra (Banka). Reid (1968) also mentions its possible occurrence in Thailand, but we have seen no specimens to confirm this. This species fits well in the *umbrosus* group except that the adults are a unicolorous brown. Thus, the adults can easily be confused with *sintonoides* and members of the *aitkenii* group. *Anopheles brevipalpis* has scales on the anterior pronotum and on the humeral crossvein of the wing, characters that are absent on *sintonoides* and species in the *aitkenii* group. The *aitkenii* group species also have narrow erect scales on the occiput while *brevipalpis* and *sintonoides* have broad erect occipital scales. *Anopheles brevirostris* is a small rare species known only from Peninsular Malaysia. *An. brevirostris* is similar to *umbrosus* in: the propleural setae, the number of setae on the upper mesepimeron, the pupal trumpet and the weakly developed palmate setae 1 on 2 of the larval abdominal segments. On the other hand, *brevirostris* is distinct because it has: a short proposcis and palpi when compared to the forefemur, broad foretarsal pale bands, short serrate aedeagal

leaflets, blunt setae 9 on the pupa and no stigmal process on the larva. The one remaining species, *collessi*, is known only from Brunei and Malaysia (Peninsular and Sabah). This species is extremely similar to *letifer* and *whartoni*, and occurs in 2 Malay provinces, (Kedah and Kelantan), that are adjacent to Thailand. This species is best separated from *letifer* and *whartoni* in the adult, larval and egg stages. Adults of *collessi* have the following wing character combination that differs from both *letifer* and *whartoni*: extreme base of vein Cu with a small pale mark or scattered pale scales, and base of vein 1A above upper dark mark with 5 - 25 dark scales. The larva of *collessi* has seta 1-X bifid, seta 1-A with 15 or more branches and seta 3-C with 5 - 15 (usually 8 or more) branches. Larvae of *letifer* and *whartoni* have 1-X simple, 1-A with 7 - 13 branches and 3-C with 2 - 9 branches. The pupa of *collessi* can be separated from that of *letifer* by having a *whartoni* type tragus on the trumpet, but it cannot be separated from the pupa of *whartoni*. The reader should refer to Reid (1968) for information on the distinctive egg of *collessi*.

BIOLOGY. Larvae of this group are generally confined to still water, such as freshwater swamps, jungle pools, ditches or drains in plantations, large isolated stream pools or brackish water pools and swamps. Some seem to have a definite association with the dark colored acid water that comes from black peaty soil (Hodgkin 1950). Most are usually found in shaded situations where there is either emergent vegetation or numerous leaves in the water. Adults can frequently be found resting in the vegetation or on tree trunks near larval sites. The females of these species are primarily zoophilic, but will also attack man during daylight under shaded conditions. Certain species have anthropophilic tendencies, and these will also enter houses to feed.

MEDICAL SIGNIFICANCE. Of the 12 species in this group, 5 have been incriminated as vectors of malaria and/or filarial parasites, and those incriminations occurred in Malaysia. These same 5 species also occur in Thailand, but to date there is no confirmation they serve there as vectors of human pathogens.

KEYS. The following keys have been modified from those of Reid (1968). The keys to the adults and pupae are the most reliable. The larvae, particularly of the *letifer* subgroup, are so similar that certain species are currently not separable.

KEYS TO THE SPECIES OF THE *AN. UMBROSUS* GROUP IN THAILAND

ADULTS

1. Palpus with pale band, apical segment usually entirely pale scaled. *separatus* (p. 128)
   Palpus entirely dark scaled. 2

2(1). Base of hindtibia with distinct pale band, usually 1.5 - 4.0 times as long as segment width; base of R and Cu usually with several scattered pale scales; accessory pale fringe spot often present at apex of vein R_2. . . . . *roperi* (p. 124)
   Base of hindtibia dark scaled or with small pale spot; base of R and Cu with dark scales; wing without fringe spot at vein R_2. 3

3(2). With propleural setae on both sides (1 - 6). 4
   Without propleural setae (rarely with one small seta on one side). . 5

4(3). Upper mesepimeron with 9 - 19 setae and a few inconspicuous dark scales; tarsomeres all dark or with minute spots at joints; aedeagal leaflets short and knife-like. . . . . *baezai* (p. 114)
Upper mesepimeron with 1 - 6 setae and no associated scales; fore-and hindtarsomeres with small pale bands; aedeagal leaflets long and thread-like. . . . . *umbrosus* (p. 110)

5(3). Vein 1A with pale scales proximal to median dark mark, infrequently with 2 - 3 dark scales near base. . . . . *letifer* (p. 118)
Vein 1A with 5 or more dark scales at base, infrequently vein nearly all dark scaled. . . . . *whartoni* (p. 122)

PUPAE

1. Caudal margin of abdominal terga with small denticles. 2
Caudal margin of abdominal terga smooth, without denticles. *baezai* (p. 114)

2(1). Paddle with refractile border more than 0.75 its length; without pigmented projection below the root of trumpet; seta 9-V, 4 - 6 times as long as wide, tapering to point. . . . . *umbrosus* (p. 110)
Paddle with refractile border less than 0.65 its length; with pigmented ventrolateral flange of dorsal plate below the root of trumpet; seta 9-V about 2 - 3 times as long as wide, with tip usually more rounded. 3

3(2). Seta 0-IV small with 1 - 2 branches; rim of trumpet with 2 thickened darkly pigmented areas. . . . . *separatus* (p. 128)
Seta 0-IV large with 4 - 14 branches; rim of trumpet without thickened darkly pigmented areas. . . . . (*letifer* subgroup) - 4

4(3). Seta 9, on VI - VII, 3.5 - 4.0 times as long as wide, tapering to sharp point; female genital lobe same color as cercal lobes; sides of male genital lobes nearly parallel. . . . . *roperi* (p. 124)
Seta 9, on VI - VII, 2 - 3 times as long as wide, with more rounded tips; female genital lobe distinctly more darkly pigmented than cercal lobes; sides of male genital lobe convergent apically. 5

5(4). Tragus on trumpet complex, nearly T-shaped in outline; seta 2-III with 7 - 17 branches; seta 6-III with 1 - 4 branches. . . . *letifer* (p. 118)
Tragus more simple and spatulate; seta 2-III with 15 - 23 branches; seta 6-III with 3 - 7 branches. . . . . *whartoni* (p. 122)

LARVAE

1. Seta 1 with developed leaflets on at least abdominal segments IV - V; median dorsal valve with stigmal filament. . . . . *umbrosus* (p. 110)
Seta 1 with filamentous branches, without leaflets on any abdominal segment; median dorsal valve without stigmal filament or process. 2

2(1). Seta 6-IV with 7 - 10 branches; seta 2-C usually with 5 or more fine branches near tip; seta 3-A with truncate tip. . . . . *baezai* (p. 114)
Seta 6-IV with 2 - 6 branches, usually 2 - 4; seta 2-C simple or with up to 4 branches near the tip; setae 2-A and 3-A appear pointed. . 3

3(2). Seta 1-A with 25 or more branches; branches of seta 4-A fine, not hooked. . . . . *separatus* (p. 128)
Seta 1-A usually with less than 20 branches; seta 4-A with 1 - 2 stout, slightly hooked branches. . . . . (*letifer* subgroup) - 4

4(3). Seta 0-III with 5 or more branches. . . . . *roperi* (p. 124)
Seta 0-III usually with less than 5 branches, at least on one side.
letifer (p. 118)*
whartoni (p. 122)*

ANOPHELES (ANOPHELES) UMBROSUS (THEOBALD)
(Figures 52, 53, 54)

Myzorhynchus umbrosus Theobald 1903b: 87 (♀*).
Myzorhynchus novumbrosus Strickland 1916: 271 (A, L).
Anopheles (Anopheles) novumbrosus Strickland, Edwards 1932: 42; Colless 1948: 91 (= *umbrosus* Theobald).
Anopheles (Anopheles) umbrosus of Edwards 1932: 42 (in part); Colless 1948: 91 (♂*, ♀*, L*).
and Swellengrebel 1953: 170 (♂*, ♀*, L*); Reid 1968: 156 (♂*, ♀*, P*,
Anopheles (Anopheles) umbrosus Theobald, Reid 1950: 284 (♂*, ♀*, P*, L*); Bonne-Wepster and Swellengrebel 1953: 170 (♂*, ♀*, L*).
Anopheles (Anopheles) umbrosus (Theobald), Reid 1968: 156 (♂*, ♀*, P*, L*, E*).

This species is fairly easily recognized in all stages. The adults have dark palpi, propleural setae, narrow pale tarsal bands which are usually proximal to the joints on the hindtarsi and 1 - 6 setae and no scales on the upper mesepimeron. In addition, the male has long thread-like aedeagal leaflets. The pupa has a distinct tragus on the trumpet, denticles on the caudal margin of the abdominal terga and seta 9-V pointed and longer than those on the other segments. The larva has at least partially developed palmate setae on IV - V and a long tapering stigmal process. The egg is also distinctive (Reid 1968).

FEMALE (Fig. 52) *Head.* Vertex with broad dark erect scales except for dorsocentral pale scales; interocular space with long tan setae and short narrow white scales approximately 0.25 length of setae; palpus with dark erect scales and tapered appearance because more distal scales are shorter and decumbent, slightly shorter than proboscis; proboscis slightly shorter to equal length of forefemur; clypeus bare; pedicel with small blue-black scales on upper-outer aspects; flagellomere 1 with several broad blue-black scales, remaining flagellomeres without scales. *Thorax.* Integument dark brown, with central portion of scutum ash-gray; anterior promontory with slender pale scales centrally, darker broader scales laterally; scutum sparsely covered with short and few longer tan-yellow setae; scutal fossa without scales; scutellum with short and long setae; anterior pronotum with prominent tuft of blue-black scales on dorsocephalic aspect, short pale setae on ventrocaudal aspect; pleural setae: 2 - 6 propleural, 4 - 7 spiracular, 2 - 4 upper and 3 - 6 lower sternopleural, 7 - 11 prealar and 1 - 6 upper mesepimeral; propleuron, sternopleuron and mesepimeron without scales. *Wing.* Costa with black scales except for very small subcostal pale spot on some specimens and small

**letifer* and *whartoni* larvae currently not separable.

preapical pale spot; subcosta entirely black scaled, or with several apical pale scales on specimens with subcostal pale spot on costa; remigium with black scales; humeral crossvein with patch of black scales; vein R-R_1 with dark scales except tip which has pale scales and is adjacent to preapical pale spot on costa, and infrequent specimens with several pale scales representing pale sector spot; R_S-R_{2+3} usually with black scales to fork, infrequently with paler scales just before fork; R_2 with black scales, may have pale scales adjacent to tip of R_1, tip with black scales; R_3 with black scales except for distinct patch of pale scales on basal half, tip with black scales; R_{4+5} with distinct black scale patch on basal 0.16, remainder with pale scales or mixed pale and dark scales except tip which has white scales; M with dark scales on basal half and pale scales just before fork; M_{1+2} with dark scales at base, remainder with pale scales; M_{3+4} with dark scales at least halfway to fork; Cu_1 with several dark scales at base, distinct small dark spot at M-Cu crossvein and distinct small dark spot at apex; Cu_2 with pale scales on basal 0.66, apical 0.33 with black scales; vein 1A with several black scales at extreme base, then pale scales out to distinct small black patch of scales slightly distal to midpoint, followed by pale scales and small dark patch of scales at apex; apical dark mark on Cu_2 distinctly longer than apical dark mark on vein 1A; apical pale fringe spot narrow, extending at most from R_3 to R_{4+5}; posterior margin of wing without pale fringe spot; tertiary fringe scales blue-black, like primary and secondary fringe scales. *Halter*. Knob with dark scales. *Legs*. Coxae without scales, except occasional 1 - 2 blue-black scales on the uppercephalic aspect of forecoxa; upper midcoxa with 3 - 7 setae. Foreleg: Femur swollen on basal half, with blue-black scales dorsally and laterally, and slightly paler scales ventrally; tibia with dark scales dorsally and laterally, slightly paler scales ventrally; tarsomeres with dark scales, except for narrow apical pale bands on tarsomeres 1 and 2; tarsomeres 3 and 4 may have several dorsoapical pale scales. Midleg: Femur and tibia with dark scales dorsally and laterally, slightly paler scales ventrally; tarsomeres with dark scales except for very narrow dorsoapical pale scale patch on tarsomeres 1 - 3. Hindleg: Femur and tibia with dark scales dorsally and laterally, paler scales ventrally, apex of tibia with very narrow band of pale scales; tarsomeres with dark scales except for pale band approximately equal segment width on apices of tarsomeres 1 - 4; tarsomeres 4 and 5 may have very narrow pale basal bands. *Abdomen*. Integument brown dorsally and ventrally; without scales.

MALE (Fig. 52). As for female, with dark palps and no scales on abdomen. Wing may have more pale scales, and sector spot may be present on vein R. *Genitalia*. Basimeres with pale dorsal setae and few dark lateral scales; inner parabasal spine on very prominent lobe, outer parabasal on smaller lobe, longer and more tapered than inner, often with 3rd smaller parabasal spine slightly distal to other 2; internal spine located on mesal margin approximately midway between apex and claspette; claspette with 2 distinct lobes; ventral lobe with a single long stout seta, usually one small seta and small spicules or spines on ventral surface; dorsal lobe with club-like structure composed of 2 - 3 very closely associated flattened spines; aedeagus with 8 - 11 pairs of long thread-like leaflets, 2 - 3 longest pairs as long as aedeagus; lobes of tergum IX narrow, 3 - 5 times as long as wide, about half as long as the space between them.

PUPA (Fig. 53). Integument normally light tan. *Cephalothorax*. Wing sheath usually with darker brown barred design or series of small brown spots; antennal sheath with tip and last joint darkly pigmented; without pigmented lateral angle (projection) below trumpet root. *Trumpet*. Without secondary cleft, with narrow complex tragus that is trough-like and abruptly twisted near apex.

Abdomen. Segment VII distinctly narrower than others, often with parallel sides; caudal margins of terga with distinct denticles; setae 1 and 5 not dark and bushy; seta 0 small with 2 - 5 branches; seta 2 small with 2 - 9 branches; seta 3-IV with 12 - 18 branches; seta 9-V pointed, 4 - 6 times as long as wide, longer than other setae 9 except 9-VIII; seta 3-VI between setae 1 and 5-VI; seta 9-VIII nearly spine-like, with few weak side branches; lateral margin of VIII with several small denticles just cephalad of seta 9 base; sides of male genital pouch nearly parallel. *Paddle.* Refractile border approximately 0.8 - 0.9 of paddle length, with distinct spines on apical half; seta 1-P short, stout and single or frayed near tip.

LARVA (Fig. 54) *Head.* Capsule light tan; seta 1-A with 13 - 31 branches; 4-A branches fine, filamentous; seta 3-A with slightly frayed tip from lateral view; 2-C single or with 2 - 6 fine branches near tip; 3-C with 12 - 25 branches; 4-C single or with 2 - 4 branches; 8-C with 3 - 7 branches. *Thorax.* Seta 1-P simple or with 2 - 3 fine branches at tip; 2-P with 6 - 9 branches; 4-P with tuft of fine branches at tip and long lateral branches; 11-P with 5 - 11 densely packed, subequal branches arising from stout basal stem; 14-P with 8 - 12 branches; branches on 3-T filamentous or slightly flattened, unpigmented. *Abdomen.* Seta 1 usually with filamentous unpigmented branches on segments I, II, VI - VIII, with partially to fully flattened branches (palmate) on segments III - V, and 1, on IV - V often darkly pigmented; 0-III minute, with 2 - 5 branches; 6-III with more than 20 branches, 6-IV with 2 - 3 branches; 3-VI located between setae 1 and 5-VI; segment VIII with ventral plate on cephalic margin; spiracular area with long tapering, filamentous stigmal process; pecten plate with 7 - 9 long teeth, usually without short alternating teeth; 1-X weak, single or bifid, arising at edge of saddle.

TYPE-DATA. The ♀ holotype is located in the BMNH and is labeled: (1st label) - "Pehang Malay, Dr. Durham"; (2nd label) - "*Myzorhynchus umbrosus*, type FVT"; and (3rd label) "Pekan Hospt., Pahang, X.02". The specimen is in poor-fair condition, with the left wing, part of the right antenna, 2 forelegs and the right midleg missing. The structures still present are in good condition and exhibit the salient species characters.

DISTRIBUTION (Fig. 53). Known from Thailand with certainty only from Narathiwat Province, near the Malaysian border. This is another Malaysian-Indonesian species that apparently enters Thailand only where environmental conditions are right and tropical wet forest occurs. Iyengar (1953), Tansathit et al. (1962), and Harinasuta et al. (1970) record this species from southern southeastern and west-central Thailand respectively, but the absence of specimens for confirmation makes it impossible to determine which member(s) of the *umbrosus* species group might be involved. One larva from Narathiwat Province, THAILAND, was found in the SEATO Medical Research Laboratory collection. Additional specimens (8♂, 46♀ and 10 larval and pupal skins) in the USNM were examined from: INDIA (Assam) and MALAYSIA. An additional 2♂, 8♀ and 7 larval and pupal skins, besides the holotype, were examined in the BMNH. Reid (1963) examined 2 larvae of *roperi* from Assam, and suggested (also Reid 1968) that Christophers' (1933) record of *umbrosus* from Assam may actually refer to *roperi*. However, a single female in the USNM confirms Christophers' record. This female was collected by C. O. Masters in Assam, on 20-XII-1943, and is easily identified as *umbrosus* by 3 - 4 propleural setae, absence of scales and only 2 setae on the upper mesepimeron, and typical *umbrosus*-like wing and tarsal characters. *Anopheles umbrosus* is also known from Indonesia (Reid 1950, 1968), but records from the Andaman Islands (Christophers 1933) and Nepal (Brydon et al. 1961), need confirmation.

TAXONOMIC DISCUSSION. The name "*umbrosus*" has been applied to several closely related species in Southeast Asia, particularly in Malaysia. This has been most unfortunate because of problems associated with the presumed role of "*umbrosus*" as a vector of human malaria parasites. Colless (1948) began to clarify the situation when he synonymized *novumbrosus* under *umbrosus*. However, clarification of all the species masquerading under this name did not come until Reid's detailed study (1950), supported by the biological observations of Hodgkin (1950). Reid (1950) presents a thorough discussion of the misinterpretations and confusion that existed under the name "*umbrosus*" prior to 1950. The other *umbrosus* group members that occur in Thailand (*baezai*, *letifer*, *roperi*, *separatus* and *whartoni*) are easily separated from *umbrosus* in all stages. Females of *umbrosus* even with propleural setae missing, should be fairly easily recognized by other pleural chaetotaxy, wing and tarsal characters. Of 41 Malaysian females examined for wing variations, 19 possessed at least 2 - 3 pale subcostal (Scp) scales and pale sector (Sp) scales, 8 had pale Scp scales but no pale Sp scales, 3 had no pale Scp scales but had pale Sp scales, and 11 had no pale scales on Scp or Sp areas. The remaining wing of the female from Assam exhibited characters equal to the second category above. The hindtarsal banding is quite significant, for those pale bands present on the tarsomeres are mostly apical rather than basal (cf. *letifer*).

The larva of *umbrosus* is most distinct because of the absence of distinct palmate setae on all segments except III - V, and particularly the long tapering stigmal process. The only other known *Anopheles* larvae having large stigmal processes in Southeast Asia are: *pollicaris* (*barbirostris* group), and *pseudobarbirostris* Ludlow and *bancrofti barbiventris* Brug of the *bancrofti* group. In the Australasian region, *bancrofti bancrofti* Giles and *atratipes* (?*stigmaticus* group) also have stigmal processes. These species (except *atratipes*) possess palmate setae 1 on at least segments III - VII. In Southeast Asia *pollicaris* and *umbrosus* larvae might be found together, but should not be confused because *pollicaris* has more palmate setae and a short thumb-like stigmal process. The known distribution of *umbrosus* does not overlap with those of *pseudobarbirostris* and *bancrofti barbiventris*.

The combination of a complex trumpet, extra large seta 9-V and long refractile paddle border on the pupa of *umbrosus*, makes it difficult to confuse the pupa of this species with any other species in Southeast Asia.

The male genitalia of *umbrosus* is quite distinct because of the extremely long thread-like aedeagal leaflets. Some of the longest leaflets may approach 1.5 times the length of the aedeagus.

Some of the members of the *stigmaticus* group in the Australasian region have thread-like aedeagal leaflets, but they are much shorter than those on *umbrosus*.

BIOLOGY. Hodgkin (1950) attempted to sort out the biological requirements and habitat preferences for members of the *umbrosus* group in Malaya, but earlier species misinterpretations made this difficult. He did outline the basic larval habitat of *umbrosus* as being the dense swampy jungle of the coastal plains and foothills, where the water is stained from the peaty soil. This agrees well with the one Thai larval collection made in a heavily shaded jungle spring bog with many dead leaves in the water. Apparently, *umbrosus* is a swamp-forest species, usually not closely associated with human populations, which exhibits an opportunistic type feeding behavior. Wharton et al. (1964) and Moorhouse and Wharton (1965) have shown that adults will bite in the forest throughout the day, but they exhibit distinct peaks of biting activity during the hour before sunset and the first hour after dawn. Moor-

house (1965) determined that adult *umbrosus* are reluctant to leave the forest and enter village clearings, even at night. According to Moorhouse and Wharton (1965), those few adults that do enter village areas during the night bite outside, not in houses. A pyrethrum knock-down survey conducted by these authors also failed to yield any *umbrosus* resting in houses during the day. However, the adult behavior of *umbrosus* actually appears more plastic than described by these last authors. Reid (1961) attracted this species to human or calf-baited net traps placed under a shelter open on all 4 sides. Reid (1968), using man as bait, compared simultaneous net trap and window trap hut collections and captured 39% of the *umbrosus* by the latter method. He also compared simultaneous collections of *umbrosus* biting man outdoors versus biting man in window trap huts, and captured 14% in the huts (Reid 1968). The attraction of *umbrosus* to feed on different animals has also been measured. Reid (1961) found 2.5 times as many *umbrosus* were attracted to one calf as to 2 men. Wharton et al. (1964) found *umbrosus* will bite monkeys on the ground and on elevated platforms, but the latter only attracted 15% of the specimens. Furthermore, ground collections comparing man to monkey baits revealed an attraction ratio of 100 : 16, respectively. Additional information on the biology of *umbrosus* can be found in Wharton, Eyles et al. (1963) and Reid (1968).

MEDICAL SIGNIFICANCE. In Thailand *umbrosus* is probably too scarce to be involved in the transmission of human pathogens. Until recently *umbrosus* has been considered a confirmed vector of human malaria parasites in Malaysia. However, Wharton, Eyles et al. (1963) and Wharton et al. (1964) have shown that the *Plasmodium* infections commonly found in Malayan *umbrosus* are probably *Plasmodium traguli*, a parasite of the mouse deer, *Tragulus javanicus* (Osbeck). Subsequent *Plasmodium* infections found in *umbrosus* (Moorhouse 1965, Moorhouse and Wharton 1965) were also credited to *P. traguli*.

Records of human *Plasmodium* parasites in *umbrosus* are now considered questionable due to early confusion of the malaria species involved and the earlier inclusion of *baezai*, *letifer* and *whartoni* under the name "*umbrosus*". Reid (1968) still considers *umbrosus* a potential vector of human malarial parasites because it readily feeds on man. However, due to its usual remoteness from human populations and the absence of any confirmed human malaria parasites in thousands of dissected adults, this species is probably not a vector of human malarial parasites.

There have been several studies on the ability of *umbrosus* to transmit nonhuman *Plasmodium* species. Warren et al. (1963), found *umbrosus* moderately susceptible (19% developing oocysts) to laboratory infection of *Plasmodium cynomolgi bastianellii*. Wharton, Eyles et al. (1963) innoculated sporozoites dissected from *umbrosus* into 10 species of animals and birds (including man), but failed to produce malaria infections.

There is very little information about *umbrosus* involvement in filarial transmission. Wharton, Laing and Cheong (1963) determined that it is nonsusceptible to infection with *Wuchereria bancrofti*. The only natural filarial infection found in *umbrosus* was due to *Setaria* larvae, probably from the mouse deer (Wharton, Eyles et al. 1963).

ANOPHELES (ANOPHELES) BAEZAI GATER
(Figures 55, 56, 57)

Anopheles baezai Gater 1933: 162 (♂*, ♀*, P, L*); Farinaud 1938: 393 (♀*, L*).

Anopheles (Anopheles) baezai (var. ?) of Russell and Baisas 1936: 27 (♂*, ♀*).
Anopheles gateri Baisas 1936: 78 (P*); Reid 1950: 290 (= *baezai* Gater).
Anopheles (Anopheles) baezai gateri of Colless 1948: 88 (♂*, ♀*, L*); Reid 1950, supra cit., (= *baezai* Gater).
Anopheles (Anopheles) baezai Gater, Reid 1950: 290 (♂*, ♀*, P*, L*); Bonne-Wepster and Swellengrebel 1953: 177 (♂*, ♀*, L*); Reid 1968: 165 (♂*, ♀*, P*, L*, E*); Basio and Reisen 1971: 60.

Adults of *baezai* are fairly easily recognized by the combination of propleural seta, scales on the upper mesepimeron and absence of pale bands on the tarsomeres. The pupa is very distinct because it lacks denticles on the caudal margins of the abdominal terga. The larva is easily identified by the absence of palmate setae on the abdomen, a truncate ventral sabre piece (seta 3-A), many branches near the tip of seta 2-C, and many branches on seta 6-IV. This species is like *umbrosus* except for:

FEMALE (Fig. 55) *Thorax.* Upper mesepimeron usually with inconspicuous dark scales anteroventral to setae; pleural setae as follows: 1 - 3 propleural, 2 - 5 spiracular, 3 - 6 upper and 3 - 7 lower sternopleural, 8 - 12 prealar and 9 - 19 upper mesepimeral. *Wing.* Basal dark mark on vein Cu not reaching halfway to fork, often with scattered dark scales distal to it; distal dark mark on vein 1A shorter to nearly equal length of distal dark mark on vein Cu_2. *Legs.* Upper midcoxa with 1 - 5 setae; tarsomeres entirely dark scaled, infrequently with faint pale spots on the dorsoapical aspect of some segments.

MALE (Fig. 55). Like female, but usually with subcostal pale spot on costa. *Genitalia.* Only 2 parabasal spines; ventral lobe of claspette variable, with single long mesal seta and a variable lateral seta, from very small to nearly equal to the mesal seta; dorsal lobe with fused club originating from 3 separate basal stems; aedeagus with 4 - 6 pairs of lanceolate leaflets about 0.33 length of the aedeagus, leaflets without lateral serrations or a basal denticle.

PUPA (Fig. 56) *Cephalothorax.* Integument light tan; antennal sheath with all joints and tip the same color as cephalothorax. *Trumpet.* Tragus variable, usually short but may be very long like that of *umbrosus* or *samarensis* (see taxonomic discussion), not usually twisted near tip; secondary cleft or fold, when present, in form of small fold on rim. *Abdomen.* Terga without denticles on the caudal margins; lateral margins of segment VII not parallel; seta 0 small, often single; seta 2 often with many branches (10 or more); seta 3-IV with 6 - 7 branches; seta 9, II - VII, dark, broad, with rounded tip, not more than 2 times as long as wide, 9-VIII with strong central stem and long lateral branches; position of seta 3-VI highly variable, may be lateral, mesal or even with seta 1-VI, but usually slightly more cephalad than seta 1; segment VIII without denticles on the lateral margin above the base of seta 9; male genital pouch with sides convergent. *Paddle.* Refractile border 0.5 - 0.7 of paddle length with strong spines; seta 1-P with 3 - 7 branches on apical half.

LARVA (Fig. 57) *Head.* Capsule dark brown to black; seta 1-A with less than 25 branches; seta 3-A with truncate tip; 4-A with filamentous branches; 2-C with 2 - 8 fine branches near tip; 3-C with 10 - 25 branches (but see taxonomic discussion). *Thorax.* 4-P with tuft of fine branches at tip, lateral branches variable, usually long as on *umbrosus*, but infrequently shorter and more sparse; 14-P with 2 - 4 branches; seta 3-T filamentous and unpigmented. *Abdomen.* Seta 1 filamentous on all segments; 6-IV with 7 - 10 branches; 3-VI location variable, from directly under seta 1 to nearly midway between setae 1 and 5; spiracular area without stigmal process; pecten plate with 6 - 7 long teeth, usually with short alternating teeth; 1-X strong and single, arising at

edge of saddle.

TYPE-DATA. Gater (1933) listed the type-material as one ♂, one ♀, a larval skin and a whole larva deposited in the BMNH, and the type-locality as Pulau Langkawi, British Malaya. This is a large island off the west coast of Peninsular Malaysia, just south of the Thai-Malay border. These specimens were accessioned at the BMNH as "BM 1934-410", and since Gater did not designate a holotype they have syntype status. The ♂, ♀ and a larval skin for the ♂ are currently in the BMNH. The only whole larva accessioned in "BM 1934-410" is from Selangor, not Pulau Langkawi; however, there is a 2nd larval skin from Pulau Langkawi with this accession number. Therefore, the specimen (= whole larva) that Gater was actually referring to is questionable. The ♂ specimen is here designated as lectotype for *baezai*, and is labeled as follows: (1st label) "*Anopheles (A.) baezai* Gater, Det. by B.A.R. Gater"; (2nd label) "Bred 2464, larvae in pool I stagnant water and decaying leaves, 250 pts Cl_2 per 100,000, Pulo Langkawi"; (3rd label) "Malay Peninsula, 11 . X . 1928, B.A.R. Gater"; and (4th label) "Larval skin and hypopygium on slides, B.M. 1934.410." This specimen is in excellent condition and can be recognized as *baezai* by the characters presented in the adult key and also by its larval skin which is mounted on a slide and labeled: "Department of Biology, BM 1934.410, *Anopheles (A.) baezai* Gater, larval pelt 2464, Pulo Langkawi, 11 . X . 1928, King Edw. VII College of Medicine, Singapore." The genitalia slide preparation of the lectotype is also in the BMNH.

DISTRIBUTION (Fig. 56). This is a widespread coastal, brackish water species, that is currently known from Cambodia, Guam, Indonesia, Malaysia, Philippines, South Vietnam and Thailand. Specimens (3♂, 3♀, 6 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Chanthaburi, Ranong and Trang. Additional specimens (55♂, 110♀, 32 larval and 84 larval and pupal skins) in the USNM were examined from INDONESIA (Sumatra and Java), MALAYSIA, PHILIPPINES and SINGAPORE. Additional MALAYSIA and PHILIPPINE specimens (8♂, 14♀, 1 larva and 14 larval and pupal skins) including the type-series, were examined in the BMNH. Six females from CAMBODIA were found in the ORSTOM collections. Literature records also include Vietnam (Farinaud 1938) and Guam (Basio and Reisen 1971), but material from these areas was not available for study. The above distribution for *baezai* is based on the inclusion of *gateri* Baisas, as a synonym.

TAXONOMIC DISCUSSION. *Anopheles baezai* is easy to recognize in Thailand. The adults would most likely be confused with *umbrosus*, but the presence of scales and many setae on the upper mesepimeron is very distinct. The pupa lacks denticles on the caudal margins of the abdominal terga, a character present on all the other Thailand members of this group. The larva is also easily identified by the numerous branches on abdominal seta 6-IV and other previously discussed characters. Considerable variation has been noted in this species. In Malayan specimens Gater (1933), and Reid (1950) claim the subcostal pale spot on the costa is uncommon (10% and 33% respectively), while Colless (1948) claims 80% of Borneo specimens have this spot, as do nearly all the specimens from the Philippines. Interpretation of this spot is highly subjective, Reid (1950) plainly defines the spot as "at least one or two pale scales breaking the anterior margin of the costa", but the other authors are not that explicit. Using the above definition and USNM specimens, 44% (11/25) of the female *baezai* from Malaysia and 37% (10/27) of the female *baezai* from Java have a pale subcostal spot. On the other hand 67% of those Malay females and 79% of the Java females had pale scales at the apex of the subcostal vein and on the posterior border of the costa, thus the definition of the pale scales

breaking the anterior margin of the costa is very important. Philippine specimens usually possess this spot on the costa and have faint pale spots on the apices of the tarsomeres. The latter character is less commonly seen in Malayan specimens. The shape of the 9th tergal lobes of the male was used by Colless (1948) to differentiate Malaysian and Philippine specimens, but Reid (1950) felt this was probably intraspecific variation. After examining specimens from both areas we feel that this latter interpretation is correct. The length of the tragus on the pupal trumpet is highly variable in this species, even in a single sibling brood (Reid, personal communication). Specimens were examined where the tragus graded between practically non-existent to excessively long and protruding some distance beyond the rim of the trumpet. The major variations detected on larvae involve the lateral branches of setae 3-C and 4-P. Several USNM larval specimens from Subic Bay, Luzon, Philippines, have only 6 - 9 branches on seta 3-C. On the basis of 3-C counts, these specimens are intermediate between *baezai* and *samarensis*. All larvae seen from areas other than the Philippines have 3-C with 10 or more branches. On infrequent specimens, regardless of origin, the lateral branches of 4-P are more sparse and shorter than usual. On these latter specimens, 4-P looks more like that of *letifer* rather than *umbrosus*. Such variations are most pertinent when problems arise, such as the status of *samarensis* in the Philippines.

BIOLOGY. This species is associated with coastal brackish water habitats. Usual larval habitats include drains and pools with moderate to heavy shade that have decaying leaves and sticks in the water. Nipa palms are often associated with these habitats. In Thailand, larvae have been found only in tin mine pools, pits or excavations in Ranong Province. Such surface mines are common in southern Thailand and the water in them is usually acid and without mosquito larvae. Hodgkin (1950) states that *baezai* larvae appear to prefer slightly acid waters with a pH of about 6.3 - 6.8. This would be expected of a brackish water species. Besides the chloride data listed on the lectotype label, Colless (1948) lists salinity levels in North Borneo collection sites as varying between 300 - 1,020 parts chlorine per 100,000 parts water. Apparently during the evolution of the tin mine pits, the salinity and acidity levels are compatible for a while with *baezai* larval requirements. In other countries *baezai* larvae have been collected in the following habitats: mangrove swamp, tidal or coastal swamps, stagnant drains or ditches, ground pools in a salt marsh and a buffalo (carabao) wallow. Basio and Reisen (1971) gave no data regarding the pH or salinity of the water in the last habitat.

Certain behavioral aspects of adult *baezai* are also known. Hodgkin (1950) commonly found adults resting during the day on the smooth bases of nipa palm fronds about 1 - 3 feet above the ground. Preliminary data (Hodgkin 1950) indicated that *baezai* prefers to feed on man. More recent studies (Reid 1961, Reid and Weitz 1961) have shown *baezai* to be strongly zoophilic, with a 1 : 27 man to calf ratio and a 1 : 16 man to goat ratio. Although one of the major sources of blood meals for *baezai* in the latter study is still not known, it is suspected to be from the mouse deer. Wharton, Eyles et al. (1963) collected *baezai* in net traps baited with monkeys on the ground, but not on an elevated platform. Reid (1968), in tests comparing man bait in outside net traps and window-trap huts, collected only 2% (2/99) of the *baezai* in the window-trap huts. These Malayan studies indicate that *baezai* primarily feeds on cattle and other mammals rather than man, and that it is reluctant to enter houses. Only one adult female from Chantaburi Province was collected in Thailand biting man.

MEDICAL SIGNIFICANCE. Hodgkin (1950) found a 0.9% sporozoite rate in *baezai* from Malaya, and he considered this species a likely vector of human malaria parasites in that area, although some of the sporozoites did not appear to be of human origin. Experiments (Hodgkin 1950) to transmit the sporozoites from wild caught *baezai* to monkeys, and to determine the susceptibility of *baezai* to infection with human malaria parasites, met with little success. Warren et al. (1963) have shown in the laboratory that *baezai* is refractory to *Plasmodium cynomolgi bastianellii*. Wharton, Eyles et al. (1963) infected 1 or 2 *baezai* with *Plasmodium sandoshami* Dunn, Eyles and Yap, from a flying lemur, *Cynocephalus variegatus* Audebert, and found *baezai* had a low susceptibility (23%) to infection with *Plasmodium traguli*. Current interpretations (Reid 1968) suggest that *baezai* is probably not a vector of human malaria parasites, and based primarily on circumstantial evidence, is probably a vector of a mouse deer malaria parasite (Wharton et al. 1964).

The involvement of *baezai* in filarial parasite transmission is poorly known. No naturally infected *baezai* were found by Reid et al. (1962), but those authors were able to infect 34% of exposed mosquitoes in a laboratory with periodic *Brugia malayi*.

Current information indicates that *baezai* is probably not involved in the transmission of human malaria or filarial parasites, particularly in Thailand where its population levels are usually low.

ANOPHELES (ANOPHELES) LETIFER SANDOSHAM
(Figures 58, 59, 60)

Anopheles (Anopheles) letifer Sandosham 1944: 129 (♀*, L*); Iyengar and Menon 1956: 785; Stone, Knight and Starcke 1959: 21; Reid 1963: 107; Reid 1968: 173 (♂*, ♀*, P*, L*, E*).

Anopheles umbrosus of Stanton 1915: 171 (L*); Puri 1931: 117 (L*); Swellengrebel and Rodenwaldt 1932: 97 (in part); Christophers 1933: 162 (♂*, ♀, P, L*) (in part); Gater 1934: 104 (L*); Gater 1935: 176 (♂, ♀*); Reid 1950: 294 (= *letifer* Gater).

Anopheles (Anopheles) species "A" near *umbrosus*, of Colless 1948: 93 (♀*, L*); Reid 1950: 294 (= letifer Gater).

Anopheles (Anopheles) letifer Gater, of Reid 1950: 294 (♂*, ♀*, P*, L*); Bonne-Wepster and Swellengrebel 1953: 180 (♀*, L*).

Best distinguished from the other members of the group by adult female and pupal characters. The female is characterized by the absence of propleural setae, base of wing vein Cu all dark, base of vein 1A all pale or rarely with 1 - 5 dark scales near origin, foretarsomeres without distinct pale bands and hindtarsomeres primarily with basal pale bands. The pupa is distinct on the basis of a T-shaped tragus, but this structure is difficult to observe. The larva is nearly identical to the larva of *roperi* and cannot always be differentiated. *Anopheles letifer* is like *umbrosus* except for:

FEMALE (Fig. 58) *Head.* Palpus and proboscis with more decumbent scales, appearing thinner; posterior hard palate of cibarium with small median heavily sclerotized area immediately anterior to ventral papillae. *Thorax.* Scutal integument gray, with faint dark longitudinal lines; pleural setae: 0 (rarely 1) propleural, 2 - 7 spiracular, 3 - 6 upper and 2 - 6 lower sternopleural, 7 - 15 prealar and 7 - 10 upper mesepimeral. *Wing.* Scales on veins narrower and decumbent, thus veins appear thinner; costa nearly always with

small subcostal pale spot; R-R_1 with small sector pale spot; preapical pale spot usually completely across R_2; basal dark mark on M usually reaching about halfway to fork; basal dark mark on Cu rarely reaching more than halfway to fork; 1A with pale scales proximal to median dark mark, infrequently with 2 - 3 dark basal scales; distal dark mark on 1A slightly less or equal to length of distal dark mark on Cu_2. *Legs*. Upper midcoxa with 3 - 6 setae; fore- and midtarsomeres unbanded or with faint apical pale spots; hindtarsomeres with pale bands about 1 - 3 times as long as wide at joints 1-2, 2-3, 3-4 and 4-5, major portion of each band on bases of tarsomeres 2, 3, 4 and 5 (cf. *umbrosus*).

MALE (Fig. 58). Like female, but subcostal pale spot on costa and sector pale spot on vein R more distinct. *Genitalia*. Basimeres without obvious pale dorsal setae; only 2 parabasal setae; ventral lobe of claspette with single long mesal seta, and 1 - 3 small lateral setae near base; median ventral membrane of claspette covered with thorn-like spines; dorsal lobe of claspette with fused club originating from 3 separate basal stems, 1 stem internal to the others; aedeagus with 5 - 6 pairs of lanceolate leaflets about 0.33 length of the aedeagus, leaflets without lateral serrations, but usually with a small basal denticle; lobes of tergum IX short and wide, approximately 1.5 times as long as wide and slightly less than 0.5 as long as the space between them.

PUPA (Fig. 59) *Cephalothorax*. With pigmented angulate projections below the root of the trumpet and on the wing sheath; antennal sheath with all joints and tip the same color as the majority of the cephalothorax. *Trumpet*. With complex tragus which is bent inward near the tip and nearly T-shaped; distal half of pinna with generally narrower diameter than that of *umbrosus* and *baezai*. *Abdomen*. Lateral margins of segment VII not parallel; seta 0, on II - VIII large, with 3 or more branches, 0-IV with 4 - 14 branches, nearly as large as 2-IV; 2, on II - VII large, with 5 or more branches; 2-III with 7 - 17 branches (cf. 15 - 23 *whartoni*); 6-III with 1 - 4 branches (cf. 3 - 7 *whartoni*); 9, on III - VII, 2 - 3 times as long as wide, with rounded tip, 9-VIII nearly fan-like, with small central stem and long lateral and apical branches; caudal margin of sternum VIII with denticles just internal to 9-VIII; female genital lobe (ventral) distinctly more darkly pigmented than cercal lobes; sides of the male genital lobes sharply convergent. *Paddle*. Refractile border 0.50 - 0.65 of paddle length; seta 1-P long slender and single or with 2 - 4 fine distal branches; apex of paddle usually with 1 - 2 small lobes just mesad of 1-P alveolus.

LARVA (Fig. 60) *Head*. Integument brown, but not as dark as that of *baezai*; seta 1-A with 7 - 13 branches; 3-A pointed; 4-A with 1 - 2 thickened branches that are hooked apically; 2-C usually single; 3-C with 4 - 9 branches; 4-C with 1 - 3 branches. *Thorax*. 4-P with tuft of equal length branches at tip, lateral branches short and sparse; 11-P with 5 - 7 branches; 14-P with 7 - 9 branches; 3-T with filamentous branches. *Abdomen*. Seta 1 with filamentous branches on all abdominal segments; 0-III minute, with 3 - 4 branches; 6-III with 13 - 23 branches (see taxonomic discussion), 6-IV with 2 - 6 branches; spiracular area without stigmal process; pecten plate with 7 - 10 long teeth, usually alternating with short teeth; 1-X single, arising at edge of saddle.

TYPE-DATA. Reid (1950) discussed the unusual circumstances surrounding the original description of *letifer*. Sandosham (1944) referred to and described *letifer* thinking that Gater had already published the name and deposited type-specimens in the BMNH. However, Gater's manuscript and specimens were destroyed during World War II while en route to England. Due to the above confusion in naming this species, no type-specimens were selected until Reid (1950) designated a neotype and deposited it in the BMNH. This specimen

was examined by the authors and is in excellent condition except for the loss of the fringe scales on the tip of the right wing. The neotype has the following labels: (1st label) - "Selangor, Kg. Sijangkang, 16.5.1934, E.P. Hodgkin"; (2nd label) - "No 7835/12, larvae in stagnant peaty water in garden"; (3rd label) - "*Anopheles (A.) letifer* Gater, Neotype, Det. J. Reid"; and (4th label) - "liason pelts in slide collection." The larval and pupal skins of the neotype are also in the BMNH and are in excellent condition. Both skins are mounted on the same slide with the following label data: (1st label) - "Federated Malay States, *Anopheles (A.) umbrosus* Theo: *letifer* Gater. det. J. Reid, Neotype ♀, No 7835/12, Institute for Medical Research"; and (2nd label) - "Adult in pinned collection." There are also 3 ♀ and one ♂ which Reid placed in the BMNH and labeled plesiotypes. The ♂ and one ♀ of these latter specimens have associated immature skins.

DISTRIBUTION (Fig. 59). Hodgkin (1950) lists *letifer* as primarily a coastal plain species, associated with peaty soil and acid fresh water in Malaya. Data from the specimens examined here support these associations, particularly the former. *Anopheles letifer* has been reported from Thailand by Iyengar and Menon (1956), Reid (1963) and Scanlon et al. (1968). No specimens are now available to confirm these records, but we are including *letifer* here because we feel certain it does occur in Thailand. Reid's (1963) record is very important because it was made at the same time he described *collessi* and *whartoni*, 2 species very closely related to *letifer*. His record was based on 2 females collected biting man by Dr. Udaya Sandhinand in Sungai Kolok (Sungei Golok in Reid), Narathiwat Province, very near the Thai-Malay border. Scanlon et al. (1968) record specimens from Chanthaburi, Chon Buri, Prachin Buri, Ranong, Trang and Yala provinces. The specimens listed from Chanthaburi, Prachin Buri and Yala have not been found, and a close examination revealed those from Ranong are *roperi* and those from Chon Buri and Trang are *whartoni*. Reid (1968) lists the distribution of *letifer* as peninsular Thailand, Malaysia, Sumatra and Borneo. Specimens (10♂, 28♀, 3 larvae and 8 larval and pupal skins) in the USNM were examined from CAMBODIA, INDONESIA (Kalimantan) and MALAYSIA (Peninsular). Additional specimens (7♂, 14♀, and 6 larval and pupal skins), including the neotype, from MALAYSIA (Peninsular and Sarawak) and SINGAPORE were examined in the BMNH. Additional specimens (2♂ and 19♀) from CAMBODIA were found in the ORSTOM collections. The specimens of *letifer* from Cambodia appear identical with Malaysian specimens and lend support to our claim that *letifer* occurs in Thailand, and to a report of *letifer* in South Vietnam (Nguyen-Thuong-Hien 1968).

TAXONOMIC DISCUSSION. *Anopheles letifer* should be fairly easy to identify in Thailand. The adults look like *umbrosus*, but do not have propleural setae (rarely one) and pale bands on the foretarsomeres, while the pale bands on the hindtarsomeres are primarily basal (cf. *umbrosus*). The male has short aedeagal leaflets like those of *baezai*, but the lobes of tergum IX are short and wide, while those of *baezai* are normally long and slender. The greatest problem in identifying the adults will be differentiating *letifer* from *whartoni*, which also occurs in Thailand. At this time the characters described by Reid (1963) to separate *letifer* and *whartoni* seem reliable, the specimens from Cambodia are clearly separable, as are those from Malaysia. However, the differences separating these 2 species are quite small and will probably need re-evaluation when more material becomes available. *Anopheles roperi* adults have also been misidentified as *letifer* in Thailand. Normally *roperi* adults are easily recognized by the basal pale band on the hindtibia and pale scales on the remigium and basal 0.33 of vein R, but speci-

mens that have the legs missing or are rubbed can be confusing. In such cases *roperi* can usually still be separated from *letifer* by having several pale scales at the base of vein Cu, on the basal 0.33 of vein M, and several narrow pale scales in the fossal area on the scutum.

The T-shaped tragus on the pupal trumpet of *letifer* is distinct, but this character is often bent and twisted during mounting, and difficult to interpret. The best means to identify the pupa of this species is by the characters presented in the key. Only poorly mounted pupal skins of *letifer* and *whartoni* should present any identification problems.

The larva of *letifer* is much more difficult to identify, and is best identified by association with later stages. Separation from the larvae of *umbrosus*, *baezai* and *separatus* presents no problem using the above key characters, but final differentiation of whole larvae from those of *roperi* may not always be possible. Reid (1950, 1968) described seta 6-III on *letifer* as having 12 - 20 branches and used this as the primary character for separating *roperi* from *letifer* and *whartoni*. An examination of the neotype and plesiotype skins of *letifer* in the BMNH and other available associated skins revealed that 5 specimens (including the neotype and 2 plesiotypes) out of 13, have 21 or more branches on this seta on at least one side. All the specimens of *roperi* have 21 or more branches on 6-III (including the holotype larval skin). This overlap means that seta 6-III has little or no value in separating *letifer* from *roperi*. The remaining character (seta 0-III) used by Reid remains valid, but is difficult to see. Larvae of *letifer* and *whartoni* cannot be differentiated at present.

BIOLOGY. The absence of Thai *letifer* specimens in museum collections is probably a reflection of the limited areas in Thailand with suitable *letifer* habitat and the few collections made in those habitats. Hodgkin (1950) noted that while *umbrosus* larvae are found in jungle swamps, *letifer* larvae are usually found at their edge, or in water collections remaining after the swamps have been cleared or drained. *An. letifer* is apparently a species of the coastal plains in Malaysia and its larvae seem to prefer acid freshwater and be intolerant of even low salinity (Hodgkin 1950). Moorhouse (1965) usually found *letifer* larvae in brown peaty waters in well shaded ditches between rubber trees, at the edge of jungle swamps, or in clear water in wells and ditches with algae and in grassy swamps. Such habitats usually have cool still water and often have dead leaves or sticks in the water. Although Thailand has extensive rubber plantations, freshwater swamps and the peaty soil made from such swamps are not common.

A number of observations have been made on the behavior of adult *letifer*. Studies by Wharton, Eyles et al. (1963) show it bites mainly at night, and has a very low level of biting activity during the day, even in the forest (cf. *umbrosus*). The peak period of biting activity in the forest and in settlements is approximately 2000 - 2400 hours. Most adults entering settlements do so soon after dusk and rest on tall grass, shrubs or under houses prior to feeding (Moorhouse 1965). Even though *letifer* readily enters settlements, it seems more reluctant to enter houses. Studies (Wharton, Eyles et al. 1963; Reid 1968) comparing manbiting catches of *letifer* indoors versus outdoors indicate it is primarily exophagic, with 4 - 9 times as many biting man outside as inside. A pyrethrum knockdown study by Moorhouse and Wharton (1965) found that *letifer* does not rest in houses during the day. The attraction of this species to different hosts has yielded some confusing information. Hodgkin (1950) considered *letifer* primarily anthropophilic, but more recent studies (Reid 1961; Wharton, Eyles et al. 1963) obtained more zoophilic and ornithophilic feeding patterns. Another study (Reid 1968) comparing man with monkeys

shows that 3 times as many *letifer* fed on man, but of those feeding on monkeys, 43% fed in the canopy. Some of the differences found in past studies of *letifer* feeding behavior may be a reflection of the changing prosperity of the villagers, and the associated increase in the number of fowl and animals found in the villages (Moorhouse 1965).

MEDICAL SIGNIFICANCE. Hodgkin (1950) suggested that in Malaya *letifer* was probably the most important malaria vector in the *umbrosus* complex. This has been partially supported by evidence showing that *umbrosus* malaria infections are of non-human origin (see discussion under *umbrosus*), and studies by Wharton et al. (1963) and Wharton, Eyles et al. (1963) that confirm *letifer's* participation in the transmission of human malaria parasites. There is also evidence (Moorhouse 1965) that *letifer* is not a vector in other areas where human malaria is common, which suggests genetic or behavioral differences. *Anopheles letifer* is a natural vector of *Plasmodium traguli*, and laboratory studies show that it is a very efficient host for this parasite (Wharton, Eyles et al. 1963). Laboratory studies by Warren et al. (1963) and Bennett et al. (1966) indicate that *letifer* is not a good host for the simian parasite, *Plasmodium cynomolgi bastianellii*.

Wharton, Laing and Cheong (1963) and Wharton, Eyles et al. (1963) also found natural infections of *Wuchereria bancrofti* and *Dirofilaria* spp. in *letifer*, and experimental transmission tests show a high percentage of *letifer* develop *W. bancrofti* larvae to the infective 3rd stage.

Anopheles letifer seems to be a rare or uncommon species in Thailand, and probably is not involved in the transmission of human parasites, but if areas are found in Thailand where it is common, its vector capabilities in Malaya should be remembered.

ANOPHELES (ANOPHELES) WHARTONI REID
(Figures 61, 62, 63)

Anopheles letifer of Wharton 1960: 81; Reid 1963: 106 (= *whartoni*).
Anopheles (Anopheles) whartoni Reid 1963: 106 (♂, ♀*, P*, L, E); Wharton, Laing and Cheong 1963: 236; Reid 1968: 180 (♂, ♀*, P*, L, E).

This species is very closely related to *letifer* and can be recognized only in the adult and pupal stages. The adults are characterized by having dark scales on the basal half of wing vein 1A. The pupa has a spatulate tragus and 2 minor setal differences from *letifer*. *Anopheles whartoni* is nearly identical to *letifer* except for:

FEMALE (Fig. 61) *Head*. Sclerotized area of the cibarium less pronounced. *Thorax*. Pleural setae: 0 propleural, 3 - 5 spiracular, 3 - 4 upper and 2 - 3 lower sternopleural, 6 - 9 prealar, and 8 - 11 upper mesepimeral. *Wing*. Dark, even paler scales dull; subcostal pale spot on costa often very small or absent; preapical (apical of Reid) pale mark often not complete on vein R_2; R-R_1 rarely with pale sector spot; vein M with dark scales to or nearly to fork; Cu with dark scales more than halfway to fork, often dark scales to fork; 1A with 5 or more dark scales on basal half, infrequently with dark scales nearly to median dark mark. *Legs*. Upper midcoxa with 4 - 5 setae.

MALE (Fig. 61). Like female. *Genitalia*. (Based on one specimen). Aedeagus with 4 pairs of leaflets; lobes of tergum IX 2.5 - 3.0 times as long as wide, approximately half as long as space between them.

PUPA (Fig. 62) *Trumpet*. Tragus spatulate, not T-shaped at apex. *Abdo-*

men. Seta 2-III with 15 - 23 branches; 6-III with 3 - 7 branches. *Paddle.* 1-P single or with 2 - 3 apical branches.

LARVA (Fig. 63). Currently indistinguishable from that of *letifer*.

TYPE-DATA. The holotype ♀ and allotype ♂ are deposited, with associated larval and pupal skins, in the BMNH. Both were reared from eggs deposited by a ♀ collected at Singora, Maran, Pahang, Malaya.

DISTRIBUTION (Fig. 62). Reid (1968) stated that *whartoni* is known only from the eastern side of Peninsular Malaysia (Pahang and Kelantan). Specimens examined by the authors now extend this range to include Thailand and Cambodia. Specimens (3♀ and 1 pupal skin) in the USNM were examined from the following provinces of THAILAND: Chon Buri, Trang and Trat. Additional specimens (2♂, 5♀, and 4 larval and pupal skins) in the BMNH and ORSTOM collections were examined from CAMBODIA and MALAYSIA (Peninsular Malaysia). The distribution of *whartoni* is apparently confined to lowlands where it largely replaces *letifer* (Reid 1968). The specimens examined from Thailand and Cambodia also came from areas of low elevation.

TAXONOMIC DISCUSSION. The occurrence of this species in Thailand has been responsible for some previous records of *letifer*. These 2 species are nearly identical, and their differentiation is very difficult. The slight differences described by Reid for separating these species are easily overlooked. Wing vein 1A on *whartoni* has at least 5 basal dark scales; however, infrequent specimens of *letifer* may have 1 - 3 dark basal scales on 1A. Such slight differences currently appear valid, but may need modification when more material becomes available. In general, *whartoni* has the darkest wings of any species in the *umbrosus* group (except *brevipalpis*). Even areas that appear pale are dull and usually a dirty-white. Some specimens of *whartoni* have dark scales on veins M and Cu out to or nearly to the forks, and the base of 1A may have dark scales nearly out to the median dark mark. The female from Trat Province has the latter degree of dark scales, and is comparable with specimens seen from nearby in Cambodia. On the other hand, the specimen from Trang is much paler like *letifer* and has only 7 - 8 dark scales on the base of 1A, and veins M and Cu dark only 0.66 of the distance to the forks. Although such differences could be suggestive of clinal variation, specimens from Malaysia were examined that were nearly as dark as those from Cambodia and eastern Thailand.

The possibility that *collessi* may occur in Thailand must also be considered, because it has been collected in Kelantan, Malaysia. This species would also be difficult to differentiate. *Anopheles collessi* has dark scales on the basal half of vein 1A like *whartoni*, but can be separated from both *letifer* and *whartoni* by the presence of pale scales on the base of vein Cu. The presence of this character on *collessi* makes it more likely to be confused with *roperi* (see discussion under *roperi*).

The pupa of *whartoni* can usually be distinguished from that of *letifer* by the characters given in the key and description. However, there are currently no distinctive characters known that will separate the pupa of *collessi* from that of *whartoni.*

The larvae of *letifer* and *whartoni* are currently indistinguishable, while that of *collessi* is usually separable by having a branched seta 1-X and more branches on seta 3-C.

BIOLOGY. Very little is known about the biology and behavior of this species (Wharton 1960, as *letifer*). Larvae were collected by Wharton in a variety of sites that ranged from deep shaded swamps with dark peaty water to clear water habitats such as seepage pools and open grass swamps. The pH

range for the habitats fell between 5.8 - 6.6. The single immature collection from Thailand came from an island (Ko Chang) next to Cambodia. This collection was made in a heavily shaded swamp at 5 m elevation, with deeply stained water and abundant brown algae. Other larvae found in this collection include *Anopheles crawfordi, An. roperi, Uranotaenia annandalei* Barraud, *U. bimaculiala* Leicester and *U. longirostris* Leicester.

Adults have been collected biting humans (Malaysia and Thailand) and in human bait net traps (Malaysia). Wharton (1960) found adults present throughout the year in a riverine lowland area of Pahang, but abundant only during a 2 month period (April - May) following heavy rains. Females bit throughout the night, apparently without regard to physiological age, but the peak biting period was the 2 hours after sunset (1800 - 2000 hr). In comparative tests between bare leg catches on man outside houses and inside houses, only 3% of the females were caught indoors. Blood engorged females were also collected resting indoors before dawn, but pyrethrum knockdown surveys in houses during the daytime did not recover *whartoni* specimens. These data suggest that *whartoni* in comparison to *letifer*, prefers to feed earlier in the evening and is less likely to enter houses to bite man.

MEDICAL SIGNIFICANCE. Since *whartoni* is relatively poorly known, only limited information (Wharton 1960) is available regarding its vector capabilities. This species was found naturally infected with sporozoites and oocysts of presumed human malaria by Wharton in 1959, and specimens were also found naturally infected with *Wuchereria bancrofti* larvae in 1958 - 1959. *Dirofilaria* larvae were also found in *whartoni* during this period. Laboratory experiments by Wharton show that *whartoni* is a good host for *W. bancrofti*. *Anopheles whartoni* is probably responsible for maintaining low levels of malaria and filarial endemicity in the area studied by Wharton. The role of *whartoni* in the transmission of human pathogens in Thailand is not currently known.

ANOPHELES (ANOPHELES) ROPERI REID
(Figures 64, 65, 66)

Anopheles umbrosus, largest variety of Roper 1914: 142 (♀); Reid 1950: 298 (= *roperi*).

Anopheles (Anopheles) sp. B near *umbrosus* of Colless 1948: 95 (♀*); Reid 1950: 298 (= *roperi*).

Anopheles (Anopheles) roperi Reid 1950: 298 (♂*, ♀*, P*, L*); Bonne-Wepster and Swellengrebel 1953: 184 (♂*, ♀*, L*); Reid 1963: 107 (♀*); Reid 1968: 183 (♂*, ♀*, P*, L*, E*).

A large species that is fairly easily distinguished in the adult and pupal stages, but not always separable in the larval stage. Adults usually have an accessory pale fringe spot at R_2, pale scales on the base of veins R and Cu and on the remigium, and a pale basal band on the hindtibia. Adult males can also be separated by the long slender aedeagal leaflets. The pupa has denticles on the caudal margin of abdominal terga, a short refractile border on the paddle, seta 0-IV large with 4 or more branches, seta 9, on VI - VII, 3.5 - 4.0 times as long as wide, the female genital lobes unicolorous with the cercal lobes and the sides of the male genital lobes nearly parallel. The larva is nearly identical with those of *letifer* and *whartoni*, and generally differs only by having more branches on abdominal seta 0. *Anopheles roperi* is like *letifer* except for:

FEMALE (Fig. 64) *Head.* Proboscis and palpus with more erect (shaggy) scales on basal portions; cibarium with less pronounced sclerotized area. *Thorax.* Scutal integument with mottled gray pattern sometimes intermixed with dark patches; anterior 0.5 of scutum, particularly the lateral fossae, with scattered narrow curved pale scales; pleural setae: 0 - 3 (usually 0) propleural, 5 - 10 spiracular, 7 - 17 upper and 3 - 7 lower sternopleural, 11 - 17 prealar and 8 - 14 upper mesepimeral. *Wing.* Scales on veins broader; costa may be dark scaled to subcostal spot or may have some pale scales proximal to the humeral crossvein; subcostal spot may extend onto vein R-R_1; costa with small preapical pale spot just before and down to tip of R_1; remigium may have area of pale scales; basal half of R usually with several scattered pale scales and distinct sector pale spot; R_1 with pale scales on tip; R_S-R_{2+3} with dark scales at base, then pale scales to fork, except for distinct median dark mark; preapical pale spot on costa and R_1 usually complete on R_2; R_2 with pale or dark scales at tip, depending on presence or absence of accessory pale fringe spot; M with distinct patch of dark scales at base, then mixed pale and dark scales out to fork; Cu usually with 1 - 5 pale scales at base, often more, followed by dark mark 0.2 - 0.3 the length of the distance to the fork, remainder to fork mixed pale and dark scales or with dark mark on distal half before fork; 1A with mixed pale and dark scales proximal to median dark mark; some specimens with narrow accessory pale apical fringe spot adjacent to the tip of R_2. (For more on wing see taxonomic discussion.) *Legs.* Coxae with scales; upper midcoxa with 5 - 12 setae; fore- and midtarsomeres dark scaled, or with faint dorsoapical pale spots on T_1-T_3; hindtibia with pale basal band 1.5 - 4.0 times segment width; hindtarsomeres 1 - 4 with narrow apical pale bands, 3 - 5 with narrow basal pale bands, basal pale bands on tarsomeres 4 and 5 longer than apical pale bands on tarsomeres 3 and 4.

MALE (Fig. 64). May have dorsoapical pale spots on foretarsomeres 1 - 3; dorsal surface of 8th abdominal segment with narrow pale scales or setae dorsally. *Genitalia.* Basimeres with pale dorsal scales and dark lateral scales; ventral lobe of claspette with 1 - 3 large setae, most mesal seta usually largest; dorsal lobe of claspette with fused club originating from 3 separate basal stems, usually with single knife-like seta separate from club, but immediately adjacent to it on mesal side and difficult to distinguish from club; aedeagus with 3 - 5 pairs of long, narrow curved leaflets, nearly 0.5 length of aedeagus; leaflets without lateral denticles, but largest with small basal tooth and tiny spine-like tip; lobes of tergum IX narrow, approximately 4 - 5 times as long as wide and 0.3 - 0.5 as long as distance between them.

PUPA (Fig. 65) *Cephalothorax.* Antennal sheath with tip often more darkly pigmented than remainder of cephalothorax. *Trumpet.* Tragus long, broad and spatulate. *Abdomen.* Seta 9, on VI - VII, 3.5 - 4.0 times as long as wide, tapering to sharp point; female genital lobe unicolorous with cercal lobes; male genital lobes with sides much less convergent than those of *letifer*, nearly parallel. *Paddle.* Basal half of seta 1-P stout, apical half with brush-like tip composed of 4 - 5 nearly equal length branches.

LARVA (Fig. 66). Separable from *letifer* only by seta 0-III having 5 - 7 branches (cf. *letifer* 3 - 4); seta 6-III with 21 - 26 branches, but see taxonomic discussion under *letifer*.

TYPE-DATA. The ♀ holotype of *roperi* is deposited in the BMNH, and is in excellent condition except for the loss of the tibia and tarsomeres of the right hindleg. Label data for the holotype is as follows: (1st label) - "Selangor, Kuala Kubu, 4.IV.1941, J. A. Reid"; (2nd label) - "No. 16942/54, larvae in large pool with dead leaves in Jungle"; (3rd label) - "*Anopheles (A.) roperi*

Reid, TYPE, Det. J. Reid"; (4th label) - "Holotype"; and (5th label) "liason pelts in slide collection." The ♂ allotype (No. 16942/52, with associated immature skins) and a ♂ paratype are also deposted in the BMNH. Both specimens are in excellent condition and come from the same locality as the holotype, but the paratype has no associated immature skins or a collection number. The allotype ♂ and paratype ♂ still have their genitalia intact, and no male genitalia preparations for *roperi* were found in the BMNH. The slides containing the immature skins of the holotype and allotype are present in the BMNH collection.

DISTRIBUTION (Fig. 65). *Anopheles roperi* was reported widely distributed by Reid (1968), with records from India (Assam), Indonesia (Sumatra), Malaysia and Thailand. A single specimen examined by the authors extends this range to include Cambodia. In Thailand there appears to be some correlation between the pattern of distribution of *roperi* and that of tropical wet forests. This pattern may also be found in the other countries with this species. Specimens (7♂, 10♀, 21 larvae and 20 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Krabi, Narathiwat, Phangnga, Phuket, Prachin Buri, Ranong, Satun, Songkhla, Trang and Trat. Additional specimens (4♂, 7♀, 15 larvae, and 4 larval and pupal skins) in the USNM were examined from MALAYSIA. The single female from CAMBODIA was found in the ORSTOM collections. The identification of this specimen as *roperi* is supported by a large collection of *roperi* with associated skins from Trat Province, Thailand, which is adjacent to Cambodia. Specimens (2♂, 4♀, 2 larvae and 6 larval and pupal skins) in the BMNH that include the type-series, were examined from: INDIA (Assam) and MALAYSIA (East and Peninsular). The 2 larvae are the basis of the Assam record (Reid 1963). We concur with Reid, these larvae agree with *roperi* as currently known. Both larvae have the following label data: (1st label) "Cinnamara, Jarahaut, Assam, Dr. D. Manson"; and (2nd label) "*Anopheles umbrosus* ? *roperi* J. R. det., Malaria Survey of India." Reid (1963, 1968) suggested that Christophers' (1933) record of *umbrosus* in Assam may have been based on specimens of *roperi*; however, *umbrosus* is now definitely known from Assam (see distribution section under *umbrosus*).

TAXONOMIC DISCUSSION. Adults of *roperi* from Malaysia as defined by Reid's descriptions (1950, 1968), are easy to distinguish from the other members of the group. In Thailand, however, most adults do not strictly conform to Reid's descriptions, and these specimens are more difficult to identify and are easy to confuse with some of the other species, particularly *letifer* and *whartoni*. Malay specimens typically exhibit a mottled gray scutal pattern, a pale accessory fringe spot at vein R_2, pale scales on the costa proximal to the humeral crossvein and pale scales on the remigium and base of veins R and Cu. Most Thai specimens have a less mottled pattern on the scutum like *letifer*, and rarely have pale scales on the remigium and base of the costa. Only 80% of the Thai females have one or more pale scales on the base of vein R, and only 70% have one or more pale scales on the vein Cu. In addition, only one of the 3 Thai females with wing fringe scales intact, exhibited the accessory pale fringe spot at vein R_2. Some of these wing characters were also variable on the type-specimens. The ♀ holotype only has a very small pale spot at the extreme base of the costa, while the ♂ allotype has nearly all of the costa pale scaled proximal to the humeral crossvein. The ♂ paratype has this portion of the costa with 2 pale marks divided by a dark mark.

Although the Thai specimens described above appear quite distinct, they conform very nicely to other *roperi* characters such as: 2 pale marks

on R_{2+3} separated by a dark mark; Cu with a short basal dark mark and scattered dark scales distal to it; 1A with scattered dark scales on the basal half; numerous upper sternopleural setae; coxae with pale scales; numerous upper midcoxal setae; and hindtibia with basal pale band.

There is also considerable variation in the male genitalia, particularly on the ventral lobe of the claspette. This lobe is described by Reid as having 3 setae (spines), but we have specimens with 1, 2 or 3 setae, and these include Malayan (Negeri Sembilan) males.

Adult *roperi*, even with the above variations, should be fairly easy to recognize by the basal pale band on the hindtibia, numerous upper sternopleural and upper midcoxal setae, broader wing scales, scattered dark scales on veins Cu and 1A and the few pale scales that are usually present on the base of veins R and Cu.

Only minor variations were detected in the pupal stage. The most significant of these being the sides of the male genital lobes may be more convergent than those depicted by Reid (1968: 186). Even then, however, they are not as convergent as those of *letifer*. This life stage of *roperi* should also be easy to identify. The small denticles on the caudal margin of the abdominal terga, pigmented angulate projection below the root of the trumpet and the large many-branched seta 0 immediately places *roperi* in the *letifer* subgroup. The key characters to separate *roperi* from the other members of the *letifer* subgroup are also quite obvious.

The larva of *roperi* is much more difficult to recognize and may not be discernable without other associated stages. There is no difficulty in recognizing *roperi* larvae as belonging to the *letifer* subgroup, but identity below that level is extremely difficult. Only one character (seta 0-III) is currently known that will differentiate *roperi* larvae from those of *letifer* and *whartoni*, and it is extremely difficult to see. The validity of the seta 6-III character used by Reid (1962, 1968) is discussed under *letifer*.

Based on the specimens examined we feel that the differences noted between the majority of Thailand *roperi* specimens (also some from Malaysia) and Reid's descriptions of *roperi*, are probably infraspecific. There is certainly not enough evidence at this point, or specimens with associated immature skins to intimate that another undescribed species is involved in what we are calling *roperi*. However, that possibility does exist and should be evaluated when more material, particularly associated immature stages, becomes available. The fact that the genitalia of the ♂ allotype are still intact and available for examination will be helpful in this regard.

BIOLOGY. Reid (1968) reports that *roperi* is found in Peninsular Malaysia from the coastal plains up to about 300 m elevation in the hills, but is most numerous in wooded shaded valleys where the foothills merge into the plains. Larvae have been collected in shaded pools, swamps and ditches in Malaysia. Immatures have been collected in Thailand between 5 - 200 m elevation and from the following habitats: stream margins, running ditch, nipa palm swamp and stream and flood pools. Over 80% (17/21) of the Thai immature collections came from stream or flood pools. The water is generally cool and unpolluted in these habitats and may be clear or colored. Over 95% of the habitats were in moderately to heavily shaded secondary or primary wet forests.

The adults of *roperi* are forest mosquitoes that bite man during the entire 24 hour period, but have the highest level of biting activity during the day, with a major biting peak in the hour just before dark (Moorhouse and Wharton 1965). In Peninsular Malaysia, Wharton, Eyles et al. (1963) did not collect

roperi biting outside the forest, or in or near houses, but a more recent study (Macdonald et al. 1967) in Sarawak captured several females biting man in open rice fields near the forest in the evening. Wharton, Eyles et al. (1963) also determined that *roperi* will feed more readily on monkeys on the ground than in the canopy, and Wharton et al. (1964) indicate that less than 10% of the *roperi* captured were taken in the canopy.

MEDICAL SIGNIFICANCE. Hodgkin (1950) presented epidemiological evidence that suggested *roperi* was a vector of human malaria parasites in Malaya, but this has not been confirmed by natural sporozoite infections (Wharton, Eyles et al. 1963). *Anopheles roperi* has been found with heavy oocyst and sporozoite infections (Wharton, Eyles et al. 1963), but these were apparently from a mouse deer malaria. Sporozoites from wild caught *roperi* innoculated by the latter authors into rhesus monkeys and one man, failed to produce infections. Further experiments during that study show that *roperi* is susceptible to infection with the mouse deer malaria, *Plasmodium traguli*. An attempt (Warren et al. 1963) to experimentally infect *roperi* with *Plasmodium cynomolgi bastianellii* failed, but Bennett et al. (1966) were able to demonstrate oocyst development of a Cambodian strain of *P. cynomolgi* in *roperi*.

The only natural infection of filarial larvae in *roperi* is that of *Setaria* spp. reported by Wharton, Eyles et al. (1963). Experimentally, Wharton, Laing and Cheong (1963) showed that *Wuchereria bancrofti* could develop to mature 3rd stage larvae in *roperi*.

There seems little doubt that *roperi* is a vector of a mouse deer malaria in Malaysia; however, there is no proof that it serves as a vector of human malaria or filarial parasites in Malaysia or Thailand.

ANOPHELES (ANOPHELES) SEPARATUS (LEICESTER)
(Figures 67, 68, 69)

Myzorhynchus separatus Leicester 1908: 36 (♀).
Patagiamyia separatus Leicester, James and Stanton 1912: 61.
Myzorhynchus sinensis var. *snijdersi* Swellengrebel 1921: 114 (♂); Christophers 1924: 31 (= *separatus*).
Anopheles (Anopheles) separatus Leicester, Christophers 1924: 30; Senevet 1930: 361 (P*); Edwards 1932: 42, (in part); Gater 1934: 102 (L*), (in part); Gater 1935: 174 (♂*, ♀*), (in part); Crawford 1938: 63 (P*); Colless 1948: 87 (♂*, ♀*, L*); Reid 1950: 306 (♂*, ♀, P*, L), (in part); Bonne-Wepster and Swellengrebel 1953: 195 (♂*, ♀*, L*), (in part).
Anopheles (Myzomyia) separatus Leicester, Brug 1928: 925 (L).
Anopheles hyrcanus separatus Leicester, Swellengrebel and Rodenwaldt 1932: 69.
Anopheles (Anopheles) separatus (Leicester), Stone, Knight and Starcke 1959: 28; Reid 1968: 187 (♂*, ♀*, P*, L*, E*).

A distinctive species with the adult habitus superficially resembling members of the *hyrcanus* species group. Adults of both sexes have pale scales on the palps and more distinctive pale areas on the wings. However, both have only dark scales on the base of veins R and Cu, and the female is without clypeal scales, or a scale tuft on abdominal sternum VII. The pupa is also easily separated by having denticles on the caudal margins of the abdominal terga, a

short refractile border on the paddle, a pigmented projection below the root of the trumpet; the rim of the trumpet with 2 thickened, darkly pigmented areas and seta 0-IV small with 1 - 2 branches. The larva superficially looks like *umbrosus*, but has abdominal seta 1 without developed leaflets, median dorsal valve without a stigmal process, seta 6-IV with 6 or less branches, seta 1-A with 25 or more branches; and no stout hooked branches on seta 4-A. The species is like *umbrosus* except for:

FEMALE (Fig. 67) *Head.* Interocular space with short pale ocular scales and long silky white setae forming obvious frontal tuft; palpus with basal scales erect, but not appearing shaggy, usually with terminal segment entirely pale and narrow ring of pale scales on apex of segment 3 and base of segment 4 (segment 4 may be entirely pale scaled), pedicel with small blue-white light-refractive scales on upper and outer aspect; flagellomere 1 with several broad pale scales. *Thorax.* Integument light to dark brown with central portion of scutum mottled gray with longitudinal dark lines; pleural setae: 2 - 4 propleural, 1 - 4 spiracular, 2 - 4 upper and 2 - 5 lower sternopleural, 6 - 8 prealar and 2 - 5 upper mesepimeral. *Wing.* With pale areas larger and more distinct than on other members of group; costa with black scales, except for small subcostal pale spot which also crosses onto vein R, and small preapical pale spot; vein R-R_1 with dark scales except for well defined sector and subcostal pale spots, and pale scales at tip; R-R_1 may have several scattered pale scales between sector and subcostal pale spots; R_S-R_{2+3} with small basal dark spot, then usually pale to fork; R_2 with dark scales except for pale spot continuous with preapical pale spot on costa and R_1, tip with dark scales; R_3 with pale scales except for small basal dark spot and dark scales on tip; R_{4+5} with small dark spot at base and usually at tip, remainder with pale scales; M with basal 0.16 - 0.33 dark scaled, remainder with pale scales to fork; M_{1+2} with dark scales at base and tip, remainder pale scaled; M_{3+4} pale scaled except for dark scales at tip; Cu with dark scales on basal 0.33, remainder pale scaled to fork; Cu_2 with dark scales on apical 0.25 - 0.33; base of 1A entirely pale scaled out to small median dark spot, followed by pale scales and small apical dark spot at tip; apical pale fringe spot extending at most from R_2-R_{4+5}; tertiary fringe scales usually paler than primary and secondary fringe scales. *Legs.* Upper midcoxa with 1 - 5 setae; tarsomeres 1 - 4 on fore-, mid- and hindlegs with narrow apical pale bands or dorsoapical pale spots; hindtarsomere 5 infrequently with several apical pale scales.

MALE (Fig. 67) *Head.* Palpus with variable amount of pale scales; club entirely pale scaled or with narrow apical dark band on segment 4 or base of segment 5; segment 3 usually entirely pale on median aspect, may have outer aspect dark scaled, and narrow apical dark band; segment 2 with few mesal pale scales. *Legs.* Foretarsal pale bands may cross joints onto base of tarsomeres 2 and 3; hindtarsomere 5 often with pale scales. *Abdomen.* Dorsal surface of 8th segment with numerous median pale scales. *Genitalia.* Basimeres with pale scales dorsally, dark scales laterally, and 2 parabasal spines; claspette with 3 lobes, ventral lobe with 2 - 3 large setae and 1 small seta, middle lobe without setae, dorsal lobe with club-like structure formed from 3 - 4 separate basal stems, the outermost stems appear fused apically, but the innermost stem seems flattened and separate from the remainder; aedeagus with 4 - 5 pairs of leaflets about 0.33 as long as aedeagus, larger leaflets broad with large serrations on outer edge, smaller leaflets without lateral serrations, but may be forked apically; lobes of tergum IX narrow, approximately 4 - 5 times as long as wide, over half as long as space between them.

PUPA (Fig. 68) *Cephalothorax.* With pigmented projection below root of

trumpet. *Trumpet.* Tragus broad and spatulate with saw-tooth-like denticles on rim; rim of trumpet with 2 thickened, darkly pigmented areas, one forming part of small secondary cleft and seam. *Abdomen.* Segment VII not significantly narrower than other segments, and sides not parallel; caudal margins of terga with small denticles; segments with darkly pigmented spots, alveoli of seta 2 well marked by dark integumental spot on each tergum; seta 1 usually with few branches or single, but setae 5 on III - VI with many branches and bushy appearance; seta 0 single or double, but longer than seta 0 on *umbrosus*; seta 2 large with 3 - 20 branches; seta 3-IV with 3 - 8 branches (cf. *umbrosus* 12 - 18); setae 9, on II - VII pale, short with rounded tip, approximately 2.0 - 2.5 times as long as wide; seta 9-VIII with strong central stem and long lateral and apical branches; segment VIII with minute spicules on lateral margin above seta 9, and on caudal margin of sternum just mesal to seta 9; female genital lobe more darkly pigmented than cercal lobes; male genital lobes darkly pigmented, with moderately convergent sides. *Paddle.* Base darkly pigmented; refractile border approximately 0.55 - 0.60 of length, with minute spines; 1-P long, stout and usually single, but may have 2 - 3 minute branches near tip.

LARVA (Fig. 69) *Head.* Capsule and basal 0.66 of antenna usually darkly pigmented; basal 0.66 of antenna with many short spines; seta 1-A bushy, with 17 - 38 branches usually 25 or more; seta 3-A with thin, nearly transparent frayed tip and lateral margin from lateral view, but usually appears pointed; 4-A without stout hooked branches; seta 2-C usually single; 3-C with 7 - 18 branches; 4-C single, short; 8-C with 2 - 5 branches, usually 3 - 4. *Thorax.* 1-P with 2 - 6 fine apical branches, approximately half as long as single 3-P; 2-P very large, with 9 - 14 branches; 4-P with tuft of fine equal branches at tip, short lateral branches (cf. *umbrosus*); 11-P with 2 - 7 fine branches from stout stem. *Abdomen.* Seta 1 filamentous on all segments; 0-III minute, single; 6-III with 15 - 22 branches, usually less than 20; spiracular area without stigmal process; pecten plate with 5 - 7 long teeth, usually alternating with short teeth; 1-X approximately as long as saddle, arising on saddle well dorsad of ventral saddle margin.

TYPE-DATA. According to James and Stanton (1912) Leicester's type-female for *separatus* was lost en route to the BMNH. Those authors studied additional Leicester specimens at the Institute for Medical Research in Kuala Lumpur, and presumably sent some to the BMNH to represent Leicester's species. These specimens have been considered part of Leicester's type-series (Reid 1950, 1968). Three specimens received in the BMNH under the accession number 1912-350, possibly qualify for this status. All 3 are identifiable with *separatus* as defined by Reid (1950, 1968). One ♂ and one ♀ have labels that read "Fed. Malay States, Dr. G. F. Leicester, 1912-350". That ♀ also has a smaller label bearing "A.4", possibly referring to a rearing number. The 3rd specimen, a ♀, has the following labels: (1st label) (upper side) - "*Myzomyia Dubitans* M.S." (under side) - "Own bungalow, Kuala Lumpur, 17/11/03"; and (2nd label) - "Kuala Lumpur, Fed. Malay States, Dr. G. F. Leicester, 1912-350". This latter specimen was noted by Christophers (1924) and Reid (1950) as probably belonging to the type-series. Stone (personal communication) also noted the 3 possible types, but said he could not be sure of their status. Although Leicester (1908) described only the adult ♀ of *separatus* in the original description, he plainly says under the subheading "occurrence" (p. 37), "bred from larvae taken in large collections of water in the open near Kuala Lumpur." If this statement applies to the entire type-series, the adult ♀ labeled *Myzomyia Dubitans* and collected in his bunga-

low, cannot be considered a member of the type-series. The absence of associated larval skins in the BMNH for the other 2 specimens does not help clarify their status. No type-specimens are known for the synonym *snijdersi* which was described from specimens collected in Medan, on the east coast of Sumatra.

DISTRIBUTION (Fig. 68). This is a coastal plain species which is now known from Cambodia, Indonesia, Malaysia, South Vietnam and Thailand. Brug and Bonne-Wepster (1947) list *separatus* from Buru Island in the Moluccas, but this needs confirmation. Specimens (1♂, 2♀, 25 larvae and 3 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Narathiwat and Trang. Additional specimens (10♂, 37♀, 4 larvae and 10 larval and pupal skins) in the USNM were examined from CAMBODIA, INDONESIA (Sumatra), MALAYSIA and SOUTH VIETNAM. Specimens (6♂, 13♀ and 9 larval and pupal skins) in the BMNH were examined from MALAYSIA. Included in these latter specimens is the supposed type-series. An additional 13♀ specimens from CAMBODIA were found in the ORSTOM collections.

TAXONOMIC DISCUSSION. Adults of *separatus* are easily misidentified as members of the *hyrcanus* group because they possess the following *hyrcanus*-like characters: palpus with pale bands, pale frontal tuft, paler wing pattern, tertiary fringe scales on wing usually paler than primary and secondary fringe scales, male sternum VIII with numerous median pale scales, and male aedeagal leaflets short with large serrations out to tip. Certain other adult characters, however, clearly indicate this species belongs to the *umbrosus* group, they are: antenna with scales on the pedicel and flagellomere I only; base of wing veins R and Cu with dark scales only, preapical pale wing fringe spot (= upper apical of Reid) is adjacent to tip of R_1, while in the *hyrcanus* group this spot ends prior to the tip of R_1 (except *crawfordi*), pleuron without white scale patches; upper midcoxa without pale scales, female without clypeal scales; and female without scale tuft on sternum VII.

The immature stages (including the egg) exhibit characters that clearly indicate this species is a member of the *umbrosus* group. The pupa has a prominent tragus on the trumpet, a pigmented projection below the root of the trumpet and denticles on the caudal margins of the abdominal terga. The larva has less than 25 branches on seta 3-C, numerous branches on seta 1-A and filamentous branches on abdominal seta 1. Both the pupa and larva are easily separated from other members of the *umbrosus* group by the characters described in the keys and the above description.

BIOLOGY. Colless (1948) describes the larvae of *separatus* in Borneo as commonly found among tall grasses in open swamps away from the jungle, yet rarely collected where only small amounts of vegetation occur, thus showing a marked preference for heavily shaded situations. Despite this preference, Colless found no *separatus* larvae in jungle pools. Hodgkin (1950) specifically defined *separatus* larval requirements in Malaya, as extending from the inner fringe of the brackish water zone inland to approximately 100 m elevation in the foothills. He states that *separatus* is most common on the coastal plain in pools under light shade, and generally found in more acid (average pH 5.8) water. Hodgkin also claims the larvae do not appear to occur in jungle. Specimens examined during this study indicate immatures collected in Malaysia came from a mining pool, stagnant drains, a ditch and an artificial container (large drum), while those from Thailand came from spring fed jungle bogs, open "swamp" and a nipa palm swamp. Most of the Thailand collections came from partially open areas, but several came from heavily shaded jungle bogs with numerous leaves and sticks in the water. Biting collections have been made from man, cattle, goats and monkeys. Additional collections have been

made with net traps and light traps. Adults readily bite man in the absence of cattle or other animals (Colless 1948; Hodgkin 1950), but when one calf was compared to 2 men, *separatus* preferred the calf by a 12 : 1 ratio, and preferred 2 goats to 2 men by a 62 : 1 ratio. Wharton, Eyles et al. (1963) found *separatus* would feed on monkeys on the ground or in the canopy, but to a lesser extent than it fed on human bait offered at the same time. Reid (1968) in comparative tests using human bait indoors and outdoors, collected only 2% of the *separatus* indoors.

MEDICAL SIGNIFICANCE. Based on the above zoophilic behavior data and a rather limited distribution, *separatus* is probably not involved in the transmission of human parasites in Thailand. Hodgkin (1950) reported only one female naturally infected with malaria parasites, and failed to infect this species with human malaria parasites by experimental means. Warren et al. (1963) and Bennett et al. (1966) had only limited success in experimentally infecting this species with various strains of *Plasmodium cynomolgi*. Wharton, Eyles et al. (1963), however, found *separatus* susceptible to experimental infection with *Plasmodium traguli*. Only one unidentified filarial larva has been found in wild collected *separatus* (Wharton 1960), and Wharton, Laing and Cheong (1963) were only able to obtain one mature *Wuchereria bancrofti* larva from experimentally infected *separatus*.

ANGUSTICORN SECTION

Reid and Knight 1961: 475.

This section was proposed for those species possessing a simple, tubular type trumpet, having the longest axis vertical and more or less in line with the stem of the trumpet, and with a single cleft or notch of varying depth on one side. Certain species of this section (e.g. *gigas*) have the trumpet pinna broadly expanded rather than tubular, however, all the species covered herein have the simple tubular type trumpet. For further information on the anopheline trumpet types refer to Reid and Knight (1961).

LOPHOSCELOMYIA SERIES

Edwards 1932: 37.

Members of this small series may be recognized by the following combination of characters.

ADULT (*General*). Head with erect broad scales on vertex; scutum pale centrally, dark laterally; anterior pronotum with scales; pleural sclerites darkly pigmented; coxae very pale; fore-and midcoxae with long curved (plume) scales projecting caudoventrally; basal half of forefemur slightly swollen; hindfemur with apical half swollen, with prominent tuft of scales (black proximally, white distally) on apical 0.25 - 0.33; tarsomeres without pale bands; wings with pale scaled areas; abdominal tergum VIII usually with scales. *Female*. Palpus with slightly shaggy scales. *Male*. Dorsal lobe of claspette without club, with compact group of separate flattened setae; aedeagus without leaflets.

PUPA. Seta 1, on V - VII much smaller than seta 5 and with few branches; seta 9, V - VII either frayed or with branches, or with distinctly recurved tip.

LARVA. Seta 1-A small, single or with several branches; 3-C single or with few branches; 4-C single or with branches on distal half; 5, 6, 7-C short

with few branches or single; 11-C longer than antenna, single or with few branches on distal half; 11-P very small, single or branched; seta 6 long on segments 1-VI.

DISTRIBUTION. This small series is restricted to the Oriental Region, and is known from India and Sri Lanka across to Indo-China and south to Indonesia. There are only 3 species recognized in Thailand. One of these, *bulkleyi,* is recorded only from southeast Thailand, and the other 2, *asiaticus* and *interruptus*, are widely distributed but rarely collected in Thailand.

TAXONOMIC DISCUSSION. This series currently contains 5 species, of which *annandalei* Prashad, *asiaticus*, *interruptus* and *noniae* Reid belong to the *asiaticus* species group. The 5th species, *bulkleyi*, was placed in this series by Reid and Knight (1961), and is separated from the members of the *asiaticus* group only by differences in the scale tufts on the legs.

The *asiaticus* group can be divided into 2 subgroups of 2 species, each possessing characters that will differentiate it from the other subgroup (see key). The 1st subgroup contains *annandalei* and *interruptus* which are apparently separable only by a single larval character (Reid 1968), while the 2nd subgroup contains *asiaticus* and *noniae* which have distinctive characters in several stages. Since *annandalei* and *noniae* are not covered later, both deserve further comment.

Anopheles annandalei was recorded (Reid 1963) from northeast India and Java (= synonym var. *djajasanensis*), and Reid (1968) added Thailand to this list. This latter distribution record was apparently based on correspondence from Dr. E. I. Coher, who claimed to have found both *annandalei* and *interruptus* in Thailand (Reid 1968: 206). Neither specimens of *annandalei* nor *interruptus* have been found in the Coher and Beales material from Thailand in the USNM, and since no other specimens from Thailand are known that conform to *annandalei*, we consider the Thai record of *annandalei* doubtful and needing confirmation. Possibly the Coher identification of *annandalei* was based on a wing character which was previously considered valid (Puri 1929), but has since been found on *interruptus* in Malaya (Reid 1963).

The record of *annandalei* sensu stricto, from Java came about when Puri (1929) synonymized *annandalei* var. *djajasanensis* Brug, under *annandalei* because he claimed the larvae of both have simple thoracic pleural setae. Based on available specimens, Reid (1963, 1968) agreed with this synonymy. Our examination of the holotype larva and male and female paratypes of *djajasanensis* in the BMNH reveals that Puri (1929) and Reid (1963) were probably wrong in considering this Indonesian taxon as a synonym of *annandalei*. However, this discrepancy is only part of the *annandalei-djajasanensis-interruptus* problem. This problem cannot be resolved until more Indian and Indonesian specimens are available for study. Consequently, we have decided to leave *djajasanensis* in synonymy with *annandalei* until a regional study of this series can be undertaken.

Anopheles noniae was described by Reid (1963) based on Malaysian specimens. This species is very closely related to *asiaticus*, but can be differentiated in the adult, pupal and larval stages (see taxonomic discussion under *asiaticus*). The immatures of *noniae* only occur in internodes of living upright bamboo (*Gigantochloa scortechinii* Gamble) with bore holes from the chrysomelid beetle, *Anisodera goryi* Baly. *Anopheles noniae* is not presently recorded from Thailand, but species that occur in such hidden habitats often remain unknown for long periods. Workers in Thailand should be on the watch for *noniae*.

MEDICAL SIGNIFICANCE. None of the species in the *Lophoscelomyia*

series are known to be capable of or involved in the transmission of human pathogens.

KEYS TO SPECIES OF THE *LOPHOSCELOMYIA* SERIES IN THAILAND

ADULTS (*bulkleyi* from original description).

1. Legs with clusters of erect dark scales on tarsomere 2 of midleg and tarsomeres 1 and 2 of hind leg. . . . . *bulkleyi* (p. 134)
   Legs with erect scales only on hindfemur, as prominent tuft of scales (black proximally, white distally) on apical 0.25 - 0.33. *asiaticus* sp. group (p. 135) 2

2(1). Abdominal tergum VIII with pale golden scales; wing without apical pale fringe spot at R_{4+5}; subcostal pale spot of costa extending onto vein R-R_1. . . . . *asiaticus* (p. 136)
   Abdominal tergum VIII without pale scales; wing with narrow apical pale fringe spot at R_{4+5}; subcostal pale spot when present, confined to costa and tip of subcosta. . . . . *interruptus* (p. 140)

IMMATURES (*asiaticus* group only, *bulkleyi* unknown).

1. *Pupa*: Setae 9, on VI - VII frayed or weakly branched; internal border of paddle without fringe hairs. *Larva*: Setae 4-A, 3-C and 11-C usually simple; dorsum of thorax and abdominal segments IV - V with large central black marks. . . . . *asiaticus* (p. 136)
   Pupa: Setae 9, on VI - VII long and unbranched, slightly hooked at tip; internal border of paddle with fringe hairs. *Larva*: Setae 4-A, 3-C and 11-C branched; dorsum of thorax and abdominal segments IV - V without central black marks. . . . . *interruptus* (p. 140)

ANOPHELES (ANOPHELES) BULKLEYI CAUSEY

Anopheles bulkleyi Causey 1937b: 23: 543 (♂).
Anopheles (Anopheles) bulkleyi Causey, Bonne-Wepster and Swellengrebel 1953: 129 (♂); Reid and Knight 1961: 481; Reid 1968: 195.

This species is known only from the adult male, which is recognizable by the legs having clusters of dark scales on tarsomere 2 of the midleg and tarsomeres 1 and 2 of the hindleg.

The following is Causey's description. "Male. *Head*: proboscis, palpi, and antennae all dark without white markings; occiput mainly dark with few white scales along median line. *Thorax*: integument dark and ash gray with brownish collar; prothoracic lobes covered with brown scales; mesonotum sparsely clothed with small whitish hairs; pleurae mainly ash gray, scales wanting, but some evidently rubbed off. *Legs*: heavily clothed with brownish scales except for few white scales on coxae; tarsi of second pair of legs with dark scales in collar-like cluster on second tarsal segment, and on third pair of legs larger cluster on distal end of first and all of second tarsus. *Abdomen*: clothed with luxuriant growth of long brown hair; scales absent except on terminal segments where they form large brown cluster over dorsal, ventral, and lateral portion of hypopygium. *Wings*: with widely-spaced black and

white scales; costa with faint white spot at tip of subcosta and first longitudinal vein; proximal half of subcosta denuded of scales, but apical half all dark; first vein with three small white spots on distal half and four on basal half, the largest one situated just basal to origin of third vein; second vein all dark except for scattered white scales on first branch and patch of white scales on second branch; third vein mainly white with few dark scales on basal half; fourth vein mainly dark except for few white scales on first branch and large central white spot on second branch; fifth vein with two dark spots on stem, three on first branch and one on second; sixth vein all white except one dark spot beyond mid point."

FEMALE, PUPA and LARVA. Unknown.

TYPE-DATA. Causey (1937b: 543) indicated the type-male from near Chandburi (probably Chanthaburi), Siam, had been deposited in the USNM. However, it is not in that museum and there is no record of its having been received. Causey (1966, personal communication) indicated the type was probably among specimens lost en route to Brazil.

DISTRIBUTION. Known only from the type-locality, Chanthaburi, Thailand. Reisen, Burns and Basio (1971, Table 7) list 2 specimens of *Anopheles buckleyi* [sic] collected from Don Muang Royal Thai Air Force Base, 25 km north of Bangkok. Don Muang is a very busy urban area that includes international airline facilities, and is situated in flat rice plains and far removed from jungle or forest-like habitats. The only specimen (the lost type) of *bulkleyi* ever collected came from a tree hole in tropical wet forest. Almost 20 years of active anopheline collecting from numerous habitats, including the type-locality, have failed to collect additional specimens. We are highly skeptical of this record and suspect the 2 specimens were misidentified.

BIOLOGY. The type-male was reared from a larva collected in a tree hole. Despite extensive collecting from treeholes in Thailand between 1961 - 66, no additional specimens have been collected.

TAXONOMIC DISCUSSION. Reid and Knight (1961) placed *bulkleyi* in the *Lophoscelomyia* series based primarily on combination of abdominal and coxal scales, unspeckled legs, unbanded tarsi and the pale mesal and dark lateral areas of the scutum. The tufts of outstanding scales on the legs were considered of secondary importance since *wellingtonianus* Alcock from Peninsular Malaysia (subgenus *Anopheles*, series *Anopheles*) and *squamifemur* Antunes from South America (subgenus *Lophopodomyia*) also have this character. This assignment appears reasonable based on the characters given in the original description, however, it must be regarded as tentative, pending the collection of additional specimens and stages. Even if *bulkleyi* is eventually determined to be a true member of the *Lophoscelomyia* series, it will apparently have no close relatives. Besides leg scaling differences, the wing of *bulkleyi*, as described, is quite distinct from that of the species in the *asiaticus* group.

ANOPHELES ASIATICUS SPECIES GROUP
(*An. asiaticus* group, Reid 1968)

Adults distinguished from *bulkleyi* only by having a prominent tuft of scales (black proximally, white distally) on the apical 0.25 - 0.33 of the hindfemur, instead of on the mid- and hindtarsomeres.

ANOPHELES (ANOPHELES) ASIATICUS LEICESTER
(Figures 70, 71, 72)

Anopheles asiaticus Leicester 1903: 291 (A, L-biology); Stanton 1912: 4; Stanton 1915: 6: 164 (L).

Lophoscelomyia asiatica Leicester in Theobald 1904: 13; Alcock 1911: 244 (= *Myzorhynchus asiatica*); Stanton 1912: 4 (= *Anopheles asiaticus*).

Lophomyia asiatica of Giles 1904: 366; Theobald 1910: 55 (= *Lophoscelomyia asiatica*).

Lophoscelomyia asiatica Theobald, Leicester 1908: 21 (♂, ♀, L); Strickland 1913: 138 (= *Myzorhynchus asiaticus*).

Anopheles (Anopheles) asiaticus Leicester of Christophers 1924: 23; Edwards 1932: 42; Gater 1934: 110 (L*); Gater 1935: 180 (♂*, ♀*); Bonne-Wepster and Swellengrebel 1953: 156 (♂*, ♀*, L*); Reid 1963: 108 (♀*, L*); Stone 1967: 198.

Anopheles (Anopheles) asiaticus (Leicester), Stone, Knight and Starcke 1959: 15; Reid 1968: 196 (♂, ♀*, P*, L*, E*).

Adults of *asiaticus* are easily recognized by the scale tufts on the hindfemur, pale golden scales on tergum VIII and the absence of a pale wing fringe spot at R_{4+5}. The pupal stage is recognized by the frayed or weakly branched seta 9 on segments VI - VII and the absence of fringe hairs on the internal border of the paddle. The larva is very conspicuous due to the large central dark mark on the dorsum of the thorax (not seen on skins) and the usually single setae 4-A, 3-C and 11-C.

FEMALE (Fig. 70) *Head.* Vertex with broad dark erect scales except dorsocentral patch of pale scales above interocular space; interocular space with short curved pale scales adjacent to eyes, long pale setae internal to scales forming distinct pale frontal tuft; palpus dark scaled with scales on basal half more erect, infrequently several dorsal pale scales at base of segments 3, 4 and 5; palpus approximately equal to length of proboscis; proboscis entirely dark scaled, labellum nearly bare, paler; clypeus bare; pedicel with small gray scales on upper, inner and lower outer aspects; flagellomere 1 with numerous small dark scales, remaining flagellomeres without scales. *Thorax.* Scutal integument creamy-gray centrally, brown laterally, except small mesal brown area in prescutellar area adjacent to scutellum; anterior promontory with slender pale scales centrally, several darker scales laterally; scutum sparsely covered with thin pale seta-like scales and much longer tan setae; scutellum with median brown spot, several thin pale seta-like scales and much longer dark brown setae; anterior pronotum with dark scales on ventrocephalic half; pleuron mostly dark brown, particularly lower portion of sternopleuron, meron and metameron, in comparison with white coxae; pleural setae: 2 - 3 propleural, 2 - 4 spiracular, 5 - 9 prealar, 2 - 4 upper and 1 - 4 lower sternopleural and 1 - 5 upper and 0 lower mesepimeral. *Wing.* Costa with pale humeral, subcostal and apical spots; humeral and subcostal pale spots variable in size, rarely absent; subcostal pale spot extends onto R_1; remigium with dark scales; humeral crossvein without scales; R-R_1 with dark scales except subcostal pale spot and pale tip; R_S-R_{2+3} with dark scales to fork; R_2 dark scaled with white tip, infrequently with small basal pale spot; R_3 entirely dark scaled or with small pale spot on basal 0.33; R_{4+5} dark scaled; M dark scaled to fork; M_{1+2} and M_{3+4} dark scaled; Cu, Cu_1 and Cu_2 entirely dark scaled; 1A dark scaled; base of veins R_S, R_{4+5}, M, Cu, and 1A with prominent clumps of

black scales resulting in distinct spotted appearance; fringe scales dark except apical pale spot from above R_1 down to R_2. *Halter.* Knob with dark scales. *Legs.* Upper forecoxa with several small dark scales; mid- and hindcoxae with long pale, curved plume scales projecting ventrocaudally on lower half; upper midcoxa with 2 - 4 setae. Foreleg: trochanter with patch of dark scales on caudal aspect; femur swollen on basal half, dark scaled except for narrow pale basal band; tibia and tarsus with dark scales. Midleg: trochanter with setae and pale scales; femur dark scaled except for narrow pale basal band and small dorsoapical white spot; tibia and tarsus with dark scales. Hindleg: trochanter with setae and pale scales; femur dark scaled except narrow pale basal band and long pale scales at apex; femur with apical half swollen and prominent tuft of long erect scales on apical 0.3, scales in tuft approximately equal length, black proximally, pale distally; tibia and tarsus with dark scales. *Abdomen.* Integument light brown, except distinct dark brown-black mark on tergum IV; with long brown setae; without scales except tergum VI may have several yellow scales on caudal margin, tergum VII usually with several yellow scales on caudal margin, tergum VIII covered with yellow scales dorsally, black scales laterally and sternum VIII covered with black scales.

MALE (Fig. 70) *Head.* Palpal segment 3 with small pale basal band, segment 4 with narrow pale basal and apical bands, and segment 5 with narrow pale basal band and apical half entirely pale scaled. *Wing.* Subcostal pale spot on costa large; more pale scales on other wing veins. *Abdomen.* Scales on segments VI - VIII as on female, but less extensive. *Genitalia.* Basimeres with yellowish dorsal and dark lateral scales; 2 parabasal spines with fine attenuate hooked tips, innermost spine set on prominent tubercle; ventromesal spine on basimere located approximately midway between apex and claspette; claspette with 3 distinct lobes; ventral lobe with large central seta and much smaller seta dorsolaterally; middle lobe with 2 - 3 large setae, much larger than those on ventral lobe; dorsal lobe with 3 broad curved blade-like spines very close together, not fused; aedeagus simple, without leaflets or spines.

PUPA (Fig. 71). Integument uniform light tan. *Trumpet.* Simple, with fairly wide opening, meatus approximately 0.3 - 0.5 length of trumpet. *Abdomen.* Most setae small, single or with few branches; seta 0 single on all segments; 8-II present, with 1 - 4 branches; 1, on V - VII very weak and short, with 3 - 11 branches; 5, on V - VII dark, long and curved with stout central stem and about 7 - 20 strong lateral branches; 5-VII almost equal length of segment VIII; 9, on II - IV small, peg-like; 9, on V - VII long, curved and sharp pointed, with few short fine lateral branches or frayed, approximately 0.3 - 0.4 of segment length; 9-VIII with stout central stem and many subequal branches; 1-IX as long or longer than seta 0-VIII, extending beyond caudal margin of segment IX. *Paddle.* 0.75 - 0.80 as wide as long; refractile border 0.55 - 0.65 of paddle length, beyond refractile border with long dense fringe hairs to just before 1-P; internal border without fringe hairs; apex slightly emarginate at 1-P attachment; 1-P with 12 - 25 subequal branches from short stout base; 2-P weak with 2 - 4 branches.

LARVA (Fig. 72). Living and whole mounted specimens with dark mark resembling Maltese cross on dorsum of thorax, and smaller central dark mark on abdominal tergum IV and rarely terga IV - V; skins without above pigmentation. *Head.* Antenna of nearly uniform diameter except near apex, with weak spines mostly on basal and mesal aspects; seta 1-A at outer margin on basal 0.25, weak, and approximately 0.25 - 0.33 as long as antennal stem, with 2 - 6 fine distal branches; 4-A long and single; 1-C as long as 3-C; 2-C

long and single, rarely forked; 3-C single, rarely forked, about half as long as 2-C; 4-C single, barely reaching level of 2-C alveolus, laterocaudal to 2-C and closer to 3-C; 5-C long, single, reaching level of 4-C alveolus; 6-C short, fine and usually single, closer to 5-C than 7-C; 7-C with 2 - 6 branches, longer than 6-C; 8, 9-C short and single; 11-C slender, single or infrequently forked on distal half, longer than antenna; maxillary palpus with stout darkly pigmented seta on outer distal margin, with many finely frayed short branches on distal 0.66. *Thorax.* Seta 1-P short with 2 - 6 branches from basal half, inserted about own length from 2-P; 2-P long with 8 - 16 branches and small faintly sclerotized base; 3-P single adjacent to 2-P, approximately equal length of 1-P, 4-P with large darkly pigmented base, and stout stem and lateral branches; 11-P short, fine and usually single; 14-P with 3 - 6 branches; 4-M approximately in line with and equal length of 3, 5-M; 3-T well developed, with slightly flattened branches and long narrow attenuate filaments; thoracic pleural tubercles without prominent spines; long thoracic pleural setae single. *Abdomen.* With small anterior tergal plates and very small posterior plates at least on III - VII; seta 0 small, single on II - VIII; seta 6 long on segments I - VI, plumose on I - III, long slender and single on IV - V, slightly shorter with approximately 12 - 20 branches on VI; 1-I minute and single; 1-II with 3 - 7 filamentous branches; 1, III - VII with well developed flattened, evenly pigmented leaflets, leaflets with shallow notched shoulder filaments half or more as long as leaflet; most other setae single or with few branches, including seta 13; pecten plate with approximately 20, mostly long teeth; seta 1 of the spiracular area dorsocaudal to pecten plate, long and single; 1-X single, slightly longer than saddle.

TYPE-DATA. Leicester (1903) is a short paper entitled, "A breeding place of certain forest mosquitoes in Malaya", where he reported finding a fairly large number of species (many new) breeding in bamboo. These species are not defined below generic level, except in 2 cases where he says "two anopheles, *Anopheles leucophyrus,* [sic] and a new species with beautifully feathered hind legs like an *Aedeomyia,* and which I have named *Anopheles asiaticus,* . . ." Further down that page he also says, "*Anopheles asiaticus* I believe to be exclusively a bamboo breeder;. . ." We agree with Stone (1967) that these entries constitute a description and therefore satisfy the rules of the International Commission of Zoological Nomenclature pertaining to original descriptions prior to 1930. Consequently, this publication has priority over the previously considered original description of *asiaticus* (1904). Moving the date of the original description from 1904 back to 1903, should have no effect on the status of the holotype. This specimen, a ♀ in the BMNH, was sent to Theobald along with the 1904 description by Leicester, and is in poor to fair condition with the following parts missing: all legs, except left hindleg; antennae; and most of left palpus. This specimen is labeled: (1st label) - "Bamboo, Ampang jungle, 6 miles fr. Kuala Lumpur, 27/6/03, No 10, *A. asiaticus*" (on underside of cardboard minuten stage); (2nd label) is circular type-label; (3rd label) - "Kuala Lumpur, Dr. Leicester"; and (4th label) - "*Lophomyia asiatica* (Type) Leicester." The data underneath the minuten stage is hand penned by Leicester, while that on labels 3 and 4 is hand penned by Theobald. This specimen was collected nearly 3 months prior to the publication (15 Sept.) of Leicester (1903) and is most probably the specimen on which he based his 1903 description. This is supported by Leicester writing the correct name "*A. asiaticus*" underneath the minuten stage, not "*Lophoscelomyia asiatica*" as it was named in Theobald (1904). The "*Lophomyia asiatica*" label and the 1904 name "*Lophoscelomyia asiatica*" are probably Theobald modifications of the name Leicester

had on his manuscript description sent to Theobald. Apparently, Theobald modified the name so that he could describe a new genus "*Lophoscelomyia*" on the page preceeding the *L. asiatica* description. This is supported in part by Leicester (1908) crediting the 1904 species, *Lophoscelomyia asiatica*, to Theobald not himself, even though Theobald (1904) clearly says that *Lophoscelomyia asiatica* is Leicester's species.

Because of the above circumstances, we feel the specimen previously considered the holotype of *asiaticus* based on the 1904 publication, is a specimen used by Leicester in discussing *asiaticus* in his 1903 paper, which he then selected to represent this species and sent to Theobald along with his full length description. Therefore, this specimen remains the rightful holotype.

DISTRIBUTION (Fig. 71). This species is known from Malaysia and Thailand, where it is collected almost exclusively from bamboo habitats. Specimens (12♂, 15♀, 74 larvae and 37 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Nakhon Si Thammarat, Phangnga, Ranong and Tak. Other specimens (33♂, 39♀, 13 larvae and 55 larval and pupal skins) in the USNM were examined from MALAYSIA. An additional 3♂ and 4♀ specimens (including the holotype) from MALAYSIA were examined in the BMNH.

TAXONOMIC DISCUSSION. This is the only species besides *noniae* that has scale tufts on the hindfemur and the immature stages in bamboo. A search in the USNM revealed 13♂, 15♀, 4 larvae and 37 larval and pupal skins of *noniae* from Malaysia. Reid (1963) presented the following characters for separating these 2 species. (*Adults*) - *asiaticus* with much more distinct clumps of black scales on the base of wing veins M and 1A; wings generally paler than those of *noniae*. (*Pupa*) - *asiaticus* with meatus about half the total length of trumpet (0.67 on *noniae*); *asiaticus* seta 9-VII simple or slightly frayed (strongly branched on *noniae*). (*Larva*) - *asiaticus* with seta 4-C short, just reaching level of 2-C bases (*noniae* 4-C long, reaching to or beyond tips of 3-C); *asiaticus* 1-A with 2 - 6 distal branches (*noniae* 1-A with 5 - 9 branches from near base). The larval characters presented by Reid are very distinct, this stage shows the clearest differences between *asiaticus* and *noniae*. Although we examined over 140 larvae or larval skins of *asiaticus* and *noniae* from Malaysia and Thailand, none had forked setae 2-C as illustrated by Strickland (1914). Reid (1963) suggested that Strickland's larva might have been a variation of *noniae*, or a new species. Reid (1963) also described differences in the dark pigmented marks on the larvae of *asiaticus* and *noniae*. The dark mark on the thorax of *asiaticus* typically has a cephalic extension which is lacking on *noniae*. We found this a constant difference on the material in the USNM, although the thoracic mark on *asiaticus* is quite variable. The dark mark on the abdomen of the larva was described as lozenge-shaped and confined to segment IV on *asiaticus*, while both segments IV and V on *noniae* have a pyramidal mark that is joined where the segments meet. This mark was highly variable on *asiaticus* larvae (including Malay specimens) with less than half having a lozenze-shape and most with a round mark on segment IV, or infrequently with a small amount of pigment spreading onto segment V. The 4 larvae seen of *noniae* have this mark as described by Reid.

Seta 9-VII on *asiaticus* pupae in Thailand is apparently more variable than that described for specimens from Malaysia. Several specimens were noted with this seta moderately frayed or branched, but not enough to cause confusion with *noniae* when used in conjunction with the trumpet character.

The adult seems to be the most difficult stage to separate from *noniae*. A number of *asiaticus* specimens with skins from Thailand were noted with darker

wings and less distinct scale clumps. An examination of the available specimens revealed that *asiaticus* has 2 - 4 upper midcoxal setae, while *noniae* has 3 - 9. This character should be of value in separating these species. The adult of *asiaticus* has a very distinct dark mark on abdominal tergum IV. This character was present on the 92 adults examined, while *noniae* only occasionally has a dark mark on terga IV - V or V alone.

All stages of *asiaticus* are easily separated from those of *interruptus* by the key characters and descriptions.

Several characters were seen on the adults that deserve further comment. The humeral pale spot on the costa although usually larger, may be only 2 - 3 pale scales on each wing or even only 1 wing (1/15). Wing veins R_3, R_{4+5}, M_{3+4}, Cu_1, Cu_2 and 1A, with proper lighting, may appear bronzy, similar to *djajasanensis*, as described by Brug (1926). The erect pale scales on the hindfemur tuft are usually as long as the erect black scales (includes holotype), not shorter as depicted by Reid (1968: 197).

BIOLOGY. This species is found in hilly-mountainous terrain in close association with large stem bamboos. In Thailand immatures have been collected between 130 - 700 m elevation, while collections in Malaysia were made between 30 - 1,060 m elevation. To date the immature stages have always been found in association with bamboo. The preferred habitat seems to be dried fallen bamboo that has a large enough split or hole to allow the internodes to collect water. However, infrequent collections in Thailand and/or Malaysia have been made from bamboo stumps, fallen split green bamboo and upright dried or green bamboo internodes. No adults have been collected in biting collections in Thailand, however, Reid (1968) reports small numbers captured with human bait in the forest. The natural adult food source is not known. It is interesting to note that nearly 5 years of concentrated jungle collecting occurred in Thailand before this species was first collected in Tak Province. Apparently *asiaticus* has a very spotty distribution in Thailand.

ANOPHELES (ANOPHELES) INTERRUPTUS PURI
(Figures 73, 74, 75)

Anopheles annandalei var. *interruptus* Puri 1929: 387 (♂, ♀*, L*, E*).
Anopheles asiaticus of Christophers 1915: 385 (♂*); Puri 1929: 394 (= *annandalei* var. *interruptus*).
Anopheles (An.) annandalei var. *interruptus* Puri, Puri 1931: 113 (L*); Christophers 1933: 139 (♂*, ♀*, L*); Bonne-Wepster and Swellengrebel 1953: 155 (♀*, L*); Reid 1963: 111 (P*).
Anopheles (An.) annandalei of Edwards 1932: 42 (in part).
Anopheles (An.) interruptus Puri, Reid 1968: 203 (♂*, ♀*, P*, L*, E*).

Identification of this species should not present problems in Thailand. The adults are distinct on the basis of the additional pale wing fringe spot and lack of pale scales on the abdomen. The pupa is easily recognized by abdominal seta 9 and paddle characters, while the larva is distinct on the basis of the head setal branching and the absence of dark marks on the thorax and abdomen. Like *asiaticus* except:

FEMALE (Fig. 73) *Head.* Palpus usually with narrow pale bands at base of segments 3 - 5. *Thorax.* Scutal integument gray centrally except median brown area on prescutellar area adjacent to scutellum, dark brown to black laterally; scutum sparsely covered with narrow curved pale scales

and longer brown setae; scutellum with narrow curved pale scales and long dark brown setae. Pleural setae: 1 - 3 propleural, 3 - 5 spiracular, 4 - 6 prealar, 2 - 4 upper and 2 - 5 lower sternopleural and 2 - 5 upper mesepimeral; upper and lower sternopleural setal patches with 3 - 7 and 4 - 8 pale scales respectively. *Wing.* Costa with humeral, subcostal and apical pale spots; humeral pale spot small, not extending onto base of vein R; subcostal pale spot of variable size, not extending onto vein R-R_1; R_1 with pale tip; R_S-R_{2+3} with 3 patches of large black erect scales, at base of R_S, level of R_{4+5} base and at R_2-R_3 fork; R_2 with pale tip; R_3 entirely dark scaled or with pale tip; R_{4+5} with patch of large black erect scales at base, entirely dark scaled except pale tip; M entirely dark scaled, with 4 patches of large distinct erect scales, at base, level of M-Cu crossvein, level of R-M crossvein and at M_{1+2}-M_{3+4} fork; M_{1+2} and M_{3+4} entirely dark scaled, or with pale tips; Cu entirely dark scaled; Cu_1 with slightly enlarged black scales at level of M-Cu crossvein, entirely dark scaled or with pale tip; Cu_2 entirely dark scaled or with pale tip; 1A with basal patch of large erect scales infrequently followed by small patch of pale scales, usually entirely dark scaled; upper apical pale fringe spot extends from slightly above R_1 to R_2; lower apical pale fringe spot narrow, at R_{4+5}; posterior margin of wing rarely with pale fringe spots at M_{3+4}, Cu_1 and Cu_2. *Legs.* Coxae very pale except upper portion of forecoxa; forecoxa with dark scales on dorsocephalic aspect; upper midcoxa with 2 - 3 setae, infrequently 1 - 2 scales. Foreleg: trochanter with patch of dark scales on posteromesal aspect. Midleg: femur with dorsal V-shaped pale spot near apex. Hindleg: trochanter with small patch of dark scales on mesal aspect; tibia infrequently with small pale basal band. *Abdomen.* Integument dark brown-black, with black scales on sternum VIII and occasionally tergum VIII; tergum IV same color as other terga.

MALE (Fig. 73) *Head.* Palpus with narrow pale bands at base of segments 3 - 5, apex of segment 5 also pale. *Wing.* Dark scales of patches and on subcosta very large. *Abdomen.* Without pale scales. *Genitalia.* Basimeres with dark lateral scales, without pale dorsal scales; claspette with only 2 lobes, otherwise as in *asiaticus*; aedeagus as in *asiaticus*.

PUPA (Fig. 74). Integument light tan except slightly darker trumpets. *Trumpet.* Simple, with meatus approximately 0.3 length of trumpet. *Abdomen.* Setae 5, III - IV strong and darkly pigmented; 5-IV slightly shorter than 5-V; 5-VII approximately 0.8 length of segment VIII; 9, IV - VII without branches or fraying, hooked at tip; 9-IV nearly equal 9-V; 9-VII approximately 0.3 length of segment VIII; 9-VIII darkly pigmented, with long stout central stem and lateral branches; 1-IX inconspicuous, shorter than 0-VIII. *Paddle.* 0.60 - 0.65 as wide as long; refractile border nearly entire length of paddle, with short sparsely spaced fringe hairs; internal margin with fringe hairs; 1-P with long stout pigmented stem, with 2 - 5 branches from near midpoint; 2-P fine and single or with 2 - 3 distal branches.

LARVA (Fig. 75). Integument dark tan, usually with dense curved spicules on the venter of thorax and abdomen; living and whole mounted larvae without dark marks on thorax or abdominal segments. *Head.* Antenna with weak spines along entire length; seta 1-A usually single; 4-A long with 4 - 11 branches; 2-C long, single or with 2 - 4 distal branches; 3-C with 2 - 9 branches; 4-C single, slightly closer to 3-C than to 2-C; 6-C short, single or with 2 - 5 distal branches; 7-C slightly longer than 6-C, usually with 2 - 3 branches; 8, 9-C usually single, infrequently forked; 11-C with 4 - 12 branches, mostly on internal side; distal external seta on maxillary palpus less stout than that of *asiaticus*. *Thorax.* 1-P with 10 - 15 branches, inserted close to pigmented

tubercle bearing large 2-P; 3-P single or forked, much shorter than 1-P; 11-P inapparent; 14-P with 2 - 8 branches; 4-M much shorter than 5-M; 3-T with well developed leaflets; one thoracic seta in each pleural group with barb-like side branches. *Abdomen.* Seta 6 long with numerous branches on segments I-VI; 1-II a well developed palmate seta; setae 9, on I - VI spinous, with large stiff sharp pointed branches; 7-VII spinous; pecten plate usually with 10 - 15 long teeth, often with shorter teeth in between long teeth; seta 1 of spiracular area with 2 - 4 branches.

TYPE-DATA. Puri (1929) listed syntypes sent to the BMNH, Indian Museum and the Malaria Survey of India Museum, Kasauli. Three of these syntypes were examined during this study. A ♂ and ♀ in the BMNH were examined and found in good condition. These were both labeled: (1st label) - "type" on small circular label; (2nd label) - "*A. annandalei* var. *interruptus* nov. var."; (3rd label) - "A"; (4th label) - "India, Bengal, Sukna, IX·1928, Dr. I. M. Puri, B. M. 1929-450". The ♂ specimen also has a small label with the number "3870" on it. An additional syntype ♂ labeled "Syntype B" was examined in the Indian Museum collections, now housed at the Zoological Survey of India, Calcutta. This specimen consists of the ♂ genitalia on a plastic strip in a good state of preservation, and the thorax, one wing and legs from one side, all from the same specimen. All 3 specimens are from Sukna, Darjeeling District, West Bengal, India, and all agree well with Puri's (1929) and Reid's (1963, 1968) descriptions.

DISTRIBUTION (Fig. 74). In Thailand *interruptus* appears relatively scarce with most collections coming from forested hilly or mountainous areas. This scarcity may be a false indication due to the logistical problems in making collections in many of these areas during the rainy season.

According to Reid (1968) this species occurs from southwest India and Sri Lanka north to Yunnan Province, China, east to Indochina and south to Malaysia. Specimens (1♂, 4♀, 13 larvae and 9 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Chanthaburi, Chiang Mai, Nakhon Si Thammarat, Songkhla, Tak and Trang. Other specimens (1♂, 3♀ and 2 larval and pupal skins) in the USNM were examined from CAMBODIA and MALAYSIA. Additional specimens examined include: 2♂ and 1♀ (including syntypes) in the BMNH from INDIA and MALAYSIA, 1♂ (syntype) in Zoological Survey of India collections from INDIA, and 5♀ specimens from CAMBODIA in the ORSTOM collections. Recent records of this species in Southeast Asia besides Reid (1968) include CAMBODIA [Büttiker and Beales 1964 (1965)] and SOUTH VIETNAM (Nguyen-Thuong-Hien 1968).

TAXONOMIC DISCUSSION. Reid (1963) suggested *annandalei* var. *interruptus* probably deserved specific status due to its sympatric distribution with the type form in northeast India (Puri 1929). Reid elevated *interruptus* to specific status on this basis and additional evidence (in lit. from Coher, Reid 1968: 206) that both forms exist in Thailand. As discussed earlier (p. 133) we have been unable to find specimens from Thailand that correspond to *annandalei*, and therefore we do not recognize this species as occurring in Thailand. Based on the homogeneity of the specimens examined from Thailand we will follow Reid's lead and consider *interruptus* a distinct species due to its sympatry with *annandalei* in India. This decision is tentative pending further investigation, but more appropriate than considering *interruptus* a subspecies and implying genetic compatibility without a trace of evidence. This interpretation leaves *annandalei* with a very widely discontinuous distribution (northeast India and Java); however, the holotype and one of the paratypes of the Javanese synonym, *djajasanensis*, do not agree with *annandalei*. Further

study and specimens are needed to resolve the identity of the Java specimens.

Puri (1929) found one adult and one larval character to separate *interruptus* from *annandalei*. The adult character, i.e., the presence or absence of a subcostal pale spot on the costa, has since been invalidated by Reid (1963), who found both extremes on Malayan *interruptus*. Therefore, the larval character, i.e., the presence of barb-like branches on at least one of the long thoracic setae in each pleural group of *interruptus* (all simple on *annandalei*), is currently the only character that can be considered valid. In Thailand although all the larvae have the pleural setal type equivalent to *interruptus*, the number and degree of branching on those setae is highly variable. On some specimens the pleural setae are nearly simple, with only 1 - 2 very short barb-like branches, while on others these setae have up to 20 longer barb-like branches. There is apparently no correlation between the degree of branching on the long pleural setae and the degree of development of the spine-like spicules on the venter of the thorax and abdomen. Reid (1963) suggested this latter variation may be due to environmental control such as Colless (1956) and Rosen and Rozeboom (1954) demonstrated on *Aedes* larvae found in tree holes.

A number of variations detected on the Thailand specimens deserve comment. Reid (1963) found the subcostal pale spot missing on 6 of 9 adults from Malaysia. This spot was well developed on all of the Thailand specimens. The only specimen seen without this spot was a male from Malaysia. Two adults from Chiang Mai Province were seen with well developed pale fringe spots on the wing opposite veins M_{3+4}, Cu_1 and Cu_2. This condition was described previously by Puri (1929) in reference to a paratype from the type-locality. Several of the Thailand adults also had a pale basal band on the hind-tibia.

One major difference was noted between the single Malayan pupal skin studied and those from Thailand. Seta 9-III on the Malayan pupal skin was pale and 0.5 as long as seta 9-IV, while on the 4 Thai pupal skins 9-III was 0.10 - 0.25 as long as 9-IV and usually darkly pigmented.

Reid (1963) mentioned that while Indian larvae had well developed spicules on the venter of the thorax and abdomen, the Malayan larvae seldom have these structures well developed. Most of the Thai larvae have well developed spicules, but several larvae from Tak Province had these structures absent or minute and barely visible. Reid (1968) lists seta 4-A on Malayan larvae with 8 - 11 branches, while we found 4-A with 4 - 9 branches on Thai larvae. We also noted larval seta 14-P with 2 - 5 branches on Thai larvae, while the single Malayan larval skin we examined had seta 14-P with 8 branches.

The significance of the above variations is impossible to interpret at this point. It should be obvious that more specimens are needed for study from many areas before the taxonomic problems surrounding the *annandalei-interruptus* question can be resolved.

BIOLOGY. *Anopheles interruptus* has been collected between 5 - 900 m elevation in Thailand. The primary immature source in Thailand has been tree holes, however, 2 larval collections were made in root holes at or below ground level. Relatively few larvae are found in any one tree hole. This could be indicative of a tendency toward cannibalism, or simply a survival mechanism where a few eggs are laid in several tree holes. Reid (1963) reported 2 females taken in human biting collections in Malaya, and there are 2 females in the USNM which were collected biting man between 1900 - 2000 hours in Chiang Mai Province, Thailand.

ANOPHELES SERIES

Edwards 1932: 36.

The following definition for the series is taken from Reid (1968: 206).

"ADULT. Fore femur usually slender, tarsi rarely banded, coxae and abdomen without scales, ♀ palps usually slender and head scales often narrow, pronotal lobes sometimes without scales, wings with or without pale areas; spines on the dorsal lobe of the harpago mostly separate, phallosome with or without leaflets.

PUPA. Trumpets simple, longer axis vertical (except perhaps in *A. gigas*). Other characters vary with the species group; in the *aitkenii* and *culiciformis* groups, hair 1 on V-VII is small and weaker than hair 5 and usually has some branches; in the *lindesayi* group hair 1 is strong, often simple, and may be nearly as long as the segments; in all three groups the paddles are usually rather narrow and generally with long fringe hairs.

LARVA. Antennal hair usually less than half as long as shaft, outer clypeal hairs in Malayan and Bornean species usually simple or few-branched, frontal hairs simplified in tree-hole species, long pleural hairs of the thorax simple or branched, pleural hair ep1 simple, or with branches but those are seldom spine-like from the base as in the *Myzorhynchus* series."

The above definition was directed more toward species that occur in Malaysia, but it also fits most of the other species in the series. Since this is such a diverse, widely distributed series the reader should refer to Reid and Knight (1961) for problems inherent in this arrangement and discussions on the differences in the various species groups.

DISTRIBUTION. As currently defined this series is cosmopolitan and probably the most widely distributed anopheline series. According to Reid and Knight (1961) there are 8 species groups and other unassociated species with the following distributions: *maculipennis* group - Nearctic and Palearctic; *plumbeus* group - Nearctic and Palearctic; *punctipennis* group - Nearctic; *pseudopunctipennis* group - Nearctic and Neotropical; *aitkenii*, *culiciformis* and *lindesayi* groups - Oriental; *stigmaticus* group - Australasian; and the unassociated species, *atratipes* from the Australasian, *concolor* Edwards from the Ethiopian, and *algeriensis* Theobald, *claviger* (Meigen), *habibi* Mulligan and Puri and *marteri* Senevet and Prunelle from the Palearctic region.

Members of all 3 species groups known from the Oriental region have been recorded from Thailand, however, the earlier records of *gigas formosus* Ludlow and *gigas sumatrana* Swellengrebel and Rodenwaldt are not recognized here. Further discussion regarding this decision can be found on page 21 and in Scanlon et al. (1968: 11-12). Only the *aitkenii* and *culiciformis* species groups are considered as representing the *Anopheles* series in Thailand.

TAXONOMIC DISCUSSION. This is a most difficult series to define for the adults of many of the species are small and unicolorous, while others are large with brightly patterned wings and legs that approximate a subgenus *Cellia* habitus. In fact, Reid (1968) suggested that the *lindesayi* and *pseudopunctipennis* species groups, which have the 2 last named characters, may be more ancient and nearer to the ancestral form from which the subgenus *Cellia* diverged. The adults of the species of the *Anopheles* series occurring in Thailand all fit the former habitus described above and are easily recognized. A definition of these species follows:

ADULT. Small generally unicolorous brown species, female palpus equal

to or slightly shorter than proboscis; anterior pronotal lobes without scales; aedeagus with or without spines or hair-like leaflets.

PUPA. Trumpets simple, longer axis vertical; seta 1, on V - VII small, weaker than seta 5 (except *palmatus*), usually with branches; paddles generally narrow, usually with long fringe hairs.

LARVA. Seta 1-A less than half as long as antennal shaft, inserted on basal 0.25; seta 3-C usually simple or with few branches; setae 5, 6, 7-C large or small, but branched; seta 11-P with 1 - 4 slender branches; seta 6, on IV - VI long or short.

KEYS TO THE SPECIES GROUPS AND SPECIES OF THE *ANOPHELES* SERIES IN THAILAND

ADULTS. (*kyondawensis* adults unknown).

1. Erect head scales long and narrow (Fig. 80), only slightly expanded apically; flagellomeres without scales. *aitkenii* sp. group. . . . 2
   Erect head scales broad, widely expanded apically (Fig. 94); flagellomere 1 with dark scales . . . . . (*culiciformis* sp. group) *sintonoides* (p. 181)

2(1). Abdominal segments IV, or IV and V distinctly paler than other segments. 3
   All abdominal segments unicolorous. 4

3(2). Abdominal segments IV and V pale. . . . . *aberrans* [in part] (p. 152)
   Only abdominal segment IV pale. . . . . *palmatus* [in part] (p. 173)

4(2). Prescutellar space with short fine setae back to scutellum. *insulaeflorum* (p. 167)
   Prescutellar space with a distinct median bare area immediately cephalad to scutellum. . . . . *aberrans* [in part] (p. 152)
   bengalensis (p. 157)
   fragilis (p. 162)
   palmatus [in part] (p. 173)
   stricklandi (p. 171)
   tigertti (p. 164)

PUPAE (*kyondawensis* pupa unknown).

1. Trumpet with deep meatal cleft, meatus (stem) 0.33 or less as long as trumpet; seta 1-P simple, tapering to fine point; ground water habitats. . . . . *aitkenii* sp. group 2
   Trumpet with shallow meatal cleft, meatus more than half as long as trumpet; seta 1-P simple filiform, with hooked (*Cellia*-like) tip; axil, bamboo and treehole habitats. . . . . (*culiciformis* sp. group) *sintonoides* (p. 181)

2(1). Seta 9 on abdominal segments IV - VII long with blunt round tip (Fig. 91). . . . . *palmatus* (p. 173)
   Seta 9 on abdominal segments IV - VII long or short, with sharp pointed tip (Figs. 85, 89). 3

3(2). Seta 9 on abdominal segment VII less than 0.33 length of segment VIII; seta 9-IV, 2 - 6 times as long as 9-III. 4
Seta 9-VII, 0.33 - 0.50 length of segment VIII; seta 9-IV, 8 or more times as long as 9-III. 5

4(3). Seta 9-IV, 2 - 3 times as long as 9-III; tergum IX with very prominent laterocaudal knob over root of each paddle (Fig. 89); seta 9-VII, 0.12 - 0.16 as long as segment VIII. . . . . *stricklandi* (p. 171)
Seta 9-IV, 4 - 6 times as long as 9-III; tergum IX without prominent laterocaudal knobs; seta 9-VII, 0.20 - 0.25 as long as segment VIII. *insulaeflorum* (p. 167)

5(3). Refractile margin on paddle long, 0.60 - 0.75 paddle length. *bengalensis** (p. 157) *fragilis** (p. 162)
Refractile margin on paddle short, rarely reaching 0.5 paddle length. 6

6(5). Seta 6-III long, nearly equal length of segment III lateral margin; 10-IV long, nearly equal length of segment V lateral margin; 1-III weakly developed, not as stout as 3-III. . . . . *tigertti* (p. 164)
Seta 6-III short, about half as long as segment III lateral margin; 10-IV short, about half as long as segment V lateral margin; 1-III well developed, at least as stout as 3-III. . . . . *aberrans* (p. 152)

LARVAE

1. Setae 5, 6, 7-C long, well developed and plumose; 4-C branching from base; 6-VI much shorter than 6-III. . . *aitkenii* sp. group 2
Setae 5, 6, 7-C reduced, some or all short with few branches; 4-C simple or branched on distal half; 6-VI nearly as long as 6-III. *culiciformis* sp. group 8

2(1). Anterior tergal plates on segments I-VII large, 0.66 - 0.75 the width of a given segment; seta 1-P fan-like. . . . . *palmatus* (p. 173)
Anterior tergal plates on I-VII small, less than half the width of a given segment; seta 1-P not fan-like. 3

3(2). Seta 6-III with more than 15 branches. 4
Seta 6-III with less than 15 branches. 6

4(3). Seta 2-C single or with 2 - 3 main branches and short fray-like side branches about the middle. . . . . *fragilis* (p. 162)
Seta 2-C with 2 - 14 branches (rarely simple), no short fray-like branches about the middle. 5

5(4). Seta 11-II long and simple; 5-II with 3 - 6 branches; 14-P with 3 - 5 branches, rarely 5 on both sides. . . . . *aberrans* (p. 152)
Seta 11-II forked or branched beyond base; 5-II with 7 or more branches; 14-P with 5 - 8 branches, rarely 5 on both sides. *bengalensis* (p. 157)

*Characters used by Reid (1965, 1968) to separate these 2 species break down in Thailand *bengalensis*.

6(3). Setae 2-C with bases separated by approximately same distance as bases of 2-C and 3-C; 11-II forked beyond base. . . . . *tigertti* (p. 164)
Setae 2-C with bases close together and distant from bases of 3-C; 11-II long and simple. 7

7(6). Seta 1-I undeveloped, with filamentous branches; 2-VI with 4 - 5 branches; 3-C with 2 - 4 branches. . . . . *stricklandi* (p. 171)
Seta 1-I palmate, with small flattened leaflets; 2-VI with 1 - 3 branches; 3-C simple or infrequently forked distally. . . *insulaeflorum* (p. 167)

8(1). Antennal shaft markedly curved (Fig. 93); integument of thorax and abdomen smooth, without spicules. . . . . *kyondawensis* (p. 179)
Antennal shaft straight or only slightly curved; integument of thorax and abdomen with numerous spicules. . . . . *sintonoides* (p. 181)

ANOPHELES AITKENII SPECIES GROUP
(*A. aitkenii* species group, Reid and Knight 1961)

Anopheles aitkenii James 1903.

These species are small and unornamented in the adult stages and have a culicine resting posture. Unfortunately, females of the majority of species are still indistinguishable. Little attention has been paid to members of this group because they are mostly secretive forest species and do not appear to be involved in the transmission of human disease pathogens.

The adult feeding habits are almost unknown and the biological information that is available is difficult to interpret due to the difficulty in identifying the females. Even the geographical distributions of the respective species are difficult to interpret, for many published records refer to the species group rather than a given species. This group was reviewed most recently by Reid (1965, 1968) and the following group descriptions are based in part on these works.

ADULT. Small, usually unicolorous brown; with culicine resting posture; interocular space narrow; erect vertex scales very narrow; female palpus approximately equal length of proboscis, very slender with slightly expanded tips; anterior pronotal lobes without scales; aedeagus bare or with small spines, without hair-like leaflets; claspette with 2 lobes, number of setae on both lobes generally variable; dorsal lobe with outer setae separate, inner setae very close together or fused into club-like structure; ventromesal spine on basimere inserted near apex (except *acaci*).

PUPA. Trumpet with deep meatal cleft, meatus less than half as long as trumpet; seta 1-P simple and straight.

LARVA. Setae 2-C close together or with bases separated by approximately same distance as bases of 2-C and 3-C; seta 4-C branching from base; setae 5, 6, 7-C long, well developed and feathered; seta 1-A usually with 5 or more branches; seta 11-C plumose, as long as or longer than antenna; seta 1-II (palmate), well developed; seta 6-VI short, not more than 0.5 length of 6-III; seta 1-X usually branched.

DISTRIBUTION. This group is basically confined to the Oriental faunal region. Records of its members extend from western India to Amami Island in the Ryukyus and south through Indonesia to the Philippines and Misool Island off the western tip of New Guinea. In the Australasian region this group is

replaced by the *stigmaticus* species group which differs from it by several adult characters (Reid and Knight 1961). Some members of the *plumbeus* species group, i.e., *barberi* Coquillett and *judithae* Zavortink of North America, and *omorii* Sakakibara of Japan, have a very similar adult habitus to that of the *aitkenii* group. However, members of the *plumbeus* group all oviposit in treehole habitats and have immature stages quite distinct from those of the *aitkenii* group.

TAXONOMIC DISCUSSION. We recognize 12 species in the *aitkenii* group, one of which is described here as new. They are: *aberrans* n. sp.; *acaci* Baisas, *aitkenii* James, *bengalensis*, *borneensis* McArthur, *fragilis*, *insulaeflorum*, *palmatus*, *pilinotum* Harrison and Scanlon, *pinjaurensis* Barraud, *stricklandi* and *tigertti*.

The taxonomy of this group has been confused for a long time partially due to an inability to find characters to differentiate the females. However, other explanations for this confusion may have been the failure of some previous workers to consider certain larval and male genitalia characters as variable and to try to define the limits of these variations. Another important factor was the very limited number of adults reared with associated skins for comparison. This latter step is an essential part of correctly identifying many mosquito species, and is absolutely necessary in attempting to identify apparently indistinguishable adults. Reid (1965, 1968) is one of the first workers to attempt a revision of the *aitkenii* group based on reared associated specimens. His work clarified and resolved many long-standing problems and is considered a major achievement particularly in view of the limited material with which he worked.

During the present study we were extremely fortunate to have many reared specimens of several species. The examination of this material has revealed some interesting facts about variation in the male genitalia characters, the branching of larval seta 2-C and has confirmed the suspected importance of pupal characters in this group.

The number of outer dorsal setae on the male claspette has been used by many workers as a valid means of separating *aitkenii* (3 setae) from *bengalensis* (2 setae), yet *aitkenii* is variable. A review of the literature reveals: (1) Christophers (1915) originally described *aitkenii* as having "2 - 3 sword-like chaetae on the ventral lobe" (= outer dorsal lobe); (2) Puri (1930) said *aitkenii* definitely has 3 outer dorsal setae (ventral lobe of Puri) and this is distinct from *bengalensis* which only has 2; (3) Christophers (1933) said *aitkenii* has 3 outer dorsal setae and *bengalensis* usually has 2, and in figures 17(9) and 17 (10) the claspettes of these species are depicted thus; (4) Reid (1965) followed Christophers (1933) and illustrated a topotypic ♂ of *aitkenii* from Karwar with 3 outer dorsal setae, however, Reid said *aitkenii* usually has 3 outer dorsal setae, while *bengalensis* usually has 2. As can be seen the setal number on the outer dorsal lobe has vacillated from a variable number to a fixed number and then back to a variable number. The variable interpretation is the approach we feel is correct. We dissected the genitalia of 2 topotypic *aitkenii* males and found one with 2 and the other with 3 outer dorsal setae, yet the other features of these 2 specimens were in perfect agreement. We examined large numbers of 4 species, *aberrans*, *bengalensis*, *insulaeflorum* and *pilinotum*, and these all exhibited variations in the following claspette characters: outer dorsal setae; ventral setae; and in several cases the inner dorsal setae (see discussions under the respective species). Apparently, claspette characters are as variable in the *aitkenii* group as they are in other species groups in the subgenus *Anopheles*. Consequently, identifications of male *aitkenii* group members based on claspette characters alone should not be considered reliable.

Claspette characters should be used only when they can be substantiated by distinct aedeagus characters and/or associated larval and pupal skins.

The extent and location of branching on larval seta 2-C is variable and still needs considerable study, preferably utilizing F_1 siblings, so that variation parameters can be established. Such studies will definitely be needed to resolve the *aitkenii-bengalensis* problem in India, and the *bengalensis-fragilis* problem in Southeast Asia. To outline this problem further, the following parameters are currently known: Branching - *aitkenii* (2), *bengalensis* (simple to 9), *aberrans* (2 - 14), *fragilis* (simple to 5) and *tigertti* (2 - 5); Location of branching on stem - *aitkenii* (0.25 - 0.33), *bengalensis* (0.25 - 0.75), *aberrans* (0.33 - 0.50), *fragilis* (0.33 - 0.50) and *tigertti* (0.50 - 0.67). The overlap in these parameters creates considerable confusion, e.g., a significant percentage of *bengalensis* larvae from Assam have 2-C bifurcate (without frays) at 0.40 - 0.67 along the stem. Using only this character for separating species, these larvae could be *bengalensis*, *aberrans*, *tigertti* or possibly even *aitkenii*. Using additional characters, 11-II is bifurcate, eliminating *aberrans*, and 6-III has more than 15 branches, eliminating *tigertti*. Larvae of *aitkenii* have not been seen with branching so far along the stem, but only 3 larvae of *aitkenii* were seen. Larvae such as those from Assam also occur in Burma and northern Thailand. These are probably responsible for the numerous *aitkenii* collections recently listed from Burma (Khin-Maung-Kyi 1971a).

The fraying found on 2-C of *fragilis* also deserves further study. We are currently considering any amount of fraying on 2-C (1 or more tiny central branches) as indicative of *fragilis*, even when all the other characters on the larva suggest *bengalensis*. This interpretation meets its most severe test in the Philippines where specimens that are essentially *bengalensis*, may have 1 - 2 small median frays on 2-C. Since we have limited specimens and can find no other characters to define *fragilis* larvae, we follow Reid (1965, 1968) in using this arbitrary interpretation.

Other larval setal characters are apparently very stable. Such characters include: position of 2-C in relation to 3-C; the number of branches on 6-III; and whether 11-II is long and simple, or long and branching beyond the base. This latter character has been checked on over 900 whole larvae and larval skins of 11 species, and without exception these species can be divided as follows.

(A) 11-II long and simple - *aberrans*, *acaci*, *borneensis*, *insulaeflorum*, *pilinotum* and *stricklandi*.

(B) 11-II long and at least bifurcate - *aitkenii*, *bengalensis*, *fragilis*, *palmatus* and *tigertti*.

The pupae of all the members of this group have been described or are described herein, except, *aitkenii* sensu stricto, and *pinjaurensis*. Pupal characters located thus far seem very stable, consequently, this stage is one of the best means of identifying most species in the group. Characters found most reliable are: shape and length of seta 9 on segments III - VII; and the refractile margin, fringe hairs and shape of the lateral margin on the paddle.

Regardless of characters found during this study that will differentiate adults of several species, the taxonomy of the *aitkenii* group still rests on our knowledge of the immature stages and in a restricted sense, male genitalia characters. Therefore, persons working with members of this group should be resigned to the necessity of rearing adults with associated skins for positive identification. This is particularly true for workers outside of Thailand where certain characters used here need further investigation.

Five of the currently recognized species, i.e., *acaci*, *aitkenii*, *borneensis*,

pilinotum and *pinjaurensis*, are not found in Thailand. Since they are not treated thoroughly, each deserves a short discussion.

Anopheles acaci is currently known from the Philippines (Luzon) and Borneo (Reid 1968). The male is unique in this group because it has female-like antennae. The male genitalia are fairly distinct because of the 3 broad outer dorsal setae on the claspette, the aedeagus which is abruptly narrowed before the apex and the ventromesal spine which is inserted about 0.33 the length of the basimere from the apex of the basimere. The pupa is very similar to that of *pilinotum*, but has seta 5-I short and approximately as long as 2-I, seta 0 on II - VIII simple or bifid and seta 1 small and weakly developed on segments II - VII. The pupa of *pilinotum* has 5-I much longer than 2-I, 0, on II - VIII with 3 - 6 branches and abdominal seta 1 well developed. The larva is very similar to *borneensis* from which it is separated by having the branches on 3-C beginning 0.33 or more distant along the stem. Seta 2-C on *acaci* can look very much like that of *bengalensis*, but seta 11-II on *acaci* is simple while that of *bengalensis* is at least bifurcate. The immature stages of *acaci* are usually very darkly pigmented and are recorded from shaded rock pools in the forest. The type of *acaci* is apparently non-extant, but Reid (1968) mentioned 2 male and one female paratypes in the BMNH. The female and one male paratype in the BMNH have associated immature skins; however, the associated immature skins for the paratype male (Lot A-11) used by Reid (1965) to illustrate the genitalia of *acaci* are not in the BMNH, but in the USNM. There are additional immature skins on slides in the USNM that are obviously topotypic, collected on the same day as the type and probably paratypes, but there are no associated adults for these skins.

Anopheles aitkenii is recognized as being confined to the Indian subregion. This interpretation is in conflict with Reid (1965) who considered *aitkenii* as found from India to the Philippines. Reid (1965, 1968) based his Malaysian record of *aitkenii* on a single female with associated immature skins, and used a topotypic male from India to illustrate male genitalia characters. Reid's (1968) interpretation was modified and *aitkenii* was listed as only possibly occurring in the Philippines; however, he did not remove *pallida* Ludlow 1905, from synonymy under *aitkenii*, where he placed it in 1965. Under our interpretation all previous Southeast Asian references to *aitkenii* sensu stricto, necessarily refer to other species in the group, usually *bengalensis*. We have examined Ludlow's female type of *Stethomyia pallida* in the USNM and it is probably equivalent to *bengalensis* or *fragilis* rather than *acaci*, which is described as a dark species (Baisas 1946). Ludlow's specimen does not have fine setae on the caudal part of the prescutellar area and thus, is definitely not *pilinotum*. If *pallida* Ludlow 1905, is eventually found to be synonymous with either *bengalensis* or *fragilis* the name *pallida* still cannot be used because *pallida* Theobald 1901 has priority.

Our restriction of the distribution of *aitkenii* is based partly on the known *aitkenii*-like seta 2-C variations that occur on *aberrans* and *bengalensis* larvae. The primary reason for this interpretation is the distinct shape of the aedeagus, the large hood-like club and the variable number of outer dorsal setae on the claspette (Fig. 79) of the 2 topotypic males in the USNM.

A total of 9♂, 12♀, 2 whole larvae, and 2 larval and pupal skin specimens were examined in the USNM and BMNH from southern India and Sri Lanka. The single pupal skin (Sri Lanka) was badly damaged, and best left undescribed, however, seta 1-IV had 5 - 6 branches, not 11 branches as described by Reid (1965, 1968), see discussion under *bengalensis*. The holotype female is located in the BMNH and bears the following labels: (1st label) - "#44, Karwar,

15·4·02" on underside of circular minuten platform; (2nd label) - "Goa India, H. E. Aitken"; (3rd label) - small round BMNH type-label; (4th label) - "*Anopheles aitkenii* (Type) James"; and (5th label) - "SEAMP Acc #306." This specimen is in near perfect condition, all legs, antennae, palps, abdomen, proboscis and wing scales are present. The following measurements and observations were made: wing length approximately 3.0 mm; wing cell M_2, 0.5 length of petiole; wing cell R_2, 2.6 times as long as wing cell M_2 (see *bengalensis*, Fig. 80); the forefemur/proboscis ratio is 0.82; there is 1 propleural seta on the right side (the left is obscured); the prescutellar area is without fine setae as on *insulaeflorum* and *pilinotum*; and the abdominal segments are all unicolorous dark brown. Besides the holotype, 6♂, 6♀ and 1 larval topotypic specimen from the original 1902 - 03 collections by Aitken and Cogill, were examined. Two of the 6 males are located in the USNM and genitalia slide mounts of these were used for preparing the illustrations herein. Two of the 4 males in the BMNH have the genitalia intact and unmounted. Genitalia preparations of the remaining 2 males were examined and the claspettes (Reid 1965, 1968) are identical to those of the USNM specimens, except one of the latter only has 2 outer dorsal setae. Unfortunately, the shape of the aedeagus is obscured on the 2 slide mounted specimens in the BMNH. (Also see discussion under *bengalensis*).

Anopheles borneensis is known only from Borneo (Reid 1968). The male of this species has densely plumose antennae as is normal for the group (cf. *acaci*). The male genitalia are very similar to those of *fragilis* and do not have the tip of the aedeagus abruptly narrowed (cf. *acaci*). The pupa has a short refractile border on the paddle similar to *acaci*, but has much longer setae 9 which are often frayed or branched, particularly on segment VII. The larva is easily confused with that of *acaci*, but generally has seta 3-C with wide branches from the base. Seta 2-C is much more densely branched near the base than *bengalensis*. Seta 11-II is long and simple (cf. *bengalensis*). The types of *borneensis* were listed by Stone et al. (1959) as in the Malaria Research Headquarters, North Borneo, but Reid (1968) says they are probably lost. Immatures of *borneensis* are recorded from clear, cool running water under dense shade in the forest.

Anopheles pilinotum is the species in the Philippines and eastern end of Indonesia that has previously been called *insulaeflorum* (Harrison and Scanlon 1974). Adults can be separated from all other group members (except *insulaeflorum*) by the short fine setae on the prescutellar area of the scutum that occur nearly all the way back to the scutellum. The male has short distinctive setae on the ventral lobe of the claspette and more short spines on the tip of the aedeagus (Fig. 79). The pupa is very similar to both *acaci* and *insulaeflorum*, but can be separated from the former by having seta 1 well developed with numerous branches on segments III - V, and from the latter by having: the paddle refractile border less than half the paddle length, the outer margin of the paddle straight or nearly straight some distance, and seta 0, II - VII with 2 - 6 (usually 3 - 5) branches. The larva of *pilinotum* is very similar to that of *insulaeflorum*, but can be separated from the latter by having: seta 1-X with 2 - 4 branches and seta 0 on II - VIII with 3 - 6 branches. The holotype of *pilinotum* and other members of the type-series are deposited in the USNM collection. Several paratypes are deposited in the BMNH. Immature stages of *pilinotum* are most often collected in clear running forest stream pools under heavy shade.

Anopheles pinjaurensis is known only from a single male collected in Punjab, India. The only distinctive character from *aitkenii* is an extremely

long aedeagus (Christophers 1933: 110).

BIOLOGY. All the females of this group apparently oviposit in ground water habitats. The most commonly encountered immature collection sites are seepage marshes, pools or quiet clear running forest streams with heavy shade. Certain species appear to have quite specific habitat requirements, e.g., *tigertti* found only in fresh water crab holes, while others have more general requirements, or their specific requirements are still unknown. Adult females of this group are occasionally collected biting man, there are records (Christophers 1933; Macdonald and Traub 1960; Scanlon and Esah 1965; Harinasuta et al. 1970) which make presumptive identifications of *aitkenii* and *bengalensis* respectively, but these records need confirmation. Hopefully, the few adult characters offered here will allow workers to confirm or eliminate certain species as feeding on man. The natural food sources of this group are unknown and none of the species are known to be involved in the transmission of human pathogens.

ANOPHELES (ANOPHELES) ABERRANS NEW SPECIES
(Figures 76, 77, 78, 79, 83)

A majority of the adults of this species can be identified on the basis of certain abdominal segments being paler than others. Males cannot be identified by genitalia characters alone. The pupal and larval stages are quite distinct, and each can be differentiated from other Thai species by several highly reliable characters.

FEMALE (Fig. 78) *Head.* Vertex with very narrow erect scales, slightly expanded and notched at tip; interocular space narrow, with short white scales and long dark brown frontal setae; clypeus without scales; pedicel and flagellomeres without scales, antennal whorl setae 3 - 5 times as long as segments; proboscis long, slender with decumbent scales; ratio forefemur/proboscis (sample 25 females), range 0.81 - 0.96, mean 0.89; palpus very slender, approximately equal length of proboscis, with 2 apical segments slighty swollen, scales decumbent. *Thorax.* Anterior promontory without scales; scutal integument tan, often with paler orange longitudinal line on each side of slightly darker median (acrostichal) longitudinal line; scutum without scales, with mixed long and short dark brown setae in anterior promontory, acrostichal, dorsocentral, lateral prescutal, fossal, antealar and supraalar groups; with bare prescutellar space; scutellum with long and short dark brown setae, without scales; anterior pronotum with sparsely scattered setae, without scales; pleural area pale tan, without scales; pleural setae; 1 propleural, 1 - 6 spiracular, 1 - 3 prealar, 1 - 3 upper and 1 - 4 lower sternopleural and 2 - 5 upper and 0 lower mesepimeral. *Wing.* Unicolorous, with narrow dark scales; humeral crossvein without scales; cell M_2, 0.5 - 1.0 length of stem (from crossvein). *Halter.* With dark brown scales. *Legs.* Coxae without scales, upper midcoxa with 3 - 5 setae; femur, tibia and tarsi long, slender and entirely dark scaled. *Abdomen.* Without scales, with long brown setae, integument always brown to black on segments I - III and VI - VIII; segments IV - V distinctly paler, often yellow (see taxonomic discussion), infrequently same color as other segments.

MALE (Figs. 76, 78, 79). Like female except antennae with more and longer whorl setae; palpus with 2 apical segments distinctly flattened and club-like. *Genitalia.* Basimeres without scales, with 2 parabasal spines on tubercle; ventromesal spine inserted near distimere on distal 0.25 of basimere;

claspette with 2 lobes; dorsal lobe with 2 - 3 outer setae, inner club formed from 1-2 separate basal stems; ventral lobe usually with 3 large, 1 small setae and numerous minute spicules; aedeagus bare, 3 or more times as long as width at base, tapering to rounded tip less than 0.5 width of base.

PUPA (Fig. 76). Integument light tan to light brown. *Cephalothorax.* Dorsum (between trumpets) often darker than remainder; seta 7-C with 2 - 5 branches. *Trumpet.* Same degree of pigmentation as surrounding cephalothoracic integument; with deep meatal cleft, meatus less than 0.33 as long as trumpet. *Abdomen.* Seta 0 small and simple; seta 9 long and narrow with sharp tapered point on IV - VII; 9-IV, 10 or more times (usually 15) as long as 9-III; 9-VII, 0.33 - 0.50 as long as segment VIII; seta 1, on IV - VII long, with few branches; 1-III well developed, as stout as 3-III; 1-IV with 1 - 4 branches (rarely 1 or 4); 1-VI with 1 - 3 branches; 1-VII with 1 - 3 branches; 6-III short, about 0.5 as long as segment III; 5-I approximately equal to or shorter than 2 and 3-I; seta 5 strongly developed on segments IV - VII, 0.67 to nearly equal length of segment, with stout central stem and decumbent branches; 5-IV branches decumbent, too close to stem to count; 10-IV short, about half as long as segment V lateral margin. *Paddle.* Refractile margin short, 0.33 - 0.50 (rarely slightly more than 0.50) as long as paddle; outer margin straight or nearly straight on distal half; fringe hairs 0.5 or more as long as 1-P; 1-P simple and stout, with tip slightly curved; 2-P simple or with 2 - 3 distal branches.

LARVA (Fig. 77). Usually with distinctive pale and dark color pattern involving thorax and abdominal segments (also see taxonomic discussion); ventral and lateral aspects of abdomen often with dense cover of minute spicules. *Head.* Antenna base slightly wider than tip; antenna with long spicules, particularly on mesal and ventral surfaces; seta 1-A short with 4 or more branches, inserted on basal 0.17 - 0.20 of antenna; 2, 3-A with one edge serrate; 4-A with 5 or more branches; setae 2-C with bases separated by approximately same distance as bases of 2-C and 3-C on one side; 2-C with 2 - 14 branches originating 0.33 - 0.50 way along stem; 3-C approximately 0.33 as long as 2-C, simple or split into 2 - 5 distal branches; setae 4-C slightly wider apart than setae 3-C, with 3 - 8 branches from near base; 5, 6, 7-C well developed and plumose, 5-C usually extending forward to tip of setae 4-C; 8-C with 1 - 3 branches (rarely 3 on both sides); 9-C with 4 - 9 branches; 11-C approximately equal to length of antenna, with many branches particularly at apex. *Thorax.* On whole larvae usually pale yellow in comparison with some brown abdominal segments. Seta 1-P with 8 - 14 branches, about 0.5 length of 2-P, without sclerotized base; 2-P with 10 - 17 branches, arising from sclerotized tubercle; 2-P tubercle with prominent apical spur or tooth; 3-P short, simple or bifurcate distally, closer to 2-P than 1-P is to 2-P; 4-P with stout stem and numerous short lateral and apical branches, slightly longer than 2-P; prothoracic pleural tubercle with distinct slender spine; 11-P simple or with 2 - 6 fine distal branches; long pleural setae usually simple; infrequently bifurcate distally especially on pro- and metathorax; 13-P with 8 - 19 dendritic branches; 14-P with 3 - 5 branches, rarely 5 on both sides; 4-M small, simple or with 2 - 4 branches, inserted caudally to long and simple 3 and 5-M; 3-T unpigmented or slightly pigmented with well developed flattened leaflets without filaments. *Abdomen.* On whole larvae, segments I - III and VI - VIII brown or gray, while segments IV - V and X usually noticeably paler, often yellow (see taxonomic discussion). Anterior tergal plates 0.25 - 0.33 width of segment on I - VII; posterior tergal plates commonly on segments IV - V as well as VI - VII; seta 0 small and simple on II - VII, larger and simple or with

2 - 3 branches on VIII; 1-I unpigmented, undeveloped with filamentous branches, or with poorly developed flattened leaflets; 1, on II - VII pigmented, with well developed flattened leaflets and filaments; 5-II with 3 - 6 branches; 11-II long and simple; 6-III with 18 or more branches; 6, on IV - V, 0.50 - 0.67 as long as 6-III, with few branches from base; 6-VI very short, branched, less than 0.33 as long as 6 on IV - V; 13 on I - VII with 5 or more branches; stigmal knob on median dorsal valve unpigmented, nearly transparent; pecten plate with 11 - 16 teeth; 1-X with 2 - 4 (rarely 4) branches.

TYPE-DATA. The holotype ♀ with associated larval and pupal skins mounted on one slide is located in the USNM, and bears the following label data: "Thailand, Chiang Mai, Muang, Doi Suthep, 05667-6, 10 Dec. 1969, SEAMP Acc # 233." The allotype ♂ with associated larval and pupal skins on one slide and a slide mounted genitalia (SEAMP Prep. #71/176) is also in the USNM, and is number 05667-1 with the same data as above. An additional 4♂ and 3♀ in the USNM with the above collection data and different rearing numbers in collection 05667, have been selected as paratypes; these specimens either have associated slide mounted larval and pupal skins or only a pupal skin. Four slide mounted whole larvae with the above data were also selected as paratypes to demonstrate the color banding pattern seen only on whole larvae. Two ♀ with skins (05667-3, 05667-7), one ♂ without skins (05667-8), one ♂ with a pupal skin (05667-103) and 2 whole larval slides were selected as paratypes and sent to the BMNH. One ♀ with skins (05667-10), one ♂ with a pupal skin (05667-101) and 2 whole larval slides were selected as paratypes and sent to the Department of Medical Entomology, SEATO Medical Research Laboratory.

There are 8 other slide mounted whole larvae of *aberrans* from this collection not selected as paratypes. These larvae are also in the USNM collection.

The collection (05667) from which the holotype, allotype and paratypes were selected was made on Doi Suthep, a mountain just west of the city of Chiang Mai in northern Thailand. The type-locality is a small stream between 600 - 640 m elevation on the mountain, just below the paved road going up to a famous Buddhist temple. This collection was made by Captain Harrison from small, nearly isolated, pools beside the stream, under the heavy shade of secondary deciduous forest. (See additional biological data under biology section.)

This species has been named *aberrans* for the banding pattern found on most adults and larvae, which deviates from the usual unicolored appearance of species in this group.

DISTRIBUTION (Fig. 83). Based on specimens in the USNM, *aberrans* has a wide distribution in Thailand, but is apparently confined to forested foothills and mountainous regions. These specimens were collected between 140 - 1,400 m elevation, above the coastal and many of the flat rice plain areas. Specimens (74♂, 84♀, 180 larvae and 237 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Chanthaburi, Chiang Mai, Chon Buri, Mae Hong Son, Nakhon Sawan, Phrae, Ranong, Songkhla and Trat. An intense search was made in the USNM and BMNH for specimens of *aberrans* from other countries. A series of 10 slides (larval skins) in the BMNH from Peninsular Malaysia were found, some of which may be this species. These slides have the following label data: "Fed. Malay States, 1920-454, Dr. H. P. Hacker", and individual rearing numbers. Skin numbers 483.D_5, 483.D_7, 483.D_8 and 483.E_{10} in particular, had setae 8-C, 14-P and 11-II that agree with *aberrans*. Unfortunately, there is no indication of where in Malaya these were collected. None of the plates or descriptions

presented by Reid (1965) suggest that *aberrans* occurs in Malaysia. However, since there are specimens from Songkhla, in southern Thailand, and the immature taxonomic characters are the most reliable, the above skins in the BMNH probably represent Malayan *aberrans*. Further collecting in Southeast Asia will probably reveal that this is a fairly widely distributed mainland species.

The distribution of *aberrans* in Thailand is similar to that of *bengalensis*, consequently, these species are sometimes collected together. On the other hand they may occur isolated, but very near to each other. Specific differences in the habitat requirements for these 2 species are not currently known. The following table will demonstrate known larval associations of *aberrans* and *bengalensis*.

TABLE 4. Collection associations of *aberrans* and *bengalensis* immatures from Thailand provinces where both were found

Province	*aberrans* only	both species	*bengalensis* only
Chanthaburi	22	10	8
Chiang Mai	2	2	2
Chon Buri	1	5	2
Mae Hong Son	1	0	1
Phrae	0	1	2
Ranong	0	0	3
Songkhla	4	3	9
Trat	3	1	8
Total	33	23	35

TAXONOMIC DISCUSSION. Specimens of this species were apparently first collected in Thailand by the Thurmans in the 1950's, but overlapping larval and male genitalia characters with *bengalensis* (see *aitkenii* group) kept it from being recognized as a distinct species. Almost invariably this species has previously been identified as *bengalensis*, except for male specimens with 3 outer dorsal claspette setae that were called *aitkenii*. This species is obviously related to *bengalensis*, but not as closely as is *fragilis*. Based on larval characters, *aberrans* appears more closely related to *fragilis* and *bengalensis* than to *tigertti*. Larvae of *aberrans* can be differentiated from the first 2 species by having seta 11-II long and simple, 5-II with 3 -

6 branches and 14-P with 3 - 5 branches, while it differs from *tigertti* larvae by having 11-II long and simple, 5-II with 3 - 6 branches, 6-III with 18 or more branches, 4-A with 5 or more branches and the stigmal knob on the median dorsal valve unpigmented. Larvae of *aberrans* key out to *bengalensis* in Rattanarithikul and Harrison (1973: 5, couplet 9), but can be separated from that species by the above stated characters.

The pupae of *aberrans*, *bengalensis*, *fragilis* and *tigertti* are also quite similar. However, the pupa of *aberrans* can be differentiated from those of *bengalensis* and *fragilis* by having only 2 - 4 branches on I-IV and having a short refractile margin on the paddle, and can be differentiated from the pupa of *tigertti* by having 6-III short and only about half as long as segment III, 1-III at least as stout as 3-III and 10-IV about half as long as the lateral margin of V.

The male genitalia of *aberrans* are easily separated from those of *tigertti* by the latter having spines on the aedeagus. Similarities in the male genitalia of *aberrans*, *aitkenii* and *bengalensis* have already been noted (see *aitkenii* complex). Apparently both *aberrans* and *aitkenii* can have 2 - 3 outer dorsal setae on the claspette (see below) while *bengalensis* normally has 2. The inner dorsal club on *aitkenii*, however, is made up of 2 longer flattened hood-like setae, while those on *aberrans* and *bengalensis* are approximately as long as the outer dorsal setae. Futhermore, the shape of the aedeagus of *aitkenii* also appears distinct.

The pupae of *aberrans*, *insulaeflorum* and *pilinotum* have similar refractile margins on the paddle, however, the very long sharp seta 9 on *aberrans* cannot be confused with the short seta 9 on *insulaeflorum* and *pilinotum*, or the long bluntly rounded seta 9 on *palmatus*. Pupae of *aberrans* should never be confused with those of *stricklandi*, for the paddle of the latter is very different and seta 9 is even shorter than that of *insulaeflorum*.

Larvae of *aberrans* are easily separated from those of *insulaeflorum*, *palmatus* and *stricklandi* by the last 3 having the bases of setae 2-C much closer together than those of 2-C and 3-C on one side.

Certain variable characters were noted which deserve further comment. Male genitalia (claspette) variations are based on slide preparations of genitalia from 8 males confirmed by associated immature skins. The outer dorsal setae on the claspette exhibited the following differences: 2 specimens with 2 outer dorsal setae on both sides; one specimen with 2 outer dorsal setae on one side and 3 on the other side; and 5 specimens had 3 outer dorsal setae on both sides. The inner dorsal club had the following differences: one specimen with inner dorsal club arising from a single basal stem, and 7 specimens with the inner dorsal club arising from 2 separate basal stems.

The integument of adult abdominal segments IV - V was usually paler than that of the other abdominal segments. Based on adults confirmed by associated immature skins, the frequency of paler integument was: Chiang Mai 100% (9♂ and 8♀), Chanthaburi 75.5% for males (40/53) and 82.5% for females (52/63); too few specimens for valid sample from other areas, but 5 females from Chon Buri, Nakhon Sawan, Phrae and Songkhla did not have this pattern. An attempt to correlate this character with elevation, or some other environmental factor, cannot be made without further specimens and more data from the collection sites.

A banding pattern on the abdomen of the larvae is also variable. When present, segments IV - V and X are paler than the others. This banding was noted on the following collections of larvae: 100% (16/16) from Chiang Mai, 76% (93/122) from Chanthaburi and 33% (1/3) from Trat. Larvae from the

following collections did not exhibit banding: Chon Buri (16), Nakhon Sawan (1), Phrae (1), Ranong (1) and Songkhla (13). Larvae not having this color pattern were otherwise identical to those having the bands.

The presence of posterior tergal plates on larval segments IV - V seems to be much more common on *aberrans* than *bengalensis*. While the latter only infrequently had these plates on IV - V, *aberrans* had plates on these segments on about 50% of the specimens sampled (more than 50).

BIOLOGY. There are no data regarding adult behavior for *aberrans*. The immature stages are found in habitats quite similar to those utilized by *bengalensis*, *insulaeflorum* and *palmatus*. Records indicate larvae have been collected at elevations between 140 - 1,400 m from: stream margins, stream pools, rock pools, springs, seepage pools and elephant footprints on stream margin. These collections were made in light to heavy shade (usually heavy), in cool clear water with dead leaves and sometimes roots and with the bottom composed of silt or mud, not sand. The majority of collections came from primary or secondary wet forests, with others from evergreen and secondary deciduous forests. The requirements for this species seem to be more closely associated with the forest and heavy shade, than do those for *bengalensis* which can be found in more open-forest margin areas. This trend is supported by records of larvae of *aberrans* being collected only with those of *bengalensis*, *insulaeflorum* and *palmatus*. These 2 latter species are definitely forest species.

The following observations were made during the original collection (05667) at the type-locality. Collections were made in small shallow pools or indentations in the margin of a small rather swiftly flowing stream. The water in the collection sites was usually no deeper than 2.5 - 4.0 cm and the bottom was silty mud with no algae or vegetation except a few dead leaves. Larvae were always associated with either rocks (usually), a dead root mass hanging in the water or infrequently from holes left in the bank by rotten roots. The water in the collection sites was always back up water with practically no current. The larvae are quite noticeable on the water surface particularly when moving, because of the pale pattern on the body. They apparently feed out in the open, but are sensitive to light even though in partial to heavy shade, and quickly dart back into a shelter such as under a rock or a small hole in the bank when a shadow is cast across them.

ANOPHELES (ANOPHELES) BENGALENSIS PURI
(Figures 78, 79, 80, 81, 82)

Anopheles aitkenii var. *bengalensis* Puri 1930: 955 (♂, L).
?*Stethomyia pallida* Ludlow 1905: 129 (♀) (*non* Theobald 1901).
Anopheles (Anopheles) aitkenii var. *bengalensis* Puri, Christophers 1933: 109 (♂*, L*).
Anopheles (Anopheles) aitkenii bengalensis of Baisas 1946: 30 (P*, L*) (in part).
Anopheles (Anopheles) bengalensis Puri, Reid 1965: 113 (♂*, ♀, P*, L*, E*); Reid 1968: 238 (♂*, ♀, P*, L*, E*).
Anopheles (Anopheles) aitkenii of Reid 1965: 107 (♂*, ♀, P, L*, E) (in part); Reid 1968: 31: 237 (♂*, ♀, P, L*, E) (in part).

The adults of *bengalensis* cannot be identified without associated immature skins. The pupal stage is distinguishable from all the other species except

fragilis. The larva is distinct from all the other group members found in Thailand, but not on the basis of 2-C branching. Since this is the most commonly encountered member of the group in Thailand, we have decided to describe it in detail and to use it as a guideline for the remaining species descriptions.

FEMALE (Figs. 78, 80). Unicolorous brown. *Head.* Vertex with very narrow erect scales, slightly expanded and notched at tip; interocular space with short white scales, long frontal setae dark brown; clypeus without scales; pedicel and flagellomeres without scales, antennal whorl setae 3 - 5 times as long as segments; proboscis long slender, with decumbent scales; ratio-forefemur/proboscis (sample, 25 females), range 0.89 - 1.24, mean 1.04; palpus very slender, approximately equal length of proboscis, with 2 apical segments slightly swollen, scales decumbent. *Thorax.* Anterior promontory without scales; scutal integument tan, usually with paler longitudinal line on each side of slightly darker median (acrostichal) longitudinal line; scutum without scales, with mixed long and short dark brown setae in anterior promontory, acrostichal, dorsocentral, lateral prescutal, fossal, antealar and supra-alar groups; with bare prescutellar space; scutellum with long and short dark brown setae, without scales; anterior pronotum with sparsely scattered setae, without scales; pleural area pale tan without scales; pleural setae: 0 - 2 propleural, 1 - 3 spiracular, 1 prealar, 1 upper and 2 - 4 lower sternopleural and 3 - 5 upper and 0 lower mesepimeral. *Wing.* Unicolorous, with narrow dark scales; humeral crossvein without scales; cell M_2, 0.1 - 1.0 length of stem (from crossvein). *Halter.* With dark brown scales. *Legs.* Coxae without scales, upper midcoxa with 3 - 5 setae; femur, tibia and tarsomeres long, slender and entirely dark scaled. *Abdomen.* Unicolorous brown with brown setae, without scales.

MALE (Figs. 78, 79, 80). As for female except antennae with more and longer whorl setae; palpus with 2 apical segments distinctly flattened and club-like. *Genitalia.* Basimere without scales, with 2 parabasal spines on tubercle; ventromesal spine inserted near distimere on distal 0.25 of basimere; claspette with 2 lobes; dorsal lobe with 2 separate outer setae, inner club formed from 1 - 2 separate basal stems; ventral lobe usually with 3 large and one small setae, and numerous minute spicules; aedeagus bare, 3 or more times as long as width at base, tapering to rounded tip about 0.5 or less width of base.

PUPA (Fig. 81). Integument unicolorous pale to light tan. *Cephalothorax.* Seta 7-C with 2 - 6 branches. *Trumpet.* Simple, with deep meatal cleft, meatus less than 0.33 as long as trumpet. *Abdomen.* Seta 0 small and simple; 1-IV with 3 - 12 branches; 1-VI with 2 - 7 branches; 1-VII with 3 - 9 branches; 5-I well developed, much longer than 2 and 3-I; seta 5 more strongly developed than seta 1 on V - VII, approximately 0.50 - 0.75 as long as segments; 5-IV without strong central stem, with 3 - 7 branches from near base; 5-VII with 6 - 13 branches; seta 9 long and narrow with sharp tapered point on IV - VII; 9-IV, 9 or more times as long as 9-III; 9-VII, 0.33 - 0.50 as long as segment VIII. *Paddle.* Refractile margin 0.60 - 0.75 as long as paddle; fringe hairs approximately 0.5 length of 1-P; outer distal margin evenly convex, without straight section; 1-P simple and stout; 2-P with 2 - 6 branches.

LARVA (Fig. 82). Unicolorous tan or gray. *Head.* Antenna base slightly wider than tip; antenna with long spicules on basal 0.67, particularly on mesal side; seta 1-A short with 4 or more branches, inserted on basal 0.20 - 0.25 of antenna; 2, 3-A with one edge serrate; 4-A with 8 or more branches; setae 2-C with bases separated by approximately same distance as bases of 2-C and

3-C on one side; 2-C rarely simple, usually with 2 - 9 branches originating 0.25 - 0.75 way along stem, branches equal or nearly equal length; 3-C approximately 0.25 - 0.38 as long as 2-C, usually split into 2 - 5 branches on distal half, rarely simple; setae 4-C slightly wider apart than setae 3-C, with 2 - 7 branches from near base; 5, 6, 7-C long, well developed and plumose, 5-C reaching forward nearly to alveoli of 2-C; 8-C with 2 - 8 branches, rarely 2; 9-C with 3 - 7 branches; 11-C approximately equal length of antenna, with many branches particularly at apex. *Thorax.* Seta 1-P with 7 - 15 branches, about 0.5 length of 2-P, without sclerotized base; 2-P with 8 - 18 branches, arising from sclerotized tubercle; 2-P tubercle with prominent apical spur or tooth; 3-P short and simple, closer to 2-P than 1-P is to 2-P; 4-P with stout stem and numerous short lateral and apical branches, slightly longer than 2-P; prothoracic pleural tubercle with distinct slender spine; 11-P with 2 - 5 fine distal branches; one long pleural seta on pro-, meso- and metathorax often with 2 - 3 distal branches, frequently these setae simple on one or more segments; 13-P with 4 - 14 dendritic branches; 14-P with 5 - 9 branches, rarely 5 on both sides; 4-M small and branched from base, inserted caudally to long and simple 3 and 5-M; 3-T with well developed flattened leaflets without filaments. *Abdomen.* All segments unicolorous; anterior tergal plates 0.25 - 0.33 width of segment on I-VII; posterior tergal plates small, usually only on VI - VII, infrequently on IV - VII; seta 0 small with 2 or more branches on II - VII, larger with 4 or more branches on VIII; 1-I unpigmented, undeveloped or with poorly developed flattened leaflets; 1-II pigmented, with well developed flattened leaflets, with or without well developed filaments; 1, on III - VII pigmented, well developed (palmate) with filaments; 5-II with 7 or more branches; 11-II with 2 - 4 branches on distal half; 6-III with 20 or more branches; 6, on IV - V, 0.50 - 0.67 as long as 6-III; 6-VI short, less than 0.33 as long as 6, on IV - V; seta 13 with 5 or more branches on I-VIII; stigmal knob on median dorsal valve unpigmented, nearly transparent; pecten plate with 11 - 16 teeth; 1-X with 3 - 8 branches.

TYPE-DATA. A type ♂ and ♀ with the ♂ genitalia mounted on a slide were deposited in the BMNH according to Puri (1930). Unfortunately, these specimens have not been found. Reid (1965, 1968) lists paratypes as present in the Indian Museum, Calcutta and the National Institute of Communicable Diseases, Delhi. The type-locality of *bengalensis* is listed as Marianbarie (Bengal Terai), near Sukna in West Bengal, India. The ♀ type of *pallida* Ludlow, is located in the USNM and has the following label data: ["H", *Stethomyia pallida* Ludlow, Camp Stotsenberg, Maj Whitmore.]. This specimen has a forefemur/proboscis ratio of 1.15, which fits in the range known for *bengalensis*, but is outside that known for *aberrans*.

DISTRIBUTION (Fig. 81). Since the immature stages are currently the only means of identifying this species, the following distribution is based entirely on either whole larvae, pupae or adults with associated skins. This may be the most widely distributed species in this group. The confirmed distribution extends from Assam in the west to Amami Island (Japan) in the northeast and south through Malaysia to the Philippines. Specimens (45♂, 64♀, 271 larvae and 174 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Chanthaburi, Chiang Mai, Chon Buri, Kanchanaburi, Krabi, Lampang, Mae Hong Son, Nakhon Nayok, Nakhon Ratchasima, Nan, Narathiwat, Phangnga, Phrae, Phuket, Prachin Buri, Ranong, Sara Buri, Satun, Songkhla, Trang and Trat. Additional specimens (8♂, 20♀, 88 larvae and 60 larval and pupal skins) in or on loan to the USNM were examined from BURMA, HONG KONG, INDIA (Assam), MALAYSIA, PHILIPPINES, JAPAN

(Amami Island) and SOUTH VIETNAM. A number of adults in the BMNH labeled *bengalensis* could not be confirmed, however, specimens (5 larvae and 9 larval and pupal skins) were examined from CHINA (Formosa), HONG KONG, MALAYSIA (Peninsular, NORTH VIETNAM and PHILIPPINES.

Kanda and Kamimura (1967) recorded *bengalensis* from Japan (Amami Island), which is apparently the most northern record (27 - 28° N) for this group. We were able to borrow 2 adults with associated immature skins from this island, and all stages agree very well with *bengalensis*.

There are published records of this species in Indonesia, and some of those listed under *aitkenii* by Reid (1965) probably refer to *bengalensis*. Although we could not confirm adults identified as this species from Indonesia, we feel that it most likely occurs there, probably on the western islands of Java and Sumatra.

No specimens from Bengal (type-locality) were available, but numerous larvae from Assam are in the USNM. These larvae all agree with the *bengalensis* concept, but the bifurcate variation of 2-C is apparently more common, possibly giving rise to numerous records of *aitkenii* in Burma (Khin-Maung-Kyi 1971a). See the taxonomic discussion (*aitkenii* group) for more information on this variation.

Reid (1968) describes *bengalensis* in Malaysia as a hill or mountain species that is uncommon or replaced by *fragilis* at elevations below 150 m. In Thailand, *bengalensis* has been collected at elevations as low as 10 m, and apparently utilizes suitable habitats at low elevations regularly. The lack of collections from northcentral and northeastern Thailand (Fig. 81) almost certainly reflects limited collecting efforts in those areas rather than the actual distribution of *bengalensis*, which is probably throughout most of the country where suitable habitats occur. However, most of the suitable habitats seem to be hill or mountainous areas where man has not drastically altered the ecology. Since most ground water habitats in the plains or low lands are polluted, turbid and have higher temperatures, *bengalensis* is usually absent or uncommon in those areas. (Also see biology section).

TAXONOMIC DISCUSSION. This species is very closely related to *fragilis*, in fact, sibling rearings are needed to confirm the validity of the only immature character (larval seta 2-C) to separate these 2 in Thailand. We identified several larvae from southern Thailand as *bengalensis* with 2-C either bifurcate or simple. These specimens could possibly be *fragilis* without frays on 2-C. Reid (1965, 1968) said that pupae of *bengalensis* and *fragilis* in Malaya could be separated by *fragilis* having the following setal branches: 1-IV (4 - 10), 5-IV (5 - 7), 1-VII (3 - 7), 5-VII (6 - 13) and 7 of the cephalothorax (3 - 7); while, *bengalensis* has 1-IV (3 - 7), 5-IV (3 - 5), 1-VII (1 - 5), 5-VII (8 - 13) and 7 of the cephalothorax (2 - 3). As seen in the above description, branching variation on Thai *bengalensis* completely nullifies these differences. Unfortunately, we were unable to find any other differences, thus, the pupae of *fragilis* and *bengalensis* cannot be differentiated in Thailand. The male genitalia of these 2 species are also very similar. Previous authors describe the inner dorsal club on the claspette of *fragilis* with a single stem, while that of *bengalensis* was supposed to have 2 basal stems. Of 13 genitalia preparations we examined from *bengalensis* confirmed by immature skins, 10 had this structure coming from 2 basal stems and 3 had a single basal stem.

During recent years 2 new species (*tigertti* and *aberrans*) have been found hidden among Thailand specimens previously considered *bengalensis*. The pupa, larva and male aedeagus of *tigertti* are very distinct from those of *bengalensis*. Moreover, *tigertti* is a crab hole inhabitant, and not frequently

encountered. The larvae and pupae of *aberrans* are also very distinct from those of *bengalensis*, but the best larval characters are hard to see. The nearly identical development of head seta 2-C on *aberrans* and *bengalensis*, kept *aberrans* hidden for several years. The close affinities of these 2 species is emphasized further by overlapping male genitalia characters, which invalidate previously used outer dorsal setal counts on the claspette. Fortunately, some adults and larvae of *aberrans* can be distinguished by the presence of pale abdominal segments, a character not seen on *bengalensis*. These 2 species are often found together (see Table 4, p. 155), and workers in Thailand should be very careful with their identifications of "*bengalensis*".

Reid (1965, 1968) listed 2 characters by which he differentiated his single Malayan female of *aitkenii* (with skins) from *fragilis* and *bengalensis*, they are: pupa 1-IV with 11 branches; and position of fork on larval seta 2-C. After examining Reid's specimen of *aitkenii* from Peninsular Malaysia in the BMNH, we consider it equivalent to *bengalensis*. Characters checked on the pupal skin, 1-IV (11 branches), 1-VII (6 - 7 branches), paddle refractile border 65 - 70%, paddle apical fringe 0.5 length of 1-P and 2-P with 3 branches, all fit our concept of *bengalensis*. Characters checked on the larval skin, 8-C (6 - 7 branches), 14-P (5 branches each side), 5-II (10 or more branches) and 11-II (bifurcate distally), also agree with *bengalensis*. The female reared from these skins has a definite prescutellar bare space and does not exhibit pale abdominal segments.

Reid also mentioned variations he observed in *aitkenii* characters. He noted that the bifurcation of larval 2-C on Indian specimens was usually very low, about 0.25 from the base, and Indian larval 3-C are shorter than those on specimens from further east. The 2 larvae of *aitkenii* from Sri Lanka have 2-C bifurcate about 0.33 from the base and 3-C on both specimens is long, reaching or extending beyond the fork on 2-C. Furthermore, Reid followed Puri (1931) and tried to attach some significance to the branching of the long larval pleural setae on *aitkenii*. Branching patterns on these setae in *bengalensis* are extremely variable in Thailand, and apparently also on *aitkenii* as the 2 larvae from Sri Lanka have branches on the long meso- and metapleural seta, while Puri (1931) says *aitkenii* only has such branches on the long prothoracic pleural setae. The branching patterns on the long larval pleural setae are probably too variable in this group to be used as reliable taxonomic characters.

Although numerous variations were observed, only one obvious anomaly was found on a larva from Perak, Malaysia. At first glance this specimen appeared to have 2 left setae 3-C, however, further examination revealed the 2nd (also most caudal) 3-C was branched differently and was a mislocated 4-C. No alveolus or seta could be found in the location where the normal left 4-C should occur.

BIOLOGY. Our knowledge of the biology of *bengalensis* is largely based on habitats where the immature stages are found. This species definitely prefers forests, shade and clear, cool slow running streams or seepage springs for oviposition sites. Although immatures are found in isolated rock pools and stream pools, these are usually very close to either water falls or streams where slight fluctuations in water level can inundate or bring fresh water to the pools. Dead leaves, emergent or floating debris or vegetation are also abundant in most collection sites. Forest-type apparently has no basic effect on populations of *bengalensis*, as long as the shade and water conditions are satisfactory. Larvae have been collected from habitats in primary and secondary wet forests, primary evergreen forest, primary and secondary deciduous

forests, bamboo groves and heavily shaded habitats near villages. Immatures have been collected between 10 - 1,300 m elevation from the following sites in Thailand: marsh-bogs, elephant-buffalo tracks on stream margins, stream pools, stream margins, springs, seepage pools, rock pools, and a small stream inside a dark cave (near entrance)(see distribution section).

Records (Scanlon and Esah 1965, Scanlon et al. 1968 and Harinasuta et al. 1970) of female *aitkenii* or *bengalensis* biting man in Thailand now need confirmation because of our revised interpretation of *aitkenii* distribution, and the descriptions of *aberrans* and *tigertti*. Although *bengalensis* is apparently the most commonly collected species of this group in Thailand, there are no confirmed specimens that were collected biting man. Records of *aitkenii* group females collected biting man should be confirmed by allowing the females to oviposit and rearing the larvae, or, if they cannot be identified by the characters presented here, should be called "*aitkenii* group".

One observation has possible value for future larval control measures. In one collection of *bengalensis* larvae from Prachin Buri Province, 21% (20/94) of the larvae were infected with a *Coelomomyces* fungal parasite. This parasite does not appear to be *C. indiana* Iyengar or *C. anophelesica* Iyengar (R. A. Ward - personal communication), but since all specimens were mounted on slides, identification cannot be taken further.

ANOPHELES (ANOPHELES) FRAGILIS (THEOBALD)
(Figures 79, 83, 84)

Stethomyia fragilis Theobald 1903: 257 (♂).
Anopheles treacheri Leicester 1908: 19 (♂, ♀); Reid 1965: 109 (= *fragilis*).
Anopheles aitkeni stantoni Puri 1949: 483; Reid 1965: 109 (= *fragilis*).
Anopheles aitkeni treacheri of Puri 1949: 483; Reid 1965: 109 (= *fragilis*).
Anopheles (Anopheles) fragilis (Theobald), Reid 1965: 109 (♂*, ♀*, P*, L*); Reid 1968: 232 (♂*, ♀*, P*, L*).

The adults of this species cannot usually be identified without an associated larval skin. The pupa is not separable from that of *bengalensis*. The larva is distinct on the basis of one character, frayed setae 2-C. Like *bengalensis*, except:

FEMALE. Cannot be separated from *bengalensis*.

MALE (Fig. 79). Habitus like female, indistinguishable from *bengalensis*. *Genitalia.* As for *bengalensis* except club on dorsal lobe of claspette arising from single stem (see *bengalensis* variation).

PUPA (Fig. 83). Cannot be separated from *bengalensis*, but with slight differences in setal branching. *Cephalothorax*. Seta 7 with 2 - 7 branches. *Abdomen.* Seta 0 simple or often bifid or trifid, particularly on VI - VII; 9-IV, 8 times or more as long as 9-III; 9-VII, 0.33 - 0.50 length of segment VIII; 1-IV with 4 - 10 branches; 5-IV with 5 - 9 branches; 1-VI with 3 - 6 branches; 1-VII with 3 - 7 branches; 5-VII with 6 - 13 branches. *Paddle.* Refractile margin 0.60 - 0.75 as long as paddle; 2-P with 3 - 4 branches.

LARVA (Fig. 84). Nearly identical to *bengalensis*. *Head.* Seta 1-A with 4 - 10 branches; 2-C simple or with 2 - 5 nearly equal branches from 0.33 - 0.50 along stem, middle 0.33 of stem(s) with tiny fray-like branches; 3-C simple or with 2 - 3 distal branches, about 0.33 - 0.40 as long as 2-C; 9-C with 3 - 8 branches; 14-P with 4 - 8 branches; pecten plate with 9 - 13 teeth.

TYPE-DATA. Theobald designated 2 ♂ as types for *fragilis* and both are

in the BMNH. One of these syntypes is in near perfect condition and with the genitalia intact. This specimen has the following data: (1st label, underside of cardboard minuten stage) - "K. Lumpur, Drives, 8. XII. 02"; (2nd label) - "Kuala Lumpur Dr. N. E. Durham"; (3rd label) - circular BMNH "Type" label; and (4th label) - "*Stethomyia fragilis* (Type) FVT". The 2nd specimen is not complete and has certain parts mounted on 3 slides. The remaining portion of the pinned adult has the following data: (1st label, underside of cardboard minuten stage) - "K. Lumpur W. Sink, I. 03"; and (2nd label) - "Kuala Lumpur Dr. H. E. Durham". The dates on the above adults correspond to the January and December dates given by Theobald. The 3 slides belonging to the last male were incorrectly labeled by Theobald, but J. A. Reid has corrected this by a hand written note on the slide containing the abdomen and genitalia.

At the same time Reid (1965) elevated *fragilis* to specific status, he synonymized *treacherii* Leicester under *fragilis*. Reid (1965) designated one male from 5 Leicester syntypes in the BMNH as the lectotype of *treacherii*. This male has the genitalia mounted on a slide, and has the following data: (1st label, underside of cardboard minuten stage) - "Hill Stream Ampang jungle 26/8/03" (not 28/8/03 as in Reid, p. 109); (2nd label) - "A♂"; (3rd label) - circular BMNH lectotype label; (4th label) - "Fed. Malay States Dr. G. F. Leicester. 1912-350"; and (5th label) - "*Anopheles treacherii* (lectotype) Leic." The lectotype genitalia is labeled "*Anopheles treacherii* Leic. 1908 Lectotype ♂ genit. prep. JR. 15. VI. 64 Lectotype", and agrees very well with the genitalia of the *fragilis* type.

We concur with Reid that *treacherii* is probably a synonym of *fragilis*. However, as discussed under the *aitkenii* group and *bengalensis*, male genitalia in this complex are now known to be much less stable than previously thought, and too much reliance should not be placed on them. Puri (1949) based his description of subspecies *stantoni* on illustrations by several workers, and apparently, did not designate a type.

DISTRIBUTION (Fig. 83). Although this species is considered the most common member of the group in the lowlands of Peninsular Malaysia, it apparently is not common in Thailand. Reid (1965) suggested that *fragilis* probably occurred in Thailand, and it was first recorded there by Peyton and Scanlon (1966). Scanlon et al. (1968) listed larvae collected in Narathiwat, Songkhla and Yala provinces. Specimens (4 larvae) in the USNM were examined from the following provinces of THAILAND: Nakhon Si Thammarat, Narathiwat and Songkhla. Other specimens (4♂, 8♀, 9 larvae and 18 larval and pupal skins) in the USNM were examined from MALAYSIA and PHILIPPINES. Specimens 8♂, 5♀, 1 larva and 12 larval and pupal skins) in the BMNH were examined from MALAYSIA (Peninsular) and PHILIPPINES, and included the syntypes of *fragilis* and lectotype of *treacherii*. Swellengrebel and Swellengrebel-de Graaf (1919) illustrated larvae of this species from Indonesia, and Reid (1965) refers to an obscure reference of larvae with frayed setae 2-C in Burma. We have not been able to confirm these latter records, but feel that *fragilis* probably occurs in both these countries. Apparently *fragilis* is a Malaysian-Indonesian species which reaches into southern Burma in the tropical wet forest areas. This species is probably more common in the foothill streams of southern Thailand than in the flat coastal areas. Reid (1968) said *fragilis* is uncommon in the flat coastal plain of Malaysia.

TAXONOMIC DISCUSSION. This species is almost identical to *bengalensis*, so much so that F_1 sibling rearings will be needed to help resolve the status of these species. The only 2 characters we consider of value in separating these 2 species are larval seta 2-C and the male claspette setae (see discussion under

aitkenii group and *bengalensis*). The variation of fraying and branching on 2-C of larvae from Malaysia and Thailand compared with those from the Philippines, suggests that overlap may occur in these characters between *bengalensis* and *fragilis*. Of the 9 Thai-Malay larvae examined in the USNM, 5 had 2-C single, 3 had 2-C bifurcate and one had 2-C trifurcate. Those with a simple or bifurcate 2-C had dense fraying, while there was sparse fraying on the trifurcate 2-C. Of 14 Philippine larvae and larval skins examined in the USNM, 11 had 2-C trifurcate and 3 had 2-C with 4 branches. Fraying on the 2-C of Philippine specimens was not dense and was limited to only 1 - 3 tiny frays on some setae 2-C that were trifurcate and on all that were 4 branched. On 2 of the Philippine specimens with 4 branched 2-C, only one 2-C per larva exhibited fraying. This reduction of fraying with an increase in large branches, coupled with larvae that only have 1 - 2 frays on 1 of 2 setae 2-C, is highly suggestive that the parameters of 2-C currently used to separate *bengalensis* and *fragilis* larvae (at least in the Philippines) may not be valid.

Data presented under *bengalensis* show that some specimens of that species have male claspette characters that are identical to those of *fragilis*. The extent of variation for *fragilis* claspette characters is not known. Unfortunately, we had very few male *fragilis* and these came from the Philippines, which might explain the slight differences between our illustrated claspette (Fig. 79) and the illustrations in Reid (1965, 1968).

Although the above morphological characters appear to overlap, there is other very valid evidence for continuing to consider *bengalensis* and *fragilis* as distinct species. Their distributions are different, particularly in an area such as Malaysia and Thailand where there has been considerable collecting. In Thailand, *fragilis* has been collected only from southern tropical wet forest areas, while *bengalensis* is found in most forested areas throughout the country. The latter species is well adapted to habitats found in countries (e.g., China, North and South Vietnam and Thailand) with distinct wet and dry seasons, while *fragilis* apparently utilizes habitats found only in or closely associated with tropical wet forest where yearly rainfall patterns are more evenly distributed. Further evidence supporting the validity of these 2 species is the apparent abundance of *fragilis* in Malaysia at elevations below 300 m, while *bengalensis* is the more common species above that elevation (Reid 1965, 1968).

BIOLOGY. Reid (1968) listed Malaysian larvae of *fragilis* as found in streams, pools and occasionally swamps under shade in or near forests. He also noted they are usually found on rising ground and are not common on the flat coastal plain. The few Thai larval collections of *fragilis* agree with Reid's information: 154 - 185 m elevation; moderate to heavy shade, slow running seepage water, stream margin, stream pool and an elephant footprint (presumably beside a stream), cool clear water with dead leaves and/or erect vegetation and collections in or very near tropical wet forests. Nothing is known about adult habits.

ANOPHELES (ANOPHELES) TIGERTTI SCANLON AND PEYTON
(Figures 79, 85, 86)

Anopheles (Anopheles) tigertti Scanlon and Peyton 1967: 19 (♂*, ♀, P*, L*); Rattanarithikul and Harrison 1973: 5 (L*).

This is a seldom encountered forest species in Thailand, with the immature stages apparently restricted to fresh water crab holes. The species can be differentiated in all known stages except the adult female. The egg is undescribed. Like *bengalensis* except:

FEMALE. Cannot be separated from *bengalensis* at present. Ratio fore-femur/proboscis (2 females) range 0.89 - 0.96, mean 0.93; pleural setae: 1 propleural, 2 spiracular, 1 prealar, 2 upper and 2 lower sternopleural and 3 - 4 upper and 0 lower mesepimeral; upper midcoxa with 2 setae.

MALE (Fig. 79). Habitus like female, currently indistinguishable from *bengalensis*. *Genitalia*. Claspette with 2 outer dorsal setae, inner dorsal club formed from one or usually 2 basal stems; ventral lobe of claspette with one large seta next to dorsal lobe and 2 smaller more ventral setae; aedeagus with sharp tip and scattered small spines on distal half.

PUPA (Fig. 85). Integument pale and unicolorous. *Cephalothorax*. Seta 7-C with 2 - 4 branches; 12-C with 5 or more branches. *Trumpet*. Simple with deep meatal cleft, meatus less than 0.33 as long as trumpet. *Abdomen*. Seta 0 simple on all segments; 1-III weakly developed, not as stout as 3-III; 1-IV with 2 - 4 branches; 1-VI simple or with 2 - 3 branches; 1-VII simple or with 2 branches; 5-I weakly developed and short, approximately equal or shorter than 2 and 3-I; setae 5, on IV - VII well developed and very long, usually as long as or longer than segments; 6, on I - III very long; 6-III nearly equal length of segment III; seta 9 long and narrow with sharp tapered point on IV - VII; 9-IV, 10 or more times as long as 9-III; 9-VII, 0.33 - 0.50 as long as segment VIII; seta 10 on IV - V very long, 10-IV nearly equal length of segment V. *Paddle*. Refractile margin short, 0.33 - 0.50 as long as paddle; outer margin evenly convex on distal half; fringe hairs 0.67 or more as long as 1-P; 2-P simple or with 2 - 4 branches.

LARVA (Fig. 86). *Head*. Seta 1-A with 5 - 11 branches; 4-A simple or with 2 - 4 branches; 2-C with bases only slightly closer together than bases of 2-C and 3-C on one side; 2-C with 2 - 5 branches originating 0.50 - 0.67 way along stem; 3-C simple, rarely bifurcate distally; 4-C with 2 - 4 long branches; 8-C simple or with 2 - 3 branches. *Thorax*. 1-P with 8 - 10 branches; 11-P simple or with short stem and 2 - 3 distal branches; 14-P with 4 - 7 branches; one long pleural meso- and metathoracic seta bifid or trifid distally; 3-T with well developed flattened leaflets, no filaments. *Abdomen*. Anterior tergal plates small, approximately 0.25 or less width of segments I - VII; posterior tergal plates absent; seta 0 small and simple on all segments; 1-I usually with filamentous branches, rarely with poorly developed slightly flattened branches; 1-II with well developed leaflets, no filaments; 1, on III - VII well developed with filaments; 5-II with 6 - 12 branches; 11-II long and bifurcate; 6-III with 6 - 12 branches; stigmal knob on median dorsal valve of spiracular apparatus pigmented, as dark as remainder of plate; pecten plate with 14 - 18 teeth; 1-X stout and longer than saddle, simple or with 2 - 3 distal branches.

TYPE-DATA. The holotype ♂ with associated immature skins, one ♂ paratype with pupal skin and 2 paratype whole larvae are deposited in the USNM. One paratype ♂, one paratype ♀ and 2 paratype whole larvae are located in the BMNH. All of the above ♂ have genitalia preparations on slides. The holotype ♂ has the following label data: (1st label) - "00712-1, THAILAND: Prachinburi: Ban Bu Phram: 150 m. crab hole"; (2nd label) - "Forest stream 20 Jan. 66, Peyton and Kol"; (3rd label) - "Holotype No. 69239"; and (4th label) - "*Anopheles* (*An.*) *tigertti* Scanlon and Peyton 1967."

DISTRIBUTION (Fig. 85). *Anopheles tigertti* is known only from Thailand. Although this species is seldom encountered, it apparently has a wide distribu-

tion in Thailand, which seems directly correlated with tropical wet forests and restricted to areas having holes of fresh water crabs. The wide distribution in Thailand suggests that *tigertti* also probably occurs in adjacent Southeast Asian countries. Vertical distribution is known from collections between 150 - 700 m elevation. More specific collection efforts aimed at crab hole habitats are needed to understand the distribution of this species. Specimens (4♂, 2♀, 9 larvae and 6 larval and pupal skins) in the USNM (including the holotype) were examined from the following provinces of THAILAND: Chanthaburi, Nakhon Ratchasima, Prachin Buri and Tak. Specimens (1♂, 1♀ and 2 larvae) in the BMNH were examined from Prachin Buri Province.

TAXONOMIC DISCUSSION. Adult females of *tigertti* cannot be differentiated at present, but adult males can be identified on the basis of genitalia characters. The small spines on the aedeagus and the 2 outer dorsal setae on the claspette make *tigertti* easy to differentiate from the other members of the group, except for *insulaeflorum*. This latter species also has small spines on the aedeagus, but it usually has 3 outer dorsal setae on the claspette, and the scutum has fine setae in the prescutellar area almost back to the scutellum, while *tigertti* has a large prescutellar bare area.

Except for *aberrans*, the pupa of *tigertti* is easily separated from the other Thailand species in this group by having long sharp setae 9 in combination with a short refractile border on the paddle. The separation of *tigertti* pupa from those of *aberrans* requires closer examination. Pupae of *tigertti* have setae 6-III and 10-IV much longer than those of *aberrans* and 1-III of *tigertti* is weakly developed. Also, seta 5, on IV - V of *tigertti* is usually as long as or longer than the segments, while this seta on *aberrans* is usually not this long. This latter character is subject to more variation than the others listed above and should only be used in conjunction with the other characters.

The larvae of *tigertti* are easily recognized by the few branches on 6-III coupled with the widely spaced bases of setae 2-C. Only 2 other species in Thailand, i.e., *insulaeflorum* and *stricklandi*, have seta 6-III with less than 15 branches, and they have the bases of setae 2-C very close together. The other species, *aberrans*, *bengalensis*, *fragilis* and *palmatus*, have 2-C wide apart (except *palmatus*), but have 18 or more branches on 6-III (usually 20 or more). The pigmented stigmal knob on the median dorsal valve of the spiracular apparatus is also indicative of this species, but difficult to see on most specimens. The position of branching for seta 2-C is also of value in identifying *tigertti* larvae. This seta branches between 0.50 - 0.67 of the way along the stem, a character found elsewhere in this complex only on occasional larvae of *bengalensis*. Infrequently, seta 4-A with few branches and seta 0 simple on the abdominal segments, may be of assistance in identifying *tigertti* larvae.

A further study of the holotype of *tigertti* and other specimens in the USNM has revealed several structures described and/or illustrated in the original description that need modification. The inner club-like seta on the dorsal lobe of the claspette (harpago) was originally described with a single stem; however, the holotype has one side with a single stem and the other with this structure having 2 basal stems. The 2 paratypes (USNM and BMNH) have a single club-like seta on each side arising from 2 basal stems. The pupal trumpet was originally described with a deep cleft, but illustrated for the original description in error with a very shallow cleft. In general, the chaetotaxy originally illustrated for the larva and pupa had the setal thickness exaggerated, consequently, we have reillustrated the species.

BIOLOGY. The only biological data for *tigertti* concerns the immature stages. Apparently females select only the holes of fresh water crabs for

oviposition, thus, immatures are rarely collected. The identity of the crab(s) associated with *tigertti* is not known. Immatures of *tigertii* have been collected in Thailand between 150 - 700 m elevation in wet forests with heavy shade, and only from crab holes in stream banks, dry stream beds or in seepage bogs. Immature collections have been made in 4 Thailand provinces (Fig. 85), a distribution that extends across central Thailand approximately 575 km from Tak (adjacent to Burma) to Chanthaburi (adjacent to Cambodia). This distribution suggests that *tigertti* probably occurs in countries adjacent to Thailand. The dependence and association of *tigertti* with the crab hole environment is supported by the other mosquito species that have been collected with it, they are: *Culex* (*Lophoceraomyia*) *pholeter* Bram and Rattanarithikul, *Culex* (*Lophoceraomyia*) sp., *Uranotaenia koli* Peyton and Klein, *Uranotaenia spiculosa* Peyton and Rattanarithikul and *Uranotaenia* species undescribed. The immatures of these species are also found only in crab holes. The reader wishing to read more on this habitat and its arthropod (or mosquito) associates should refer to Hogue and Bright (1971) and Bright and Hogue (1972).

ANOPHELES (ANOPHELES) INSULAEFLORUM (SWELLENGREBEL AND SWELLENGREBEL-DE GRAAF) (Figures 78, 79, 87, 88)

Unclassified larva No. 1 of Swellengrebel and Swellengrebel-de Graaf 1919: 23 (L*); Swellengrebel and Swellengrebel-de Graaf 1920a: 2 (= *Stethomyia aitkenii* var. *insulaeflorum*).

Stethomyia aitkenii var. *insulaeflorum* Swellengrebel and Swellengrebel-de Graaf 1920a: 2; Swellengrebel and Swellengrebel-de Graaf 1920b: 81 (L*, and distribution in part); Swellengrebel and Swellengrebel-de Graaf 1920c: 34 (L* and distribution in part); Swellengrebel and Swellengrebel-de Graaf 1920d: 98 (distribution in part).

Anopheles (Anopheles) aitkenii var. *insulaeflorum* of Christophers 1924: 19 (distribution in part); Strickland and Chowdhury 1927: 26 (L*, and distribution in part); Swellengrebel and Rodenwaldt 1932: 111 (distribution in part).

Anopheles (Anopheles) insulaeflorum of Puri 1930: 954 (♂, L): Puri 1931: 101 (L*); Edwards 1932: 38 (distribution in part); Christophers 1933: 111 (distribution in part); Simmons and Aitken 1942: 128 (distribution in part); Russell, Rozeboom and Stone 1943: 115 (distribution in part); Knight, Bohart and Bohart 1944: 7 (distribution in part); Lee and Woodhill 1944: 97 (distribution in part); Bohart 1945: 15 (distribution in part); Puri 1949: 485 (distribution in part); Worth 1953: 174; Bonne-Wepster and Swellengrebel 1953: 97 (distribution in part); Senevet and Andarelli 1955: 331 (L); Stone, Knight and Starcke 1959: 20 (distribution in part); Reid 1963: 113; Reid 1965: 119 (L*, and distribution in part); Peyton and Scanlon 1966: 3 (♀*); Scanlon, Peyton and Gould 1968: 13; Reid 1968: 248 (L*, and distribution in part); Nguyen-Thuong-Hien 1968: 129 (♀*, L*); Basio 1971: 36 (distribution in part); Rattanarithikul and Harrison 1973: 5 (L*); Harrison and Scanlon 1974: 36 (distribution).

This species can be identified in all known stages. The egg is unknown. Males and females can be recognized on the basis of a scutal character, and the male has distinct genitalia characters. The pupa is illustrated here for the 1st time and is easily recognized by having short setae 9. The larva is easily differentiated by setae 2-C, 6-III and a developed seta 1-I. This species

is like *bengalensis* except:

FEMALE (Fig. 78). General appearance unicolorous as for most other members of group unicolorous. *Thorax.* Prescutellar space with small fine setae extending back near to posterior margin; pleural setae: 1 - 3 propleural, 1 - 6 spiracular, 1 - 2 prealar, 1 - 2 upper and 2 - 3 lower sternopleural and 2 - 6 upper and 0 lower mesepimeral; upper midcoxa with 1 - 3 setae.

MALE (Figs. 78, 79). Habitus like that of female. *Genitalia.* Claspette with 3 - 4 separate flattened outer dorsal setae, slightly shorter than inner dorsal club; inner dorsal club long, formed from 2 basal stems; ventral lobe with 3 - 4 long stout setae, most mesal large seta longest, longer than inner dorsal club; ventral lobe also with 1 - 2 small setae and numerous small spines; aedeagus with small sharp lateral spines near tip, tip rounded.

PUPA (Fig. 87). Integument tan to dark brown. *Abdomen.* Seta 0 usually simple, infrequently bifid on segments II - VIII; 1-IV with 4 - 8 branches; 1-VI with 3 - 8 branches; 1-VII with 2 - 5 branches; 5-I well developed, much longer than 2 and 3-I; 5-IV with 3 - 7 branches; 5-VII with 4 - 11 branches; 6-II usually simple or bifid, as long as segment II; 6-III simple, slightly less than length of segment III; 7-I with 2 - 3 branches, 0.50 - 0.60 as long as 6-I; 7, on VI - VII, 0.67 or more as long as following segment; seta 9 moderately long, without long tapering tip, but sharp pointed, usually dark brown; 9-IV, 4 - 6 times as long as 9-III; 9-VII, 0.20 - 0.25 as long as segment VIII; 10, on IV - V, 0.67 or more as long as following segments. *Paddle.* Refractile margin 0.50 - 0.67 as long as paddle; fringe hairs approximately 0.33 length of 1-P; outer margin evenly convex on distal half; 1-P long, simple, stout and pigmented; 2-P with 2 - 4 branches.

LARVA (Fig. 88). Unicolorous gray or brown. *Head.* Seta 1-A with 3 - 7 branches; 4-A with 4 - 8 branches; setae 2-C long, stout and simple, with bases very close together, much closer than distance between bases of 2-C and 3-C on one side; 3-C simple, rarely bifid at tip, approximately 0.33 length of 2-C; 4-C with 2 - 4 branches from base; 8-C with 2 - 6 branches; 9-C with 3 - 6 branches. *Thorax.* Seta 11-P short, simple (rarely bifid); 13-P with 3 - 6 branches; 14-P with 5 - 8 branches; all pleural setae (9, 10, 11, 12) on pro- meso- and metathorax usually simple, 12-T infrequently bifid; small median pigmented plate (frequently bilobed) often on dorsal midline between meso- and metathorax; 3-T with flattened, lightly pigmented leaflets, without filaments. *Abdomen.* All segments unicolorous; posterior tergal plates usually present on segments III - VII, that on VII twice as large as others; seta 0 simple or 2 - 3 branched (rarely 3) on segments II - VI; 0-VIII simple or 2 - 4 branched (rarely 4); 1-I with well developed lightly pigmented leaflets, without filaments; 1, on II - VII with well developed (palmate) flattened and pigmented leaflets, with filaments; 5-II with 6 - 10 (usually 8 - 10) branches; 6-III with 5 - 9 branches; 11-II long and simple; pecten plate with 13 - 17 teeth; 1-X simple, approximately as long as saddle.

TYPE-DATA. The location of the type-specimen of *insulaeflorum* is unknown. This species was described from larvae collected on Noesa Kembangan (now Nusa Kambangan), an island just south of Tjilatjap off the south coast of Java. Although topotypic specimens were not available for examination, 2 whole larvae on slides are in the USNM from Pangandaran, only 15 km from the type-locality. These larvae have seta 0 with 2 - 3 branches on segments II - VI and 1-X simple. This combination of characters is like *insulaeflorum* specimens from mainland Southeast Asia, rather than *pilinotum.*

DISTRIBUTION (Fig. 87). This is a widely distributed species that has been collected in a variety of forest habitats in Thailand. The specific habitat

requirements that determine the distribution of *insulaeflorum* are currently unknown. Specimens (31♂, 32♀, 63 larvae and 71 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND: Chanthaburi, Chiang Rai, Kanchanaburi, Krabi, Lampang, Nakhon Ratchasima, Nan, Phangnga, Phrae, Prachin Buri and Songkhla. Additional specimens (10♂, 17♀ and 7 larvae) in the USNM were examined from INDIA (Assam), INDONESIA (Java) and MALAYSIA (Peninsular). Specimens examined in the BMNH include 2 whole larvae from INDIA (West Bengal) and one larval skin from MALAYSIA (Peninsular). Other distribution records from the literature include BURMA, CHINA (Taiwan), INDIA (West), INDONESIA (Sumatra), SOUTH VIETNAM and SRI LANKA.

Hsiao and Bohart (1946) listed *insulaeflorum* from Honshu Island, Japan, based on an earlier record which they said "appears to be somewhat doubtful." This is almost certainly an erroneous record. *Anopheles bengalensis* is the only member of the *aitkenii* group known to occur in the Japanese area, and that is south of the main islands in the Ryukyus chain. The nearest records of *insulaeflorum* to Japan are those from Taiwan, and although we have a male and female from that island, the male genitalia has been lost and the identity of the specimens cannot be confirmed.

Carter (1925) recorded *insulaeflorum* from Sri Lanka and illustrated the inner clypeal differences between *aitkenii* and *insulaeflorum*. Based on these illustrations we are convinced that his "*insulaeflorum*" larva (p. 80, fig. 5d) is not *insulaeflorum* because the bases of setae 2-C are nearly as wide apart as 2-C and 3-C on one side. This illustration probably represents *aitkenii* with 2-C simple. Since we have not seen specimens of *insulaeflorum* from Sri Lanka and can find no substantial evidence it occurs there, we consider previous records of this species from Sri Lanka as doubtful.

The distribution of *insulaeflorum* in Indonesia is not completely known, but Java may be the easternmost extension. Past records of *insulaeflorum* from Ambon, Ceram and the Philippines are now known to apply to *pilinotum* (Harrison and Scanlon 1974). The past records of *insulaeflorum* from Sulawesi, Lesser Sunda Islands and the Molucca Islands now need confirmation to determine whether they apply to *insulaeflorum* or *pilinotum*. Neither species has been collected from Borneo.

TAXONOMIC DISCUSSION. This is a most unusual member of the *aitkenii* group because all the known stages can be identified on mainland Southeast Asia. The adults can be recognized by the short fine setae on the prescutellar space where other species have a bare space. The male is also distinguishable by having spines on the aedeagus and should never be confused with the other Thai species, except possibly *tigertti*. The aedeagus of *insulaeflorum* has small spines lateral only, while those on *tigertti* are lateral, dorsal and ventral. The claspette of *insulaeflorum* is also distinct from that of *tigertti*. The former has 3 - 4 outer dorsal setae and at least 3 large setae on the ventral lobe, while the latter only has 2 outer dorsal setae and only 1 - 2 large setae on the ventral lobe. The male genitalia of *insulaeflorum* are easily differentiated from those of *pilinotum* by obvious (Fig. 79) differences in the setae on the ventral lobe of the claspette and slight differences in the shape of the aedeagus tip. The male genitalia illustrations (Fig. 79) are the first made of *insulaeflorum*, although Puri (1930), gave an excellent description of the claspette. Most descriptions and apparently all illustrations previously made for the male genitalia of *insulaeflorum* actually belong to *pilinotum*. Bonne-Wepster and Swellengrebel (1953: 87, fig. 24f) were possibly illustrating *insulaeflorum* with their "*aitkenii*" having minute hairs on each side at the tip of the aedeagus,

but we cannot be certain. The minute spines at the tip of the aedeagus of *insulaeflorum* are less distinct than those on *pilinotum*, in fact, often small enough to be overlooked unless they are viewed under high magnification.

All pupal descriptions and illustrations previously called *insulaeflorum* actually refer to *pilinotum*. The pupae of these 2 species are similar, but can be differentiated by *insulaeflorum* having seta 0, on II - VII simple or bifid, the refractile margin on the paddle 0.5 or more as long as the paddle and the outer margin of the paddle evenly convex on the distal half. The pupa of *pilinotum* has seta 0, on II - VII with 2 - 6 (usually 3 - 5) branches, the refractile margin on the paddle less than 0.5 the paddle length and the outer margin of the paddle straight or nearly straight on the distal half. The pupa of *insulaeflorum* should not be confused with pupae of the other Thailand members of this group because of the combination of short setae 9, a long refractile margin on the paddle and being moderately to darkly pigmented. The pupa of *stricklandi* is the most likely member to be confused with *insulaeflorum*; however, *stricklandi* has a much shorter seta 9, shorter and more widely spaced fringe hairs on the paddle and is very pale.

The larva of *insulaeflorum* is easily separated from all the other Thailand members of this group except *stricklandi*, by having the following combination of characters: seta 2-C simple and close together, small anterior tergal plates on the abdomen, 11-II simple, 6-III with less than 15 branches and 1-X simple. The larva of *stricklandi* is very similar to that of *insulaeflorum* and workers in Thailand should be aware of the small differences (see key) that differentiate these 2 species.

The larvae of *insulaeflorum* and *pilinotum* are also very similar. The former has seta 11-P single or rarely bifid, 0, on II - VI simple or with 2 - 3 (rarely 3) branches and 1-X simple, while the latter has 11-P with 2 - 6 branches, 0, on II - VI with 3 - 6 branches and 1-X with 2 - 4 branches.

BIOLOGY. This species does not appear to be abundant anywhere in Thailand. Usually larval collections of *insulaeflorum* involve 5 - 10 specimens, even when the habitat appears to be ideal. The immatures are found only in or near forested areas. In Thailand they have been found in a number of habitats in primary and secondary wet forests, a bamboo grove and in a rural village adjacent to a forested area. These collections were usually in mountainous regions, but several were made in forested plains areas. Collections in Thailand record *insulaeflorum* between 46 - 700 m elevation, and one immature collection in Perlis, Malaysia was made at sea level. Immatures have been collected from the following sites in Thailand: isolated rock and ground pools near streams, large and small stream pools, stream margin, small seepage pools and a water pool on a fallen tree. These sites were nearly always under either moderate or heavy shade, and there was usually floating vegetation, dead leaves or brown algae in the water. The water was either clear or colored and was either stagnant or flowing very slowly.

There are no adult females of *insulaeflorum* in the USNM or BMNH that we could determine were taken in biting collections. Further, there are no confirmed published records of this species biting man. Stojanovich and Scott (1966) said this species feeds in jungle shade on cattle and man, but this needs confirmation.

ANOPHELES (ANOPHELES) STRICKLANDI REID
(Figures 79, 89, 90)

Anopheles (Anopheles) stricklandi Reid 1965: 121 (♂*, ♀*, P*, L*); Reid 1968: 250 (♂*, ♀*, P*, L*); Rattanarithikul and Harrison 1973: 5 (L*).

This species is small and pale as an adult, and only the adult males can be identified. The pupa is easily differentiated by the very short seta 9, the angular projections on tergum IX and paddle characters. The larva, although identifiable, is much more apt to be confused with *insulaeflorum*, a more commonly encountered species in Thailand. Like *bengalensis* except:

FEMALE. Cannot be separated from *bengalensis* at present. Ratio fore-femur/proboscis (sample 4 females) range 1.00 - 1.02, mean 1.01; pleural setae number 0 - 1 propleural, 2 - 4 spiracular, 1 prealar, 1 upper and 1 - 2 lower sternopleural, 1 - 3 upper and 0 lower mesepimeral; upper midcoxa with 2 setae; wing cell M_2 usually less than 1/2 as long as stem (from cross-vein).

MALE (Fig. 79). Habitus currently indistinguishable from *bengalensis*. *Genitalia*. Claspette with 3 short thick outer dorsal setae, inner dorsal club formed from 2 very broad setae; ventral lobe of claspette with 3 setae the same length as the club or shorter; aedeagus without spines or leaflets (see taxonomic discussion); basal half of aedeagus broad, then narrowing on distal half only to widen slightly for broadly rounded apex, shape similar to a bowling pin.

PUPA (Fig. 89). Integument pale to light tan. *Cephalothorax*. Seta 7-C with 3 branches; 10-C stout, usually simple or bifid. *Abdomen*. Seta 0, on II - VIII short and simple; seta 1, on III - IV well developed with few branches; 1-III with 3 - 6 branches, stem as stout as that of 3-III; 1-IV with 3 - 6 branches; 1-VI with 2 - 4 branches; 1-VII with 2 - 5 long, simple or with 2 - 3 distal branches, much longer than 2 and 3-I; seta 5, on V - VII with few branches and strongly developed, approximately 0.67 as long as following segment; 5-IV with 3 - 5 branches; 5-VII with 3 - 6 branches; 6-I simple, bifid or trifid, much longer than segment I; 6-II simple or bifid, slightly more than 0.67 length of segment II; 6-III simple or bifid, about 0.67 length of segment III; 7-I simple, bifid or trifid, about 0.75 as long as 6-I; seta 7, on VI - VII, 0.50 - 0.67 as long as following segment; setae 9 very short; 9-IV, 2 - 3 times as long as 9-III; 9-VII, 0.13 - 0.17 as long as segment VIII; 10, on IV - V, 0.50 - 0.67 as long as following segment; tergum IX with prominent latero-caudal angle over each paddle base. *Paddle*. Refractile margin 0.67 or more as long as paddle; fringe hairs short and widely spaced, 0.25 - 0.33 as long as 1-P; outer margin evenly convex on distal half; 1-P long and simple; 2-P simple or bifid.

LARVA (Fig. 90). Unicolorous yellow or tan. *Head*. Seta 1-A with 5 - 9 branches; 4-A with 5 - 8 branches; 2-C long, stout and simple, with bases very close together, much closer than distance between bases of 2-C and 3-C on one side; 3-C split distally into 2 - 4 stout, equal branches, approximately 0.33 length of 2-C; 4-C with 3 - 5 branches from near base; 8-C with 2 - 4 branches; 9-C with 3 - 5 branches. *Thorax*. Seta 1-P with 8 - 12 branches; 2-P with 12 - 15 branches; 11-P short, simple and flattened on distal half (fusiform); 13-P with 3 - 6 branches; 14-P with 5 - 6 branches; all pleural setae (9, 10, 11, 12) on pro- meso- and metathorax usually simple, 12-T infrequently bifid; without small median pigmented plate on dorsum of meso- or metathorax; 3-T with flattened unpigmented leaflets, without filaments. *Abdomen*. All seg-

ments unicolorous; posterior tergal plates usually present on segments III - VII, that on VII largest; seta 0, on II - VII with 2 - 3 branches; 0-VIII with 3 branches; 1-I branched, without flattened leaflets; 1-II with slightly pigmented flattened leaflets, without filaments; 1, on III - VII with flattened, pigmented leaflets, with filaments; 5-II with 7 - 11 branches; 6-III with 4 - 10 branches; 11-II long and simple; pecten plate with 9 - 14 teeth; 1-X simple, approximately as long as saddle.

TYPE-DATA. The ♂ holotype, ♀ allotype, and one ♂ and one ♀ paratype are in the BMNH, each with associated immature skins mounted on a single slide. The ♂ holotype is in excellent condition and has the following label data: (1st label) - "Malay Peninsula, Johore, 28.5.1935. E. P. Hodgkin"; (2nd label) - "9667/7♂"; (3rd label) - "*Anopheles stricklandi* ♂ holotype, genit. on slide"; and (4th label) - is a round BMNH "Type" label. The slide bearing the holotype genitalia and its larval and pupal skins, bears the same number and small round "holotype" label. The ♀ allotype is in excellent condition and bears the same data as the holotype except for the small round "allotype" label and the rearing number "9667/10." The larval and pupal skins of the allotype are mounted on a slide bearing that number. The ♂ and ♀ paratypes are both in excellent condition, and bear the following label data: (1st label) - "Perlis, 19.8.1934, R. E. Anderson;" (2nd label) - "8355/2" for the male, and "8355/4" for the female; (3rd label) - "*A. aitkeni* v. B"; and identification and "paratype" labels. Both paratypes have a slide bearing their larval and pupal skins; however, that of the ♂ paratype also bears a genitalia mount.

DISTRIBUTION (Fig. 89). This is a very infrequently encountered species that is known only from Peninsular Malaysia and southern Thailand. Reid (1965, 1968) suggests *stricklandi* is a lowland species, and this is supported by Thailand collections of 100 - 180 m elevation. Specimens (3♀, 1 larva and 3 pupal skins) in the USNM were examined from the following provinces of THAILAND: Krabi and Ranong. Additional specimens (1♂, 1♀ and 4 larval and pupal skins) in the USNM were examined from MALAYSIA. Specimens (2♂, 2♀ and 8 larval and pupal skins = type-series) in the BMNH were examined from MALAYSIA. Since Thailand collections were made in Ranong adjacent to Burma, this species probably occurs in Burma.

TAXONOMIC DISCUSSION. Although the adults of *stricklandi* cannot be separated (except male genitalia) from most of the other Thailand species, the immature stages are identifiable. The pupa of *stricklandi* is the easiest stage to identify, and should not be confused with that of any other species in the *aitkenii* group because it has the shortest seta 9, sparse setal branching, a very long paddle refractile margin and short sparse paddle fringe hairs. The larva is easily differentiated from all the Thai species except *insulaeflorum* by having: setae 2-C simple and very close together; small anterior tergal plates on the abdominal segments; and seta 6-III with less than 15 branches. Only a closer examination using the key characters can differentiate *stricklandi* larvae from those of *insulaeflorum*. Larvae of *stricklandi* can be separated from *pilinotum* larvae by the same characters that are used to separate *insulaeflorum* from *pilinotum*.

This species appears to be closely related to *insulaeflorum* and *pilinotum*, but the adults do not possess the short fine prescutellar setae that occur on *insulaeflorum* and *pilinotum*, and therefore, *stricklandi* females cannot be identified without associated immature skins. Male *stricklandi* have very distinct genitalia characters that look similar to those of *pilinotum*, except the aedeagus of *stricklandi* does not have small spines. Reid (1965, 1968) suggested that one specimen of *stricklandi* he examined may have had small

serrations on the aedeagus, but we have not seen this. The 2 genitalia preparations (holotype and paratype) in the BMNH do not exhibit serrations on the aedeagus. The setae on the dorsal lobe of the claspette are even broader than those encountered on *pilinotum* or *acaci* and should not be confused with any species found in Thailand. The illustration (Fig. 79) used for the claspette of *stricklandi* was taken fromReid (1965).

Reid (1965, 1968) noted that wing cell M_2 on *stricklandi* is usually half or less as long as the cell stem vein (measured from the crossvein). On the specimens of *stricklandi* we examined, this is usually true; however, one specimen had M_2 more than half as long as the stem vein, and specimens of 3 other species in the group were noted to occasionally exhibit comparable M_2 lengths. Consequently, this wing measurement may be of value in helping to define some specimens of *stricklandi*, but should be used with caution because it is not completely reliable.

BIOLOGY. Very little is known about the habitat requirements of this species. Reid (1968) lists larvae found in seepages, drains and hoof marks under shade in Malaysia. Immature collections in Thailand have been made from large and small stream pools and a large seepage pool, all under partial shade in secondary wet forest between 100 - 180 m elevation. The water from these sites was clear, stagnant or slowly running and usually contained dead leaves or green algae. All confirmed specimens of this species have come from immature collections, thus, nothing is known about the adult behavior.

ANOPHELES (ANOPHELES) PALMATUS (RODENWALDT)
(Figures 78, 79, 91, 92)

Stetomyia aitkenii var. *palmata* Rodenwaldt 1926: 794 (L*)(*Stethomyia* LAPSUS).
Anopheles (Anopheles) aitkenii var. *palmata* Rodenwaldt, Covell 1927: 7; Edwards 1932: 37.
Anopheles (Anopheles) aitkenii palmatus Rodenwaldt, Swellengrebel and Rodenwaldt 1932: 112 (L*); Gater 1934: 72 (L*); Gater 1935: 149 (♂); Russell, Rozeboom and Stone 1943: 109 (distribution).
Anopheles (Anopheles) palmatus Rodenwaldt, Lee and Woodhill 1944: 98 (♂, L); Bonne-Wepster and Swellengrebel 1953: 98 (♂, L*); Reid 1963: 113.
Anopheles (Anopheles) palmatus (Rodenwaldt), Reid 1965: 117 (♂, L*); Reid 1968; 246 (♂, L*); Rattanarithikul and Harrison 1973: 5 (L*).

This is one of the easiest species in the *aitkenii* group to identify. The larva is unique in the group because of the very large anterior tergal plates. The pupa, not previously described or illustrated, has very distinct seta 9 and paddle characters. Even some of the adults can be identified by a color pattern on the abdomen, and the male genitalia, illustrated here for the 1st time, also have distinctive characters. Like *bengalensis* except:

FEMALE (Fig. 78). Unicolorous gray-brown except pale abdominal segment IV on majority of specimens (see taxonomic discussion). Pleural setae: 0 - 1 propleural, 0 - 2 spiracular, 1 prealar, 1 upper and 2 - 4 lower sternopleural and 2 - 4 upper and 0 lower mesepimeral; upper mid coxa with 3 - 4 setae.

MALE (Figs. 78, 79). Habitus as for female. *Genitalia.* Dorsal lobe of claspette with 2 outer dorsal setae approximately as long as inner dorsal club which has 2 basal stems; ventral lobe of claspette with 4 setae approximately as long as club on dorsal lobe, also with small mesal spicules; aedeagus

very long and slender with tip slightly swollen, without leaflets or spines.

PUPA (Fig. 91). Integument tan to light brown. *Cephalothorax.* Seta 7-C with 3 - 6 branches; 10-C stout and simple, or with 2 - 3 distal branches. *Trumpet.* Simple, with deep meatal cleft, meatus less than 0.33 as long as trumpet. *Abdomen.* Seta 0, on II - III simple and short; seta 1, on II - VII well developed, longer than seta 5, on II - III and V - VII, nearly as long as following segment on segments V - VII; 1-III with 6 - 12 basic branches, usually dendritic; 1-IV with 6 - 12 basic branches, usually dendritic; 1-VI with 4 - 10 branches, not dendritic; 1-VII with 5 - 8 branches, not dendritic; 5-I with 3 branches, equal or slightly longer than 2-I; 5, on IV - VII strongly developed, length equal to seta 1 only on segment IV; 5-IV with 7 - 9 branches; 5-VII with 10 - 12 branches; 6-I with 2 - 4 branches from near base, equal to or slightly longer than segment I; 6, on II - V and VII short, simple or with 2 - 4 branches; 6-VI long, simple or bifid, at least twice as long as 9-VI; 7-I with 2 - 5 branches, about half as long as 6-I; 7-VII long, simple or bifid, approximately 0.66 as long as segment VIII; seta 9 long, brown, with round blunt tip; 9-VII approximately 0.25 as long as segment VIII; 10, on IV - V approximately half as long as following segment. *Paddle.* Twice as long as wide; refractile margin 0.33 or less as long as paddle, but bases of fringe hairs refractive around entire margin of paddle; fringe hairs long, dense, 0.50 - 0.67 length of 1-P; outer margin straight or nearly so on distal half; 1-P long, stout, simple and curved near tip; 2-P with 3 - 5 branches from near base.

LARVA (Fig. 92). Whole larva dark brown with abdominal color pattern. *Head.* Seta 1-A with 7 - 10 branches; 4-A with 5 - 7 branches; 2-C long, stout and simple, with bases very close together, much closer than distance between bases of 2-C and 3-C; 3-C split distally into 2 - 5 stout equal branches, short approximately 0.2 as long as 2-C; 4-C with 2 - 6 branches; 5, 6, 7-C short, well developed and plumose; 8-C with 2 - 4 branches; 9-C with 2 - 5 branches. *Thorax.* Seta 1-P fan-like with 15 - 18 rounded branches; 2-P with 12 - 17 branches, about twice as long as 1-P; 3-P small and simple; 11-P short, with 4 - 7 branches from near base; 13-P with 5 - 8 branches (dendritic); 14-P with 5 - 6 branches; long pleural setae on pro- meso- and metathorax simple except 9-P with 2 - 3 branches; small median plate often on dorsal midline between meso- and metathorax; 3-T with flattened lightly pigmented leaflets, with filaments; 12-T simple or bifid. *Abdomen.* All segments brown except pale yellow segment IV; anterior tergal plates very large, enclosing posterior tergal plates, 0.67 - 0.75 as wide as segment; seta 0, on II - VII simple or bifid, inserted on anterior tergal plates approximately 0.33 of way between lateral margin and center of plate; 0-VIII with 5 - 6 very long slender thread-like branches, inserted just inside or slightly posterior to caudal margin of anterior tergal plate, approximately 0.33 of way between lateral margin and center of plate; 1, on I - VII (palmate) with flattened, pigmented leaflets, with filaments; 5, on II - IV small, weakly developed; 5-II with 3 - 5 branches; 5, on I and V - VII large, well developed; 6-III with 18 - 27 branches; 11-II long with 2 - 3 distal branches; pecten plate with 13 - 18 teeth; 1-X with 2 - 3 distal branches, approximately as long as saddle.

TYPE-DATA. This species was described from specimens collected in Sidoeagoeng (Preanger Regencies), West Java, but the type-specimens are apparently non-extant.

DISTRIBUTION (Fig. 91). This species has been collected only a few times in Thailand from widely separated sites. Specimens (1♂, 4♀, 5 larvae and 9 larval and pupal skins) in the USNM were examined from the following provinces

of THAILAND: Chanthaburi, Chiang Rai, Ranong and Songkhla. There is also one larval skin in the USNM from MALAYSIA (Peninsular Malaysia). An additional 2 larval skins in the BMNH were examined from MALAYSIA (Peninsular Malaysia). Reid (1968) gave the known distribution of this species as Thailand, Malaysia (including Borneo) and Indonesia from Sumatra to the Moluccas and the western tip of New Guinea. This species has not been reported from Sulawesi or the Philippines. Scanlon et al. (1968) considered the specimens from Chiang Rai Province, Thailand, as suspect because the circumstances under which the specimens were obtained make the locality data doubtful. Sandhinand (1951) reported *palmatus* from Chiang Mai Province, but these specimens have not been seen. Scanlon et al. (1968) suggested that the records from these 2 northern provinces need further study because the known distribution of *palmatus* suggests it is a Malaysian-Indonesian species that may have its northernmost limit in southern Thailand. Since Scanlon et al. (1968), specimens of *palmatus* have been found that were collected on a mountain adjacent to Cambodia in southeastern Thailand. These specimens definitely show that *palmatus* is not confined strictly to the Malaysian-Indonesian region; however, they do not lend support to the northern Thailand records. As already shown in the *barbirostris*, *hyrcanus* and *umbrosus* groups, several Malaysian-Indonesian species previously presumed to have their northernmost distribution in southern peninsular Thailand are now known to also occur in southeastern Thailand. This disjunct distribution is apparently due in part to current precipitation patterns and the distribution of tropical wet forests. Since *palmatus* was collected in Ranong Province adjacent to Burma, it also probably occurs in tropical wet forests habitats in the southern part of that country. Reid (1965, 1968) indicated that the distribution of this species was probably associated with foothill and mountainous regions. This suggestion is supported by the Thailand collections which were made between 140 - 1,300 m elevation, usually in mountainous areas.

TAXONOMIC DISCUSSION. The larva of *palmatus* is unique in the subgenus *Anopheles* of Southeast Asia in having the abdominal anterior tergal plates very large. It is also one of 2 species in the *aitkenii* group that exhibits a color pattern on the abdomen of the larva and adult. Larvae of *palmatus* are dark brown except for a pale yellow abdominal segment IV, and should not be confused with *aberrans* larvae which usually have abdominal segments IV and V pale yellow. The adults of *palmatus* have previously been considered indistinct, however, of the one male and 4 females in the USNM only one female has the abdominal segments unicolorous while the remainder have abdominal segment IV distinctly pale yellow in comparison with the remaining brown segments. This color pattern is very similar to that found on most *aberrans* adults, which have abdominal segments IV and V pale yellow.

The male genitalia of *palmatus* were 1st described (not illustrated) by Gater (1935) from 2 males sent to him from Thailand (locality unknown). The association of this description with *palmatus* has previously been presumed correct, but could not be confirmed for lack of males. We now have a male genitalia preparation of *palmatus* (USNM) from a specimen with an associated pupal skin. This preparation confirms that Gater was describing *palmatus*, in fact, his description is very accurate and agrees with our specimen in nearly all respects. The claspette of *palmatus* looks very similar to those of *bengalensis*, *tigertti* and some of *aberrans*, except that the ventral lobe of *palmatus* has 4 large setae, instead of the 3 large and one small setae usually found on the other species. The very long aedeagus on *palmatus* males is distinct and unusual for the group, and is somewhat suggestive of that described for

pinjaurensis from northwestern India (Christophers 1933: 110).

The pupa of *palmatus* has several very distinct characters which make it easy to identify. Setae 9 are unlike those of any other member of the *aitkenii* group in having the tips bluntly rounded. Most members of the group have long extremely attenuate tips on pupal seta 9. Three species, *insulaeflorum*, *pilinotum* and *stricklandi*, have pupal seta 9 short, or moderately long as on *palmatus*, but these 3 species have the tips of seta 9 sharp pointed. The shape of the paddle on the pupa of *palmatus* is also distinct. This structure is twice as long as wide (not including fringe hairs) on *palmatus*, while on the other members of the group the width is nearly 0.67 the length. The length and refractiveness of the fringe hairs on the pupal paddle of *palmatus* are also unusual and may be of assistance in identifying this species.

The larval setal arrangement and development of 2-C and 3-C on *palmatus* suggests a relationship with *insulaeflorum*, *pilinotum* and *stricklandi*. It also implies that 6-III should have few branches, but this is not the case. Reid (1965) pointed out that Rodenwaldt's original illustration of *palmatus* showed 6-III with only 3 branches. However, this is almost certainly an error on the part of Rodenwaldt, for Reid (1965) noted 21 - 26 branches on 6-III, and we found 18 - 27 branches on 6-III. The development of seta 11-II also separates *palmatus* from the above 3 species. Seta 11-II on *palmatus* is either bifid or trifid, while those on *insulaeflorum*, *pilinotum* and *stricklandi* are simple. The affinities of *palmatus* to the other members of the *aitkenii* group is currently obscure and will probably remain thus until more extensive collections of this group have been made.

BIOLOGY. All collections of this species have been immature collections, thus, nothing is known of adult behavior. The immature stages have been collected in Thailand in moderate to heavily shaded stream pools and stream margins in primary and secondary wet forests between 140 - 1,300 m elevation. The water in these sites was clear, moving slowly and usually contained dead leaves, sticks or roots. Larvae of *palmatus* have been collected in Thailand in association with larvae of *aberrans* and *bengalensis*.

ANOPHELES CULICIFORMIS SPECIES GROUP
(*A. culiciformis* species group, Reid and Knight 1961)

Anopheles culiciformis Cogill 1903.

The adults of this group are unicolorous and similar to those of the *aitkenii* group. At least one species is known to have a culicine resting posture. Generally the adults are slightly larger than those of the *aitkenii* group. The females are indistinguishable, (except *sintoni*) and the taxonomy of the group has been almost entirely dependent upon male genitalia and larval characters. This species group was formed by Reid and Knight (1961) and the most recent review with a key to the larvae of all species is found in Reid (1968).

ADULT. Small, unicolorous brown; interocular space narrow; flagellomere 1 with dark scales; erect vertex scales broad and fan-like at apex; female palpus slightly shorter than proboscis, most distal segments slightly bushy; anterior pronotal lobes without scales; aedeagus with hair-like spicules or leaflets on distal 0.33; claspette with 3 lobes; all setae on claspette separate; 2 parabasal spines on basimere arising on very prominent tubercle; ventromesal spine inserted approximately 0.67 of distance from base to apex of basimere.

PUPA. Trumpet with shallow rounded meatal cleft, meatus 0.50 - 0.67 as long as trumpet; seta 5, on IV - VII very long, at least as long as segment; 1-P straight or filiform with a curved hooked tip.

LARVA. Setae 2-C simple, with bases very close together; 4-C simple or branched distally; 5, 6, 7-C short and reduced with few branches, not plumose; 1-A short and simple or with 2 - 5 distal branches; 11-C shorter than antenna with distal branches, or if as long as antenna then plumose from base; 6-VI usually approximately equal length of 6-III; stigmal knob on the median dorsal valve of spiracular apparatus as darkly pigmented as remainder of valve.

DISTRIBUTION. This group is confined to the Oriental faunal region, with species recorded from the west coast of India, east to Hainan Island in southern China and south into Peninsular Malaysia. The distributions of some of the species in this group approach the ranges of *barianensis* James in northwestern India, and *omorii* in Japan. The 2 latter named species are members of the Nearctic-Palearctic *plumbeus* group which resembles the *culiciformis* group in several ways. Of the 5 species known in the *culiciformis* group only 2, i.e., *kyondawensis* and *sintonoides* are known from Thailand, and they are rarely encountered.

TAXONOMIC DISCUSSION. Reid and Knight (1961) recognized 5 species in this group, they are: *alongensis* Venhuis, *culiciformis*, *kyondawensis*, *sintoni* Puri and *sintonoides*. Taxonomically, little is known about these 5 species. The females are usually not distinguishable and pupae have been described for only 3 of the species. Thus, male genitalia and larval characters are the basis for the present group arrangement of these species. Our lack of knowledge of these species is due to 3 basic factors: (1) these are all infrequently encountered forest species; (2) the immatures are found in cryptic habitats which are not normally collected during routine anopheline surveys; and (3) the included species are not known or even suspected of being involved in the transmission of human pathogens.

Reid (1968) suggested this group has affinities somewhat intermediate between the Nearctic-Palearctic *plumbeus* group and the Southeast Asian *aitkenii* group. Adults of the *culiciformis* group are: unicolorous as are most of the species in the other 2 groups; have wider vertex scales than the other 2 groups; have dark scales on the base of the antennal flagellomere 1 like members of the *plumbeus* group; and have few propleural, sternopleural and upper mesepimeral setae like members of the *aitkenii* group. The male genitalia of the *culiciformis* group have separate claspette setae and the ventromesal spine on the basimere more like species in the *plumbeus* group, yet, the aedeagus on species of the *culiciformis* group is distinct from the other 2 groups because it possesses hair-like spicules or leaflets. The pupae of the *culiciformis* group have the trumpet with a long meatus like members of the *plumbeus* group, but the development and length of seta 5 on the abdominal segments and the paddle fringe is more like species in the *aitkenii* group. The larvae of the *culiciformis* group have reduced setae 5, 6, 7-C, a reduced seta 11-C (except *alongensis* and *kyondawensis*) and a long seta 6 on IV - VI, like the species in the *plumbeus* group. The larval habitats utilized by 3 species in the *culiciformis* group are primarily tree hole-plant container habitats like those used by the *plumbeus* group. However, 2 species in the *culiciformis* group have cryptic larval habitats such as rock holes and crab holes, and a 3rd member has been collected in ground pools. These latter habitats are more like those utilized by members of the *aitkenii* group.

Since 3 species in this group are not known from Thailand, they will be

briefly discussed.

Anopheles alongensis is known only from the type-locality, Along Bay adjacent to Haiphong, North Vietnam. Specimens were reared and described in detail (as *tonkinensis*) by Galliard and Ngu (1946). Collections came from freshwater rock holes in a limestone cave. The male genitalia are distinct due to the presence of leaflets on the aedeagus and the larvae have: setae 2-C widely separated; 11-C plumose and as long as the antenna; and 6-VI very short. The pupa (Reid 1968) is similar to that of *sintonoides*, but seta 5 on V - VII is simple or branched distally. Based strictly on larval characters this species would appear to be more closely related to *kyondawensis*, but can be separated from that species by the widely separated bases of setae 2-C and the short seta 6-VI. The larval habitat of *alongensis*, i.e., rock holes in a dark cave, has a basic similarity to the shaded crab hole habitat utilized by *kyondawensis* (see *kyondawensis* for further discussion). The type-larva for *alongensis* was last reported in the Geneeskundig Laboratorium, Djakarta, Indonesia, and the types of the synonym, *tonkinensis*, were reported as in the Ecole Medicale, Hanoi, North Vietnam (Stone et al. 1959). Grothaus et al. (1971) reported larvae of this species collected in the Cam Lo area of northern South Vietnam, but this report needs confirmation.

Anopheles culiciformis was described by Cogill from adults reared from larvae collected in ground pools and one large collection from a tree hole. Apparently, all subsequent collections have been from tree holes. This species is known only from the west coast of India. Christophers (1933) described and illustrated the most pertinent characters. The male is distinct on the basis of long curved leaflets on the aedeagus. The pupa is distinct by having seta 5 on V - VII nearly twice the length of the segments. The larva has: very reduced-few branched setae 5, 6, 7-C, seta 11-C shorter than the antenna and expanded distally with numerous distal branches, no spiny-stellate setae and seta 6-VI with short lateral branches (Puri 1931). This is a forest species with the immature stages normally found in tree holes. According to Christophers (1933) there are no records of this species collected in houses or biting man. The type-specimens of this species are deposited in the BMNH.

Anopheles sintoni is known only from the west coast of India, where immatures are found in tree holes also containing *culiciformis*. This species is distinct on the basis of male genitalia and larval characters (Christophers 1933). The pupa has not been described. The male genitalia of *sintoni* have a claspette very similar to that of *culiciformis*, but lack the long leaflets on the aedeagus, replacing them with dense brush like hairs. The larva of *sintoni* has: short setae 5, 6, 7-C with more numerous branches; seta 11-C without the distal portion being expanded and with fewer distal branches than found on *culiciformis*; seta 14-P with spiny-stellate branches; and seta 6-VI with long lateral branches (Puri 1931). Christophers (1933) describes the adult of *sintoni* as having a few small scales on the median portion of the scutum, which can be used to differentiate the females of this species from *culiciformis*. Nothing is known about the adult behavior and biology. The type-specimens of this species are deposited in the BMNH.

BIOLOGY. The species in this group oviposit in 2 basic type habitats. Three species, *culiciformis*, *sintoni* and *sintonoides* primarily utilize treenole and other plant containers for oviposition. However, at least *culiciformis* can also survive in ground pools. The other 2 species, *alongensis* and *kyondawensis* utilize cryptic ground water habitats. Larvae of *alongensis* are known only from rock holes in a dark cave, while a single larva of *kyondawensis* has been found in a fresh water crab hole in Thailand. The original collections of

kyondawensis, much like those of *culiciformis* were taken from pools of clear water beside streams. Since *kyondawensis* larvae have been collected only twice, and in 2 different habitats, the basic larval habitat of *kyondawensis* is still uncertain.

There are no published records of females of this group biting man and only a single female of *sintonoides* is noted here as collected biting man. Accordingly, the species in this complex are presumed to be of no significance in the transmission of human pathogens.

KEYS. The keys to the 2 species of this complex found in Thailand have been incorporated into the keys to the species in the *Anopheles* series on pages 145-7.

ANOPHELES (ANOPHELES) KYONDAWENSIS ABRAHAM
(Figures 93, 95)

Anopheles (Anopheles) kyondawensis Abraham 1947: 173 (L*); Reid and Knight 1961: 482; Reid 1968: 221; Khin-Maung-Kyi 1971a: 288 (distribution); Rattanarithikul and Harrison 1973: 4 (L*).

This is a very poorly known species, described only from the larval stage. It can be differentiated from all other Southeast Asian anopheline larvae by the strongly curved antennae and reduced setae 5, 6, 7-C.

FEMALE. Unknown.

MALE. Unknown.

PUPA. Unknown.

LARVA (Fig. 93). Unicolorous pale yellow. *Head.* Antenna cylindrical and strongly curved inward, diameter approximately equal from base to apex, with spicules, particularly on dorsomesal aspect; seta 1-A very short, inserted on basal 0.17 of antenna, with 3 - 5 branches from midway along stem; 4-A with 5 - 10 branches, slightly longer than 2 and 3-A; maxillary palpus seta 8-MP well developed, with large central stem and many lateral and distal branches; 1-C long with fine attenuate tip; 2-C very long and simple, with attenuated tip; bases of setae 2-C adjacent, much closer together than setae 2 and 3-C on one side; 3-C short and simple, approximately 0.2 as long as 2-C; setae 4-C simple, fine and approximately as long as 3-C, with alveoli further apart than alveoli of 3-C; frontal setae very short, 5-C with 2 - 6 branches, 6-C with 3 - 6 branches and 7-C with 4 - 6 branches; 8-C short and simple; 9-C short and simple; 11-C nearly as long as antenna and plumose, with numerous lateral and distal branches. *Thorax.* Integument glabrous; seta 1-P with 5 - 8 branches from basal half of stem; 2-P arising from small sclerotized tubercle, with 8 - 13 branches and approximately 5 times as long as 1-P; 3-P simple, about as long as 1-P, closer to 2-P than distance between 1-P and 2-P; 0-P slender and bifid, posterior to 4-P; 4-P with stout central stem, numerous lateral and distal branches and shorter than 2-P; prothoracic pleural tubercle with short spine; 11-P short, fine and simple; long pleural setae 9, 10, 12 simple on all 3 thoracic segments (except 12-T); 13-P with 5 - 6 branches; 14-P with 4 - 6 branches; 1-M with 42 - 44 branches; 4-M caudal of long simple 3 and 5-M, short and with 3 - 4 branches; 3-T with slender, unpigmented flattened leaflets, without filaments; 12-T short and bifid distally; 13-T very long, simple and slightly flattened. *Abdomen.* Integument glabrous, anterior tergal plates small, less than 0.25 as wide as segment; small posterior tergal plates present on segments IV - VII; seta 0, on II - VIII short and simple; 1-I minute

and simple; 1-II with slender, unpigmented flattened leaflets, without filaments; seta 1, on III - VII (palmate) with pigmented flattened leaflets, with filaments; seta 2, on IV - VI long, simple and flattened; 3, on I - VI long and flattened, usually simple, bifid or trifid distally; 4, on VI - VII long, simple and flattened; 5-II small with 3 - 4 branches; 5, on VI - VII larger with 8 - 9 branches; 6-III as long as plumose 6, on I - II, flattened with 8 - 9 very short branches mostly on basal half; 6, on IV - VI simple, round not flattened, as long as 6-III; 6-VII very small with 2 - 3 branches; 10, on I and V - VI long simple and flattened; 11-II long simple and flattened; 12, on II and VI - VII long simple and flattened; 13, on I - IV and VI small with 4 or more branches on I - IV and VI, long simple and flattened on V and VII; stigmal knob on median dorsal valve of spiracular apparatus pigmented, as dark as remainder of valve; pecten plate with 16 - 17 subequal teeth, each with strong basal and lateral denticles; 1-X simple, slightly flattened, inserted at edge of saddle and as long as saddle.

TYPE-DATA. Abraham based his description on the examination of 11 larvae, of which 7 were in the 4th stage. These specimens were collected over a 10 day period (5 collections) in 1943, from a small village named Kyondaw (now Kyondo), near Moulmein in southern Burma. The village of Kyondaw is situated on the bank of a river of the same name, apparently a smaller tributary of the Gyaing River. The holotype larva is in the BMNH, and the slide bears the following data: "Department of Biology, King Edw. VII College of Medicine, Singapore, Type *Anopheles kyondawensis* Abraham, Lower Burma, 2-12-1943, Det. O. K. Abraham." Paratypes are reported to be deposited in the mosquito collections of the College of Medicine, Singapore.

DISTRIBUTION (Fig. 95). This species is known only from the type-locality in Burma and a single larva collected in Nan Province, Thailand. The larva from Thailand is deposited in the USNM. The latter locality, i.e., Ban Pha Man, is situated at 425 m elevation near the Laos border and nearly 400 km from the type-locality. This suggests that *kyondawensis* is widely distributed on mainland Southeast Asia, but rarely encountered, probably due to low population levels and/or a cryptic immature habitat (also see Biology section).

TAXONOMIC DISCUSSION. Reid and Knight (1961) included this species in the *culiciformis* species group on the basis of the reduced setae 5, 6, 7-C and other setae on the larval head. Since *kyondawensis* is known only from the larval stage this status must be considered tentative; however, the larva of this species does bear a number of similarities with the larva of *alongensis*, another ground water species in this group. Larvae of both these species have seta 11-C approximately as long as the antenna, with many branches from near the base, while the other members of the group have this seta short and mainly with distal branches. Differences between the larvae of *alongensis* and *kyondawensis* were noted in the species group discussion.

The only other species of this group that occurs in Thailand, i.e., *sintonoides*, has larvae that are partially covered with spicules, have large stellate spiny setae on some segments and are found only in plant container and axil habitats. The curved antenna of *kyondawensis* larvae is unique among Southeast Asian *Anopheles*, and coupled with the short setae 5, 6, 7-C on the head and long setae 6 on IV - VI, this species should not be confused with any other species in Thailand.

The single larva from Thailand exhibits slightly fewer branches on 5, 6, 7-C than the holotype, otherwise, these 2 specimens agree very well.

BIOLOGY. Reid and Knight (1961), using *culiciformis* records from tree holes and ground pools as a precedent, suggested that although the original *kyondawensis* larvae were collected in ground pools, they have the appearance

of a tree hole species and possibly the species normally occurs in tree holes. Unfortunately, there have been no other collections of *kyondawensis* in Burma (Khin-Maung-Kyi 1971a) to resolve this problem. During the last 12 years hundreds of tree hole and forest ground pool collections were made throughout Thailand without yielding a single specimen of *kyondawensis*. The single larva of this species found in Thailand was not collected until 1966, when intensive surveys of fresh water crab holes were being conducted in search of another cryptic species, *tigertti*. The crab hole with the single *kyondawensis* larva was located in a mountainous region under heavy shade in secondary wet forest, and also contained larvae of *Culex* (*Lophoceraomyia*) *bengalensis* Barraud and an undescribed species of *Uranotaenia*. It is not currently possible to define the larval requirements of *kyondawensis*. However, the collection of this species from a fresh water crab hole is highly suggestive and could explain the previous paucity of collections, because the crab hole habitat has been ignored in most countries in the Orient. The *kyondawensis* larvae collected by Abraham in Burma, came from small shallow shaded pools of clear water, along the sides of streams in hill forest, and were associated with larvae of *An. bengalensis* and *leucosphyrus* Dönitz. It seems possible that the *kyondawensis* larvae may have been swept out of crab holes into the ground pools by high water. This contention is supported by the presence of *balabacensis* (= *leucosphyrus* of early Burma workers, Khin-Maung-Kyi 1971b). Larvae of *balabacensis* normally occur in small temporary ground pools that follow flooding or rains.

ANOPHELES (ANOPHELES) SINTONOIDES HO
(Figures 94, 95, 96)

Anopheles (Anopheles) sintonoides Ho 1938a: 279 (♂*, ♀, P*, L*); Reid and Knight 1961: 492 (L); Reid 1963: 113 (L); Reid 1968: 223 (♂*, ♀*, P*, L*); Rattanarithikul and Harrison 1973: 4 (L*).

This is a brown unicolorous species in the adult stage, which can be confused very easily with members of the *aitkenii* group. The adults can be recognized by the broad vertex scales on the head and the absence of scales on the anterior pronotal lobe. The pupa has an unusual, simple type trumpet with a very short meatal cleft, a very long seta 5 on the abdominal segments and a hooked (*Cellia*-like) seta 1-P. The larva is easily recognized by the reduced setae 5, 6, 7-C on the head, the large spine-like stellate setae and the ventral and lateral parts of the thorax and abdomen covered with spicules.

FEMALE (Fig. 94). Unicolorous brown. *Head.* Palpus slender with 2 apical segments slightly swollen, with decumbent scales; palpus shorter than proboscis, ending just before labellum; proboscis shorter than forefemur; clypeus without scales; vertex with erect broad brown scales with truncate tips; interocular space very narrow, with short white scales and long dark brown frontal setae; pedicel without scales; flagellomere 1 with dark basal scales; antennal whorl setae very long, 4 - 5 times as long as flagellomeres. *Thorax.* Anterior promontory without scales; scutal integument light brown; scutum without scales, with mixed long and short brown setae in anterior promontory, acrostichal, dorsocentral, lateral prescutal, fossal, antealar, and supraalar groups; prescutellar area bare; scutellum with long and short dark brown setae, without scales; anterior pronotal lobe without scales, with long sparsely scattered setae; pleural area pale; pleural setae: 1 propleural, 3 - 8 spiracu-

lar, 1 - 3 prealar, 2 - 4 upper and 2 - 4 lower sternopleural and 2 - 5 upper and 0 lower mesepimeral. *Wing.* Unicolorous with narrow dark scales; humeral crossvein without scales; cell R_2 twice as long as cell M_2; cell M_2 usually less than half as long as stem (from crossvein). *Halter.* With dark scales on knob. *Legs.* Coxae without scales, upper midcoxa with 1 - 2 setae; legs slender, entirely dark scaled. *Abdomen.* Mottled gray-brown with long brown setae, without scales.

MALE (Fig. 94). Like female except antenna with more and longer whorl setae; palpus slightly shorter than proboscis, with 2 apical segments flattened and club-like. *Genitalia.* Basimere without scales, with 2 long parabasal spines arising from prominent tubercle, outermost spine longest; ventromesal spine on basimere long, arising about 0.66 distance from base; tergum IX without caudal processes; claspette apparently with 3 lobes and approximately 6 - 8 separate curved setae; larger setae on dorsal and middle lobes of claspette with stout bases and partially flattened; ventral lobe of claspette with smaller setae and spicules; aedeagus narrowing to truncate tip, with fine hair-like spicules on lateral aspect of distal 0.33.

PUPA (Fig. 95). Integument tan to light brown with trumpets more darkly pigmented; most setae long, slender and simple, or with fine distal branches. *Cephalothorax.* Seta 6-C equal or longer than 7-C; 10, 12-C very long, stout and usually with branches arising on distal half; 11-C very small and short, with distal branches. *Trumpet.* Simple, with shallow, widely rounded meatal cleft; meatus 0.50 - 0.67 as long as trumpet. *Abdomen.* Seta 0, on II - VII short and simple; seta 1 usually weakly developed on abdominal segments; 1-II with 5 - 12 branches, more strongly developed than 5-II; 1-III often more strongly developed than 5-III; 1, on IV - VII much weaker and shorter than seta 5, on IV - VII; 1-IV with 2 - 7 branches; 1-VI with 3 - 6 branches; 1-VII longer than other setae 1, 0.50 - 0.67 as long as 5-VII; 1-VII simple or with 2 - 6 branches; 3, on II - III stouter than setae 1, 5, on II - III; 4-VIII simple; 5-I approximately equal length of 2-I; 5-III may be weaker or stronger than 1-III; 5, on IV - VII with stout central stem, as long or longer than segment; 5-IV with 6 - 15 branches; 5-VII with 3 - 13 branches; 6-I much longer than segment I; 6-II with distal branches, approximately equal length of segment II; 6-VI nearly 2 times as long as 9-VI; 6-VII approximately 0.5 as long as 9-VII; 7-I with many distal branches, approximately 0.67 as long as 6-I; 7-VII simple, approximately 0.75 as long as segment VIII; 9, on IV - VII long, slender, tapering to sharp point, 0.33 - 0.50 as long as segments; 9-IX short spine-like; 10, on IV - V approximately 0.5 length of segments. *Paddle.* Elongate; refractile margin 0.33 - 0.50 length of paddle; fringe hairs on both margins of paddle, long and dense, 0.5 length of 1-P; outer margin of paddle evenly convex on distal half; 1-P very long and filiform with hooked tip, often bent in middle; 2-P variable, simple and stout to weak with 2 - 4 distal branches.

LARVA (Fig. 96). Head darkly pigmented; thorax and abdomen with mixed simple or compound spicules on ventral and lateral aspects. *Head.* Antenna wider at base than apex, slightly crooked with minute spicules on inner surface; 1-A simple or bifid, inserted on basal 0.25 - 0.33 of antenna; 2, 3-A with one edge serrate; 4-A simple or with 2 - 6 branches, twice as long as 2, 3-A; 2-C long, simple and slender, with bases touching or very close together, much closer together than bases of 2, 3-C on one side; 3-C short, stout and simple or split into 2 - 6 branches (often spike-like), 0.25 - 0.33 as long as 2-C; 4-C stout, simple or with 2 - 9 branches, very wide apart and twice as long as 3-C; setae 5, 6, 7-C with stout central stem, few branches and short; 5-C simple or with 2 - 7 branches, extending cephalad approximately to level

of 4-C aveoli; 7-C with 6 - 13 branches; 8, 9-C short, simple or bifid; 11-C shorter than antenna without branches at base, with numerous distal branches beginning nearer to base on inner side of seta; 8-MP on maxillary palpus with stout stem and branching beginning about midway along stem; some mouth brushes with short frays, not pectinate. *Thorax.* Seta 0-P short simple or with 2 - 3 branches; 1-P with 3 - 10 branches; 2-P with 7 - 22 branches, arising on large tubercle, as long as 4-P; 11-P short simple or with 2 - 4 fine distal branches; 13-P with 6 - 11 partially spiny stellate branches; 14-P with 9 - 20 thick spiny stellate branches; 4-M short with 3 - 6 branches; 6-M simple, stout, arising from pigmented tubercle and very long; 14-M with 5 - 9 spiny stellate branches; 3-T lightly pigmented, often with slightly flattened leaflets without filaments; usually one long pleural thoracic seta on pro-meso- and metathorax with short lateral branches. *Abdomen.* Anterior tergal plates small, less than 0.25 as wide as segment; small posterior tergal plates on II or III - VII; seta 0, on II - VIII small and simple; 1-I very small and simple; 1, on II - VII with flattened pigmented leaflets with filaments; 2-I very small and simple; 5-VIII with spiny stellate branches; 6-III with short lateral branches, as long as 6-II; 6, on IV - VI approximately 0.67 as long as 6-III, with 2 - 4 long branches; 6-VII very short with 3 or more branches; 9, on I - VI very large, with spiny stellate branches; 11-I large with spiny stellate branches; seta 13, on I - VI large with spiny stellate branches; dorsal setae not developed into spiny stellate setae; pecten plate with approximately 20 teeth with strong basal and lateral denticles; seta 2 on pecten plate with 2 - 4 distal branches; stigmal knob on median dorsal valve of spiracular apparatus as darkly pigmented as remainder of valve; 1-X with 2 - 4 distal branches, inserted near edge of saddle.

TYPE-DATA. The type-locality for *sintonoides* is Hainan Island, Kwangtung Province, China. A holotype ♂ and allotype ♀ are reported (Ho 1938a) to be deposited in the Fan Memorial Institute of Biology, Peking (Peiping), China. We were able to borrow a single topotypic ♀ from the original collections (specimen #99) from the BMNH. This ♀ appears identical to the Thailand specimens.

DISTRIBUTION (Fig. 95). This species is known from China, Malaysia (Peninsular), Thailand and South Vietnam (Reid 1968). Specimens (11♂, 16♀, 86 larvae and 35 larval and pupal skins) in the USNM were examined from the following provinces of THAILAND; Chanthaburi, Chumphon, Nakhon Nayok, Nakhon Ratchasima, Nakhon Si Thammarat, Narathiwat, Phangnga, Phatthalung, Phuket, Ranong, Songkhla, Trang and Yala. A single female in the BMNH was examined from CHINA (Hainan Island). Additional specimens from SOUTH VIETNAM were examined in the Institut Pasteur, Saigon. The distribution of *sintonoides* as depicted in Fig. 95 is probably a fairly accurate delineation of its distribution in Thailand. Numerous tree hole-bamboo collections have been made in the drier western and northern portions of Thailand, yet no specimens of *sintonoides* were collected. This species seems to be closely associated with tropical wet forest vegetation, which is primarily restricted to the southern-southeastern portions of Thailand. A considerable area of wet forest still occurs in Khao Yai National Park northeast of Bangkok, and this is the area (Nakhon Nayok and Nakhon Ratchasima) where the most northern collections of *sintonoides* were made. Vertically, *sintonoides* has been collected between 5 - 800 m elevation in Thailand. Collections in Hainan were listed as 600 m or more (Ho 1938a), and Reid (1968) lists the Malaysian specimens collected at about 305 m. Apparently, the elevation of the wet forest vegetation has little influence on the distribution of

sintonoides. However, since this is a forest species and much of the lowland wet forests in Thailand have been cut and cleared, it will probably be encountered more often in the rugged mountainous areas that still retain primary and secondary wet forest.

TAXONOMIC DISCUSSION. There are few *Anopheles* species in Thailand with which this species can be confused. The adults resemble members of the *aitkenii* group in being unicolorous, but *sintonoides* has broad erect scales on the vertex, while members of the *aitkenii* group have narrow erect scales on the vertex. The male genitalia of *sintonoides* are distinct on the basis of the fine hair-like spicules on the aedeagus and the separate claspette setae. Adults of *brevipalpis*, currently known only from Malaysia and Indonesia, may occur in Thailand, and could be confused with *sintonoides*. However, *brevipalpis* has scales on the anterior pronotum, while *sintonoides* only has setae on that structure.

We agree with the assignment (Reid and Knight 1961) of *sintonoides* to the *culiciformis* species group, for as noted by Ho (1938a), the larva and male genitalia of *sintonoides* are very similar to those of *sintoni*. Larvae of both species exhibit spiny stellate setae (only 14-P on *sintoni*), and both species have short hair-like spicules near the tip of the male aedeagus. The aedeagus of both *alongensis* and *culiciformis* have leaflets rather than spicules. Unfortunately, the pupa of *sintoni* is undescribed and cannot be compared with the pupa of *sintonoides*.

The pupa of *sintonoides* has several unusual characters for the subgenus *Anopheles* in Southeast Asia, and is easy to differentiate from the other pupae known from that area. The pupal trumpet on *sintonoides*, although simple, has the meatus unusually long and more like the trumpets found on Nearctic and Palearctic members of the *plumbeus* species group. Seta 1-P on *sintonoides* is long, simple and filiform, usually curved and with the apex hooked. This character is similar to 1-P structure seen on pupae of the subgenus *Cellia*. The unusually long seta 5 on IV - VII is also of value in distinguishing this species.

The larva of *sintonoides* is unique in Southeast Asia because of the spiny stellate setae and the thick covering of spicules on the ventral and lateral aspects. However, these characters and the thickness and number of branches on setae are variable. Reid (1968) pointed out several differences between the pupal and larval descriptions (Ho 1938a) of Hainan specimens and those found in Malaysia, South Vietnam and Thailand. Since we had more specimens to study, we found a wider range of variation on Thailand *sintonoides* than was found by Reid. Thus, some of the differences he noted are no longer significant, however, several of those differences remain. Hainan pupae are described and illustrated as having seta 5 on the abdomen as considerably longer than the segment, and seta 1-P straight. Thailand pupae have seta 5 equal to or only slightly longer than the segment, and seta 1-P curved, with the apex hooked. Hainan larvae were described and illustrated with seta 14-P having 16 - 20 branches and seta 2 on the abdomen stout and spinose. Thailand larvae have seta 14-P with 9 - 17 branches and seta 2 on the abdomen only slightly spinose. It should be pointed out that these observations, as were Reid's, are based on Ho's description, and that specimens from Hainan were not available for study. Reid (1968) considered these differences as probably due to geographical variation in *sintonoides*, rather than distinctive characters for 2 taxa, and we are in total agreement. As pointed out by Iyengar (1930), Rosen and Rozeboom (1954) and Colless (1956), larvae that occur in tree hole habitats can exhibit a tremendous range of environmentally induced

setal variation. Consequently, the differences between the Hainan and the Malay-South Vietnam-Thai specimens are not exceptional. Setae on Thailand larvae were very variable between localities and even the type of container had some effect on the thickness and branching of setae. Particularly variable were setae 3, 4-C which were stout and spine-like on some larvae, or fine and simple or with fine distal branches on other larvae. Several larvae collected in a banana stump were noticeably different from those found in tree hole or bamboo habitats. Those from the banana container had the spiny stellate setae more slender and less stout, while the other setae were slender and simple or with fine distal branches. These larvae also had fewer spicules covering the ventral and lateral aspects and those present were primarily single rather than multiple spicules.

Two anomalies were noted on the immatures. The 1st was a larva with several short frays on seta 2-C. The 2nd was a pupa with seta 2-P as long and as stout as a normal seta 1-P. Further, all the larvae that we examined had seta 11-I spiny and stellate [seta 10-I as listed by Reid (1968)].

BIOLOGY. When this species was first collected in Thailand it was considered relatively rare, but extensive treehole-natural container collections now reveal it is fairly common in the southern half of Thailand. As was noted with the 2 other natural container breeding *Anopheles* in Thailand, i.e., *asiaticus* and *interruptus*, a single natural container rarely contained more than 6 larvae, and 1 - 3 was the normal number per collection. These low numbers per container probably represent an intrinsic survival mechanism that results in a wider dissemination of eggs by a more complete utilization of the available oviposition sites by the females. Reid (1968) suggested the frayed mouth brushes may indicate that larvae of *sintonoides* are sometimes predaceous. This behavior trait would also reduce the number of specimens collected per container. Immatures have been collected in the following habitats in Thailand: large and small tree holes, holes in stumps, holes between tree roots, a banana stump, pandanus axils, bamboo stumps, bamboo internodes and split bamboos. These sites ranged from ground level to 2 m above the ground in partially to heavily shaded primary and secondary wet forest, primary and secondary bamboo groves, a mangrove thicket and a rubber plantation. As already noted these sites ranged from 5 m (mangrove) to 800 m (banana stump) elevation. Except for one female, all of the adults we examined were reared from immatures. The single female was collected in 1962 between 1900 - 2000 hours, biting man in Nakhon Si Thammarat Province. Extensive human biting collections were made within the vicinity of tree holes from which *sintonoides* larvae were collected, but these failed to yield other adult *sintonoides*. This species is almost certainly not involved in the transmission of human pathogens.

APPENDIX A:

KEY TO THE FEMALE *ANOPHELES* MOSQUITOES OF THAILAND - AN AID FOR RAPID IDENTIFICATION IN MALARIA FIELD RESEARCH*

1. Wings with contrasting pale and dark scales. 2
Wings uniformly dark, without pale scales. 51

2(1) Leading margin of wing with at least 4 separate dark areas involving both veins C and R - R_1. . . . . (Subgenus *Cellia*) 3
Leading margin of wing with less than 4 separate dark areas involving veins C and R - R_1. . . . . (Subgenus *Anopheles*). . . .27

3(2). Hindtarsomeres 3, 4 and 5 entirely white. 9
Hindtarsomeres 3, 4 and 5 not entirely white. 4

4(3). Hindtarsomere 5 entirely white 14
Hindtarsomere 5 not entirely white. 5

5(4). Tibio-tarsal joint of hindleg with large white band. 15
Tibio-tarsal joint of hindleg without large white band. 6

6(5). Apical half of proboscis with pale scales. 19
Apical half of proboscis dark. 7

7(6). Femur, tibia and tarsomere 1 speckled with pale scale patches. . 21
Femur, tibia and tarsomere 1 without pale scale patches. 8

8(7). Foretarsi with broad pale bands crossing joints; mid- and hindtarsi with pale bands slightly wider than diameter of tarsomeres. . . 22
Tarsi with only narrow apical pale bands, or entirely dark. . . . 24

9(3). Palpal segments 2 and 3 with pale spots, subapical pale band broad, approximately equal to apical band. . . . . *splendidus*
Palpal segments 2 and 3 without spots, subapical pale band narrow, approximately half the length or less of the apical band. 10

10(9). Femur, tibia and tarsomere 1 speckled with patches of pale scales. 11
Femur, tibia and tarsomere 1 without patches of pale scales. . . 12

11(10). Abdominal terga VI and VII with golden scales; vein Cu without dark scale patch at origin of vein Cu_1. . . . . *jamesii*
Abdominal terga without golden scales; vein Cu with dark scale patch at origin of vein Cu_1. . . . . *ramsayi*

12(10). Vein Cu and Cu_2 mostly dark scaled, with area of dark scales at origin of Cu_1. . . . . *annularis*
Vein Cu and Cu_2 mostly pale scaled, without dark scales at origin of vein Cu_1. 13

*Includes subgenus *Cellia*.

13(12). Wing with presector dark mark on vein R usually reaching or overlapping distal end of humeral dark mark on costa, on both wings. *nivipes**
Wing with presector dark mark on vein R not usually reaching back to distal end of humeral dark mark on costa, or only reaching that mark on one wing only. . . . . *philippinensis**

14(4). Femur, tibia and tarsomere 1 speckled with patches of pale scales; palpi usually with 3 pale bands. . . . . *maculatus*
Femur, tibia and tarsomere 1 without patches of pale scales; palpi usually with 4 pale bands. . . . . *karwari*

15(5). Basal dark mark on wing vein R with one or more pale interruptions on at least one wing. 16
Basal dark mark on wing vein R without pale interruptions. 17

16(15). Hindtarsomere 4 with distinct basal pale band. *balabacensis balabacensis*
Hindtarsomere 4 without basal pale band. . . *balabacensis introlatus*

17(15). Palpi noticeably shorter than proboscis; proboscis with narrow pale band at apex proximal to labella. 18
Palpi not noticeably shorter than proboscis; proboscis without pale band. . . . . *riparis macarthuri*

18(17). Palpi with very narrow pale bands, apical segment merely tipped with white scales. . . . . *hackeri*
Palpi with broader pale bands, apical pale band approximately as broad as preapical dark band. . . . . *pujutensis*

19(6). Femur, tibia and tarsomere 1 dark scaled, without speckled pale scale patches. . . . . *aconitus*
Femur, tibia and tarsomere 1 speckled with pale scale patches. . . 20

20(19). Abdominal sterna with median tufts of dark scales; hindtarsomeres with broad pale bands. . . . . *kochi*
Abdominal sterna without scale tufts; hindtarsomeres with narrow pale bands. . . . . *tessellatus*

21(7). Palpi with only one broad apical pale band; palpal segment 2 without dorsal pale spots. . . . . *sundiacus*
Palpi with 2 broad apical pale bands; palpal segment 2 with dorsal pale spot. . . . . *stephensi*

22(8). Palpi with apical pale band 3 - 4 times the length of preapical dark band. . . . . *vagus*
Palpi with apical pale band 2. 5 times or less the length of preapical dark band. 23

*Adults of these 2 species often not separable without associated immature skins.

23(22). Palpi with subapical pale band usually 0.33 or less as long as preapical dark band, which is 0.5 or more as long as apical pale band. . . . . *subpictus*
Palpi with subapical pale band usually 0.5 or more as long as preapical dark band, which is often less than 0.5 as long as apical pale band. *indefinitus*

24(8). Scutum with scattered short white scales; vein R_1 with small white spot between subcostal and preapical pale spots, at least on one wing. . . . . *jeyporiensis*
Scutum with scales only on cephalic end; R_1 without pale spot between subcostal and preapical pale spots. 25

25(24). Base of vein R just distal to remigium, with white or yellow-white scales. . . . . *minimus*
Base of vein R just distal to remigium, with patch of gray or black scales. 26

26(25). Vein R_{4+5} dark scaled except for small pale spots at base and apex; palpi with preapical dark band much longer than apical pale band. *culicifacies*
Vein R_{4+5} mostly pale scaled, with small dark spots near base and apex; palpi with preapical dark band and apical pale band approximately equal length. . . . . *pampanai*

27(2). Hindleg with femur or tarsomeres 1 and 2 with outstanding tufts of erect black and white scales. 28
Hindlegs without conspicuous tufts of erect scales. 30

28(27). Legs with clusters of erect dark scales on tarsomere 2 of midleg and tarsomeres 1 and 2 of hindleg. . . . . *bulkleyi*
Legs with tufts of erect scales only on hindfemur. 29

29(28). Abdominal segment VIII with pale golden scales; wing without apical pale fringe spot at R_{4+5}; subcostal pale spot of costa extending onto vein R - R_1. . . . . *asiaticus*
Abdominal segment VIII without pale scales; wing with narrow apical pale fringe spot at R_{4+5}; subcostal pale spot when present, confined to costa and tip of subcosta. . . . . *interruptus*

30(27). Clypeus with patch of dark scales on each side; basal 4 - 8 antennal flagellomeres with pale scales. . . . . *hyrcanus* group. . . . 33
Clypeus without scales; 1st (basal) antennal flagellomere only with scales. 31

31(30). Abdominal sternum VII with tuft of black scales. *barbirostris* group 41
Abdominal sternum VII without scales. 32

32(31). Hindtarsomere 5 mostly dark scaled. . . *umbrosus* group 46
Hindtarsomere 5 all white. . . . *albotaeniatus* group . . . . *montanus*

33(30). Hindtarsomeres with broad pale bands, at least one tarsomere 4 with basal pale band or patch. 34
Hindtarsomeres with apical pale bands only. 37

34(33). Basal dark mark on vein Cu short, separated by its own length or more from upper dark mark on vein 1A; base of costa with scattered pale scales, frequently with small humeral pale spot; dark mark at origin of vein R_S well defined, scales between dark mark and fork mostly white; vein Cu_2 with pale fringe spot. . . . . *nitidus*
Basal dark mark on vein Cu long, approaching within own length or less of upper dark mark on vein 1A; base of costa dark scaled or with few scattered pale scales, no pale humeral spot; dark mark at origin of R_S poorly defined, scales between dark mark and fork mostly dark; vein Cu_2 with or without pale fringe spot. 35

35(34). Humeral crossvein with patch of dark scales; remigium mostly dark scaled; basal 0.33 and preapical dark mark on vein R - R_1 dark scaled, or with very few pale scales. 36
Humeral crossvein without scales; remigium mostly pale scaled; basal 0.33 and preapical dark mark on R - R_1 usually with many pale scales. . . . . *peditaeniatus*

36(35). Hindtarsomere 4 with broad dark band, at least 0.6 length of segment; hindtarsomere 5 without or with very narrow (0.25 or less of segment) pale basal band; base of costa usually with several scattered pale scales; apical dark mark on vein Cu_2 short, rarely as long as apical dark mark on 1A. . . . . *nigerrimus* (in part)
Hindtarsomere 4 with narrow dark band, 0.5 or less (lacking in rare cases) length of segment; hindtarsomere 5 with pale basal band on 0.6 or more of segment; base of costa without pale scales; apical dark mark on Cu_2 long, usually equal or longer than apical dark mark on 1A. . . . . *argyropus*

37(33). Wing apex with short pale fringe spot not extending posteriorly beyond vein R_3. 38
Wing apex with long pale fringe spot extending posteriorly at least to vein R_{4+5}. 39

38(37). Humeral crossvein with dark scales; remigium mostly pale scaled midcoxa with white scales; smallest member of the group in Thailand. . *pursati*
Humeral crossvein without scales; remigium mostly dark scaled; midcoxa without pale scales. . . . . *lesteri paraliae*

39(37). Vein Cu with long basal dark mark, at least twice as long as most basal pale mark (when present) on Cu, and approaching within its own length or less of upper dark mark on 1A; costa usually with several scattered pale scales on basal 0.33; remigium mostly dark scaled; humeral crossvein with dense patch of black scales. *nigerrimus* (in part)
Vein Cu with short basal dark mark, equal or less length of most basal pale mark on Cu, and usually separated by its own length or more from upper dark mark on 1A; basal 0.33 of costa usually entirely dark scaled; remigium mostly pale scaled; humeral crossvein bare or with few scales. 40

40(39). Wing pattern blurred; tip of vein R_1 dark scaled; apical wing fringe spot long, beginning at or above vein R_1; preapical dark mark on vein R_1 with some pale scales; vein Cu_2 usually with pale fringe spot. . . . . *sinensis*

Wing pattern sharp, dark marks short and well defined; tip of vein R_1 pale scaled; apical fringe spot shorter, beginning at R_2; preapical dark mark on vein R_1 without pale scales; vein Cu_2 without pale fringe spot. . . . . *crawfordi*

41(31). Apical fringe spot at wing vein R_{4+5} extending back to vein M_{1+2}; abdominal sterna without pale scales. . . . . *barbumbrosus*

Apical fringe spot at R_{4+5} narrow, not reaching back to vein M_{1+2}; sterna with at least a few median pale scales. 42

42(41). Wing apex with 2 narrow pale fringe spots, no pale fringe scales at R_2; midtarsomeres usually unbanded. 43

Wing apex with 3 narrow pale fringe spots, middle spot at R_2, or with only 2 pale fringe spots, but upper spot wide with pale scales down to include R_2; midtarsomeres usually with narrow apical pale bands. 44

43(42). Abdominal sterna with many white scales scattered between median white scale tufts and white scale row on each lateral margin. *campestris**

Abdominal sterna with fewer white scales, primarily concentrated in median tufts and lateral rows, few scattered in between. *barbirostris**

44(42). First foretarsal pale band short, 0.5 or less as long as foretarsomere 5 and rarely crossing joint onto tarsomere 2; median pale scales on abdominal sterna II - VI usually total 0 - 20; central to southern Thailand. . . . . *hodgkini*

First foretarsal pale band long, more than 0.5 as long as foretarsomere 5 and usually crossing joint onto tarsomere 2; median pale scales on sterna II - VI totaling more than 20; extreme southern Thailand. 45

45(44). First foretarsal pale band longer than foretarsomere 5, with 0.33 of band on base of tarsomere 2; 2nd foretarsal pale band also crossing joint, with 0.25 - 0.33 of band on base of tarsomere 3; costa may have some pale scales on preapical dark mark. . . . . *pollicaris*

First foretarsal pale band seldom longer than foretarsomere 5, with 0.25 or less of band on base of tarsomere 2; 2nd foretarsal pale band rarely crossing onto base of tarsomere 3; costa without pale scales on preapical dark mark. . . . . *donaldi*

*This character is not always reliable, and in the absence of other adult differentiating characters, these 2 species are identified best by rearing adults with associated immature skins.

46(32). Palpi with pale bands, apical segment usually entirely pale. *separatus*

Palpi entirely dark scales. 47

47(46). Base of hindtibia with pale band 1.5 - 4.0 times segment width; base of wing veins R and Cu usually with several scattered pale scales; accessory pale fringe spot often present at apex of wing vein R_2. *roperi*

Base of hindtibia dark scaled or with small pale spot; base of R and Cu with dark scales; wing without fringe spot at vein R_2. 48

48(47). Propleuron with 1 - 6 setae on each side. 49

Propleuron without setae, or with 1 small seta on one side only. . 50

49(48). Upper mesepimeron with 9 - 19 setae and few inconspicuous dark scales; tarsomeres all dark or with minute spots at joints. *baezai*

Upper mesepimeron with 1 - 6 setae and no associated scales; fore- and hindtarsomeres with small pale bands. . . . . *umbrosus*

50(48). Wing vein 1A with pale scales proximal to median dark mark, infrequently with 2 - 3 dark scales near base. . . . . *letifer*

Vein 1A with 5 or more dark scales at base, infrequently vein nearly all dark scaled. . . . . *whartoni*

51(1). Erect head scales long and narrow, only slightly expanded apically; flagellomeres without scales. 52

Erect head scales broad, widely expanded apically; flagellomere 1 with dark scales. . . . . *sintonoides*

52(51). Abdominal segments IV, or IV and V distinctly paler than other segments. 53

All abdominal segments unicolorous. 54

53(52). Abdominal segments IV and V pale. . . . . *aberrans* (in part)

Abdominal segment IV only pale. . . . . *palmatus* (in part)

54(52). Prescutellar space with short fine setae setae back to scutellum. *insulaeflorum*

Prescutellar space with distinct median bare area immediately cephalad to scutellum. . . . . *aberrans* (in part)
bengalensis
fragilis
palmatus (in part)
stricklandi
tigertti

APPENDIX B:

SOUTHEAST ASIAN SPECIES OF THE SUBGENUS *ANOPHELES* NOT KNOWN FROM THAILAND

	SPECIES	DISTRIBUTION
1.	*acaci* Baisas	Borneo, Philippines
2.	*ahomi* Chowdhury	India (Assam)
3.	*albotaeniatus* (Theobald)	Indonesia, Malaysia
4.	*alongensis* Venhuis	North Vietnam
5.	*annandalei* Prashad	India, Indonesia
6.	*balarensis* Mendoza	Philippines
7.	*bancrofti barbiventris* Brug	Indonesia
8.	*borneensis* McArthur	Borneo
9.	*brevipalpis* Roper	Indonesia, Malaysia
10.	*brevirostris* Reid	Malaysia
11.	*collessi* Reid	Malaysia
12.	*ejercitoi* Mendoza	Philippines
13.	*franciscoi* Reid	Philippines
14.	*gigas* Giles	Borneo, Burma, China, India, Indonesia, Malaysia, Philippines, South Vietnam, Sri Lanka, Taiwan,
15.	*hunteri* (Strickland)	Indonesia, Malaysia
16.	*kweiyangensis* Yao and Wu	China
17.	*lesteri lesteri* Baisas and Hu	China, Japan, Philippines, Ryukyu Islands, South Korea
18.	*lindesayi* Giles	China, India, Japan, Malaysia, Nepal, Pakistan, Philippines, Taiwan
19.	*manalangi* Mendoza	Philippines
20.	*noniae* Reid	Malaysia
21.	*ohamai* Ohama	Ryukyu Islands
22.	*pilinotum* Harrison and Scanlon	Indonesia, Philippines
23.	*pseudobarbirostris* Ludlow	Indonesia, New Guinea, Philippines
24.	*pseudosinensis* Baisas	Philippines
25.	*samarensis* Rozeboom	Philippines
26.	*saperoi* Bohart and Ingram	Ryukyu Islands
27.	*similissimus* Strickland and Chowdhury	Malaysia
28.	*sineroides* Yamada	China, Japan, South Korea
29.	*vanus* Walker	Borneo, Indonesia, Philippines
30.	*wellingtonianus* Alcock	Malaysia

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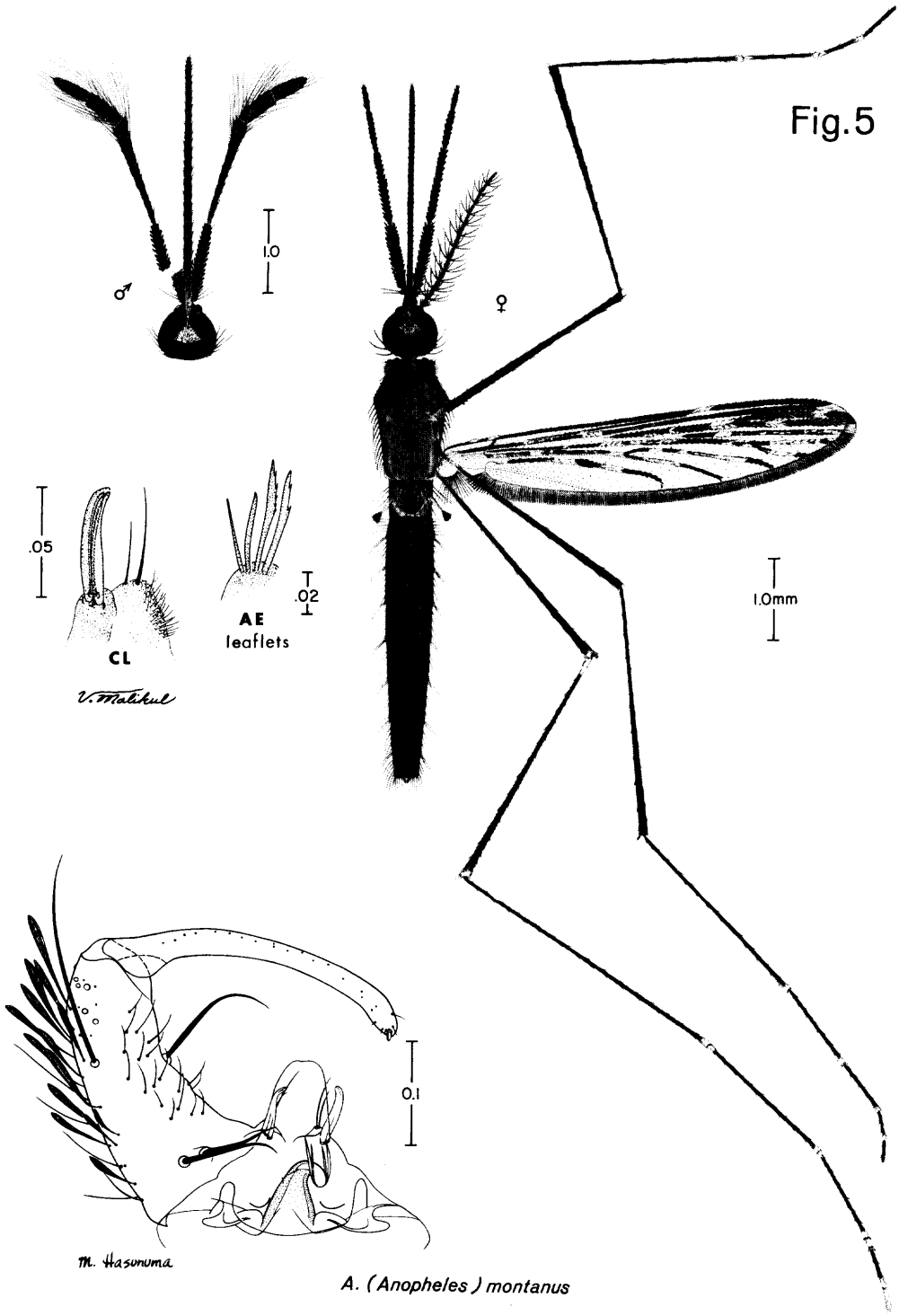
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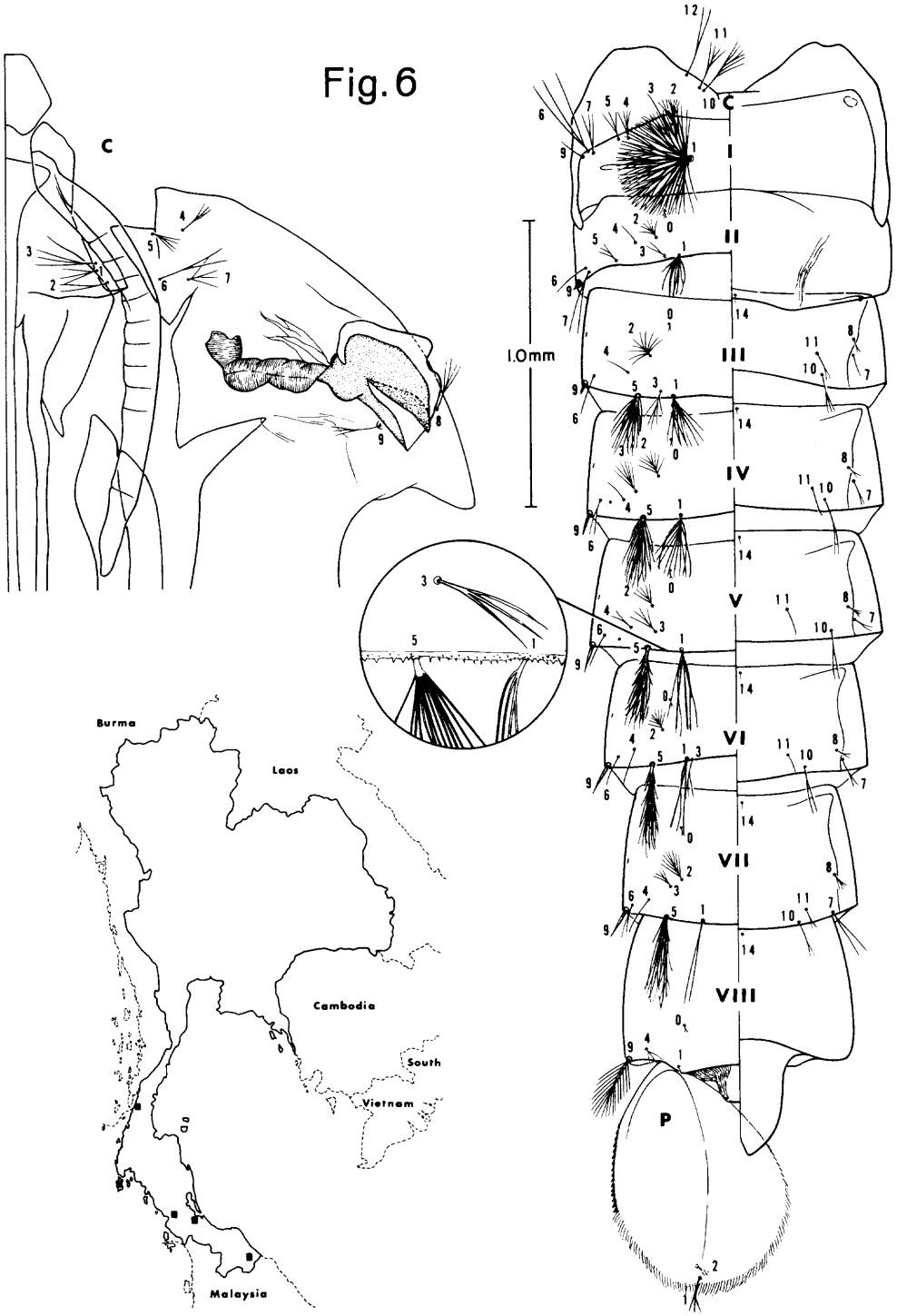
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1941. Geology, climate and faunal distribution in the Malay Archipelago. Proc. R. Entomol. Soc. Lond. (A) 16: 117-23.



A. (Anopheles) montanus

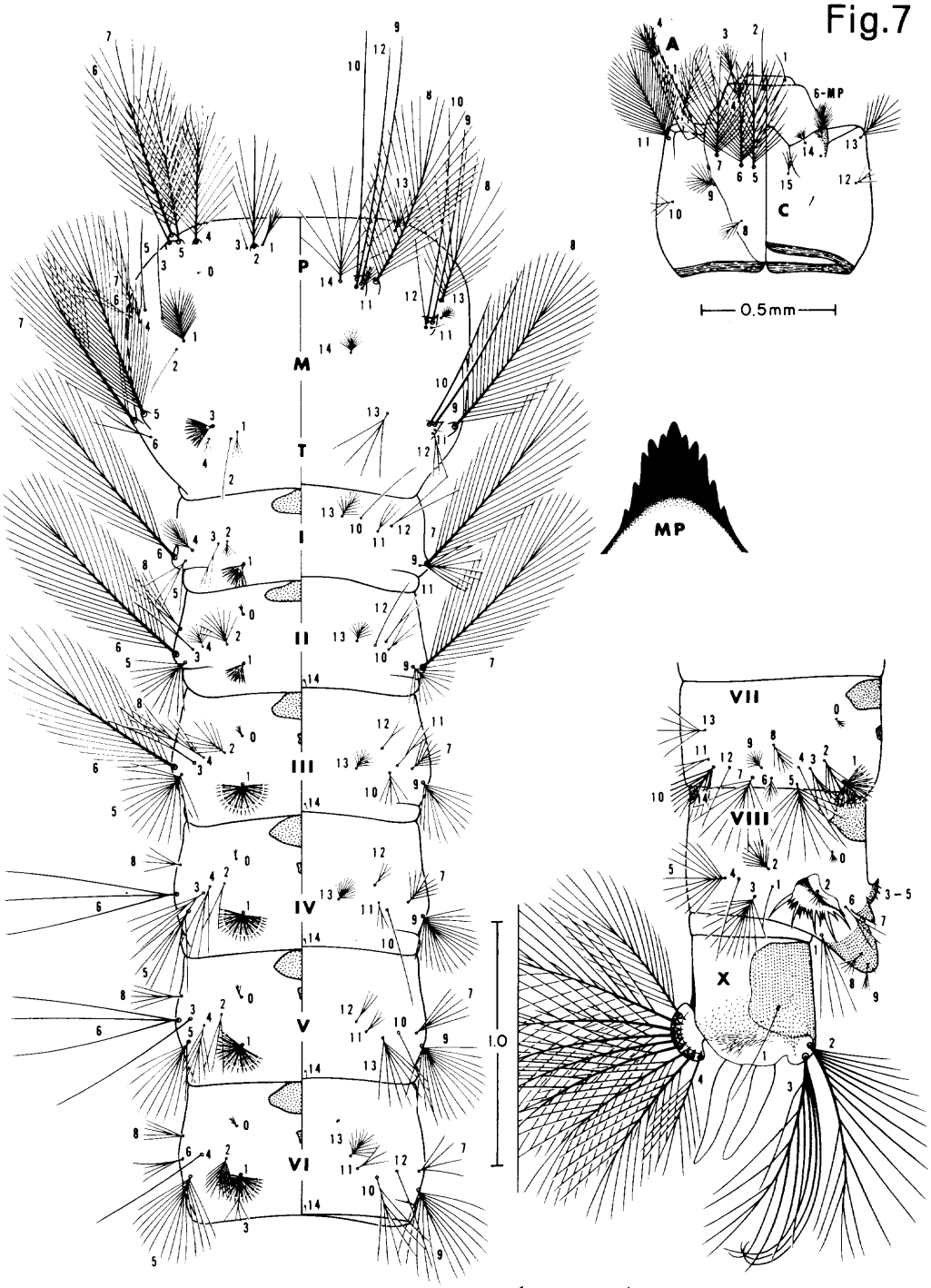
Fig. 6



A. (Anopheles) montanus

A. Hosokawa

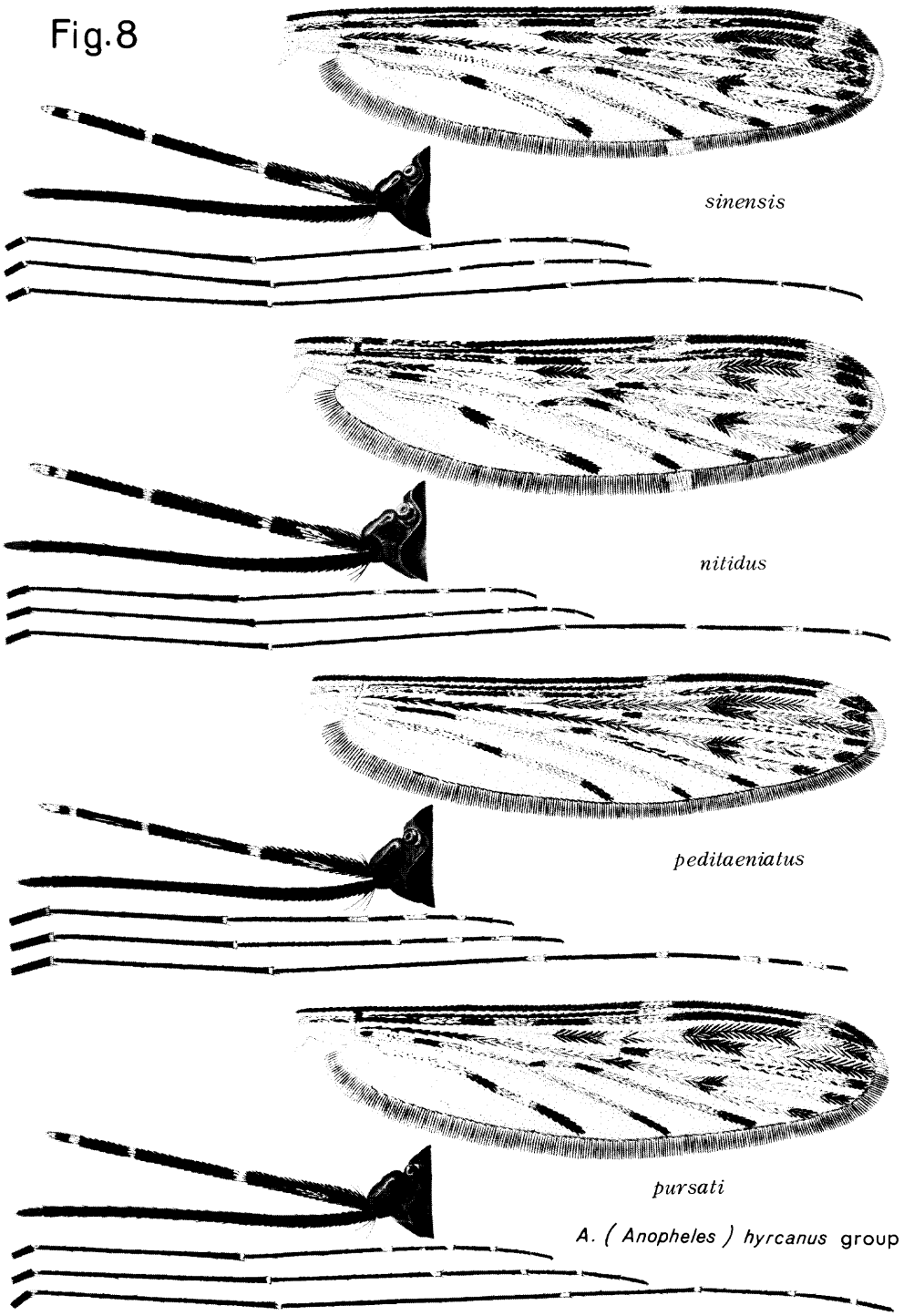
Fig.7



A. Hosokawa

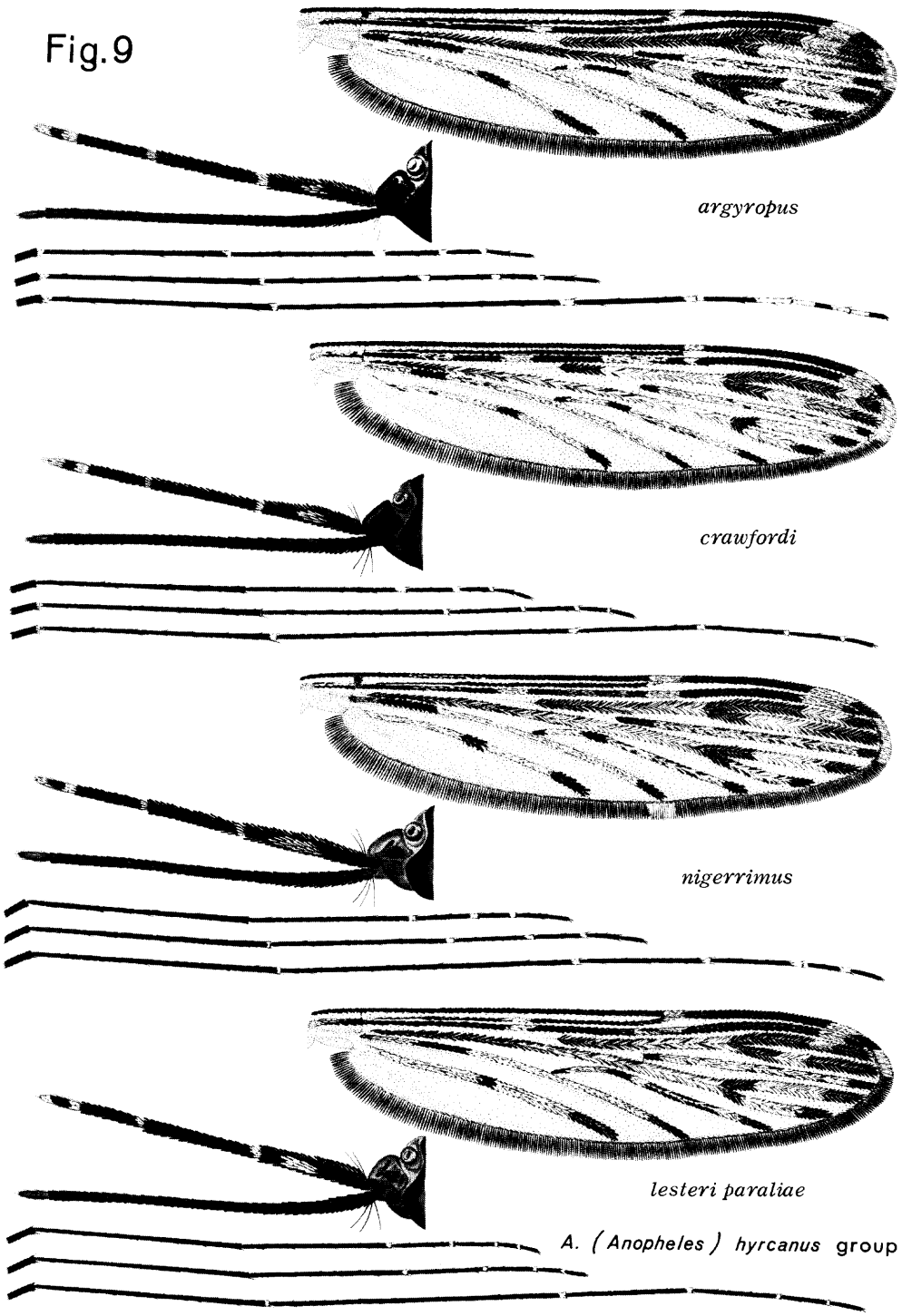
A. (Anopheles) montanus

Fig.8



A. (Anopheles) hyrcanus group

Fig.9



A. (Anopheles) hyrcanus group

Fig.10

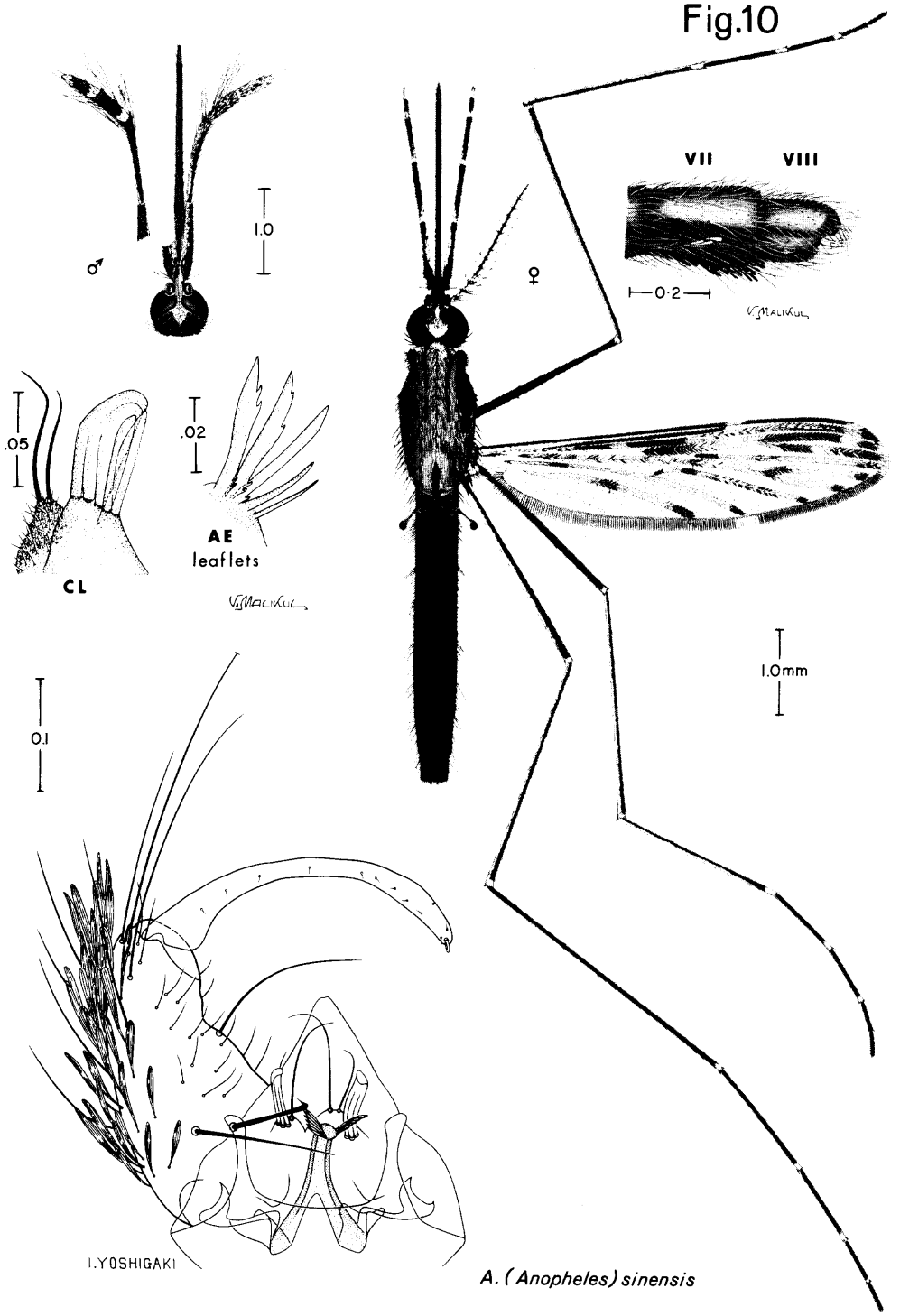
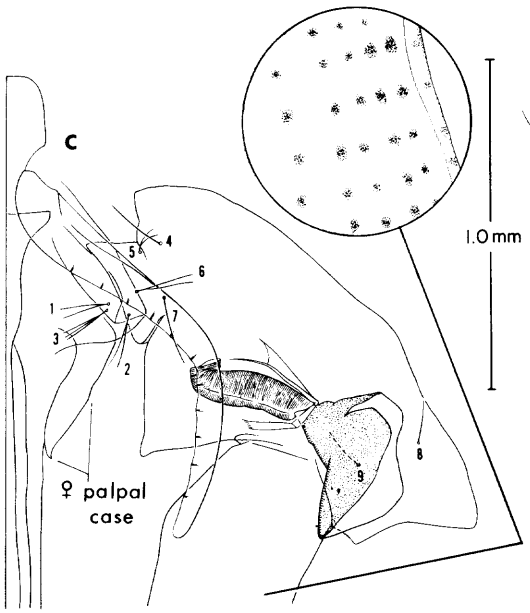
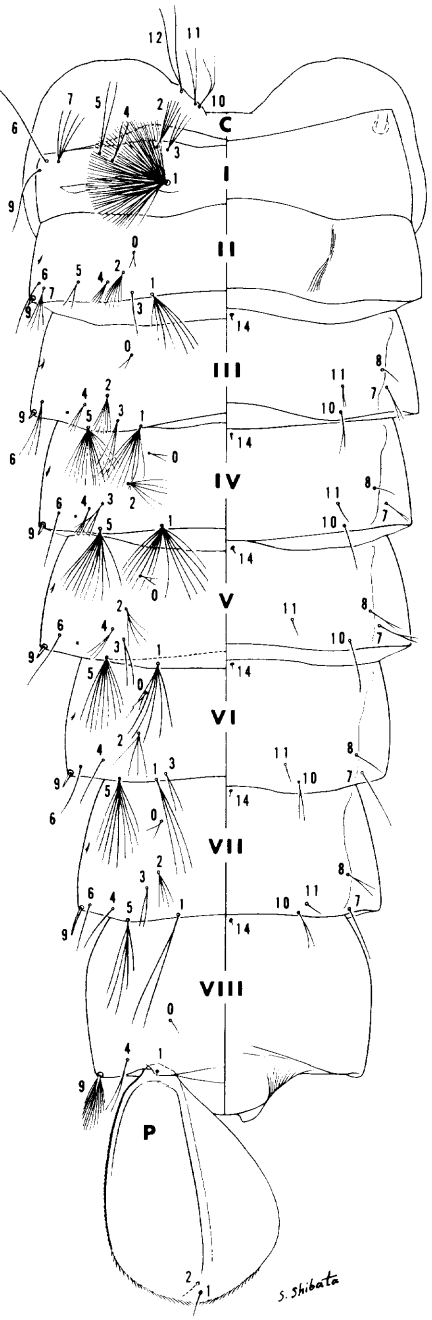
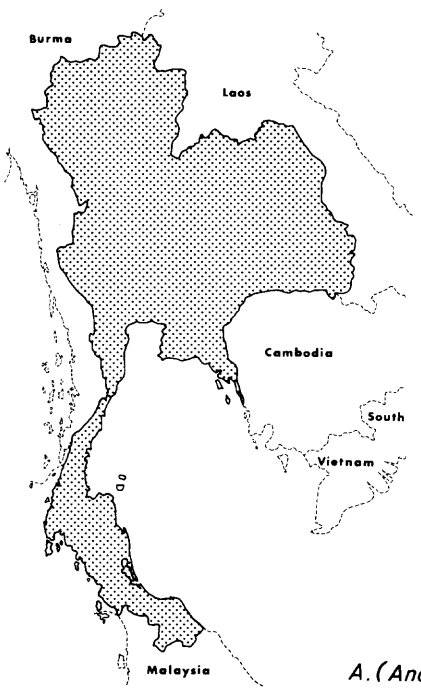

♂
1.0
♀
VII
VIII
0·2
.05
.02
AE
leaflets
CL
1.0mm
0.1
I.YOSHIGAKI
A. (Anopheles) sinensis

Fig.11

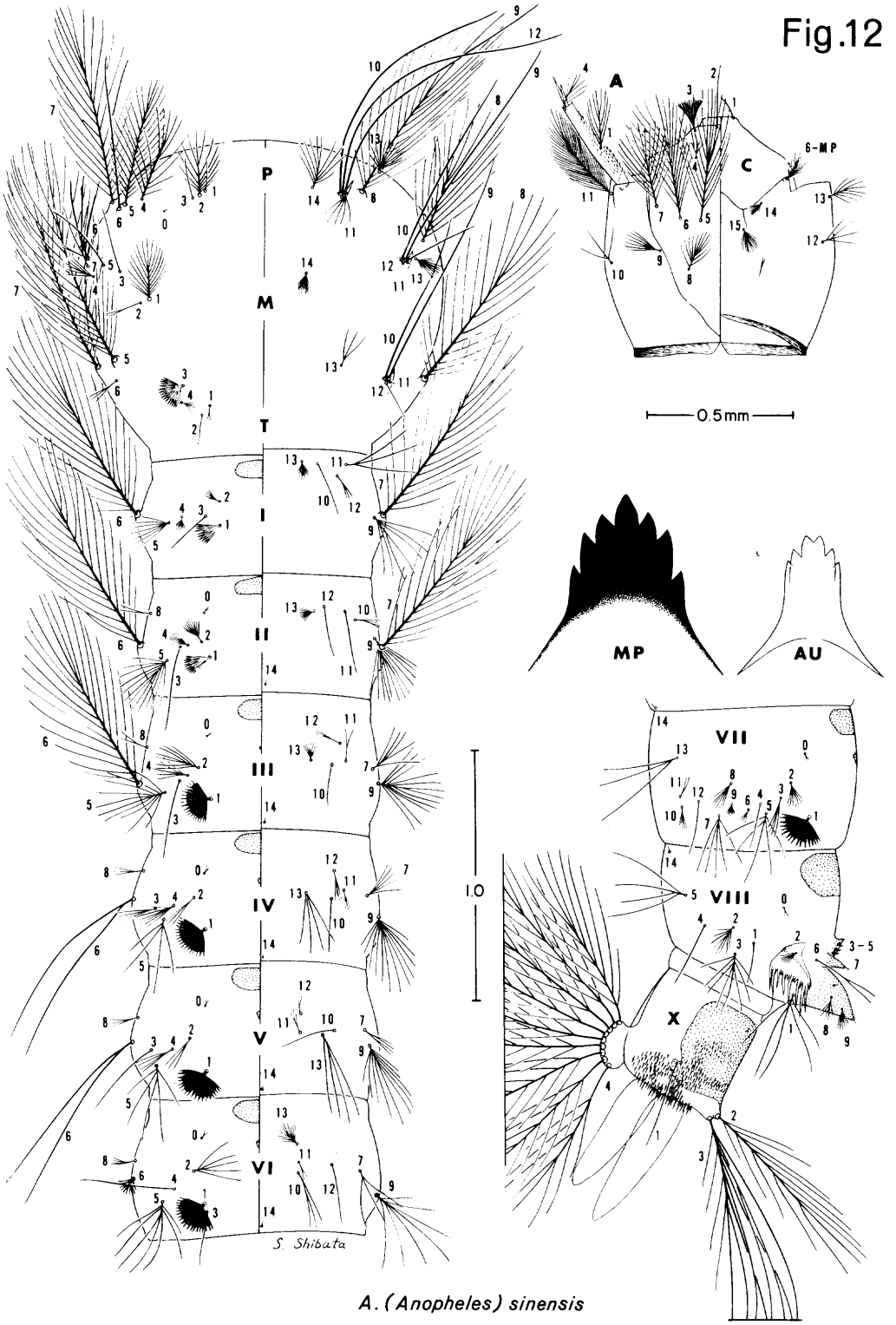






A.(Anopheles) sinensis

Fig.12



A. (Anopheles) sinensis

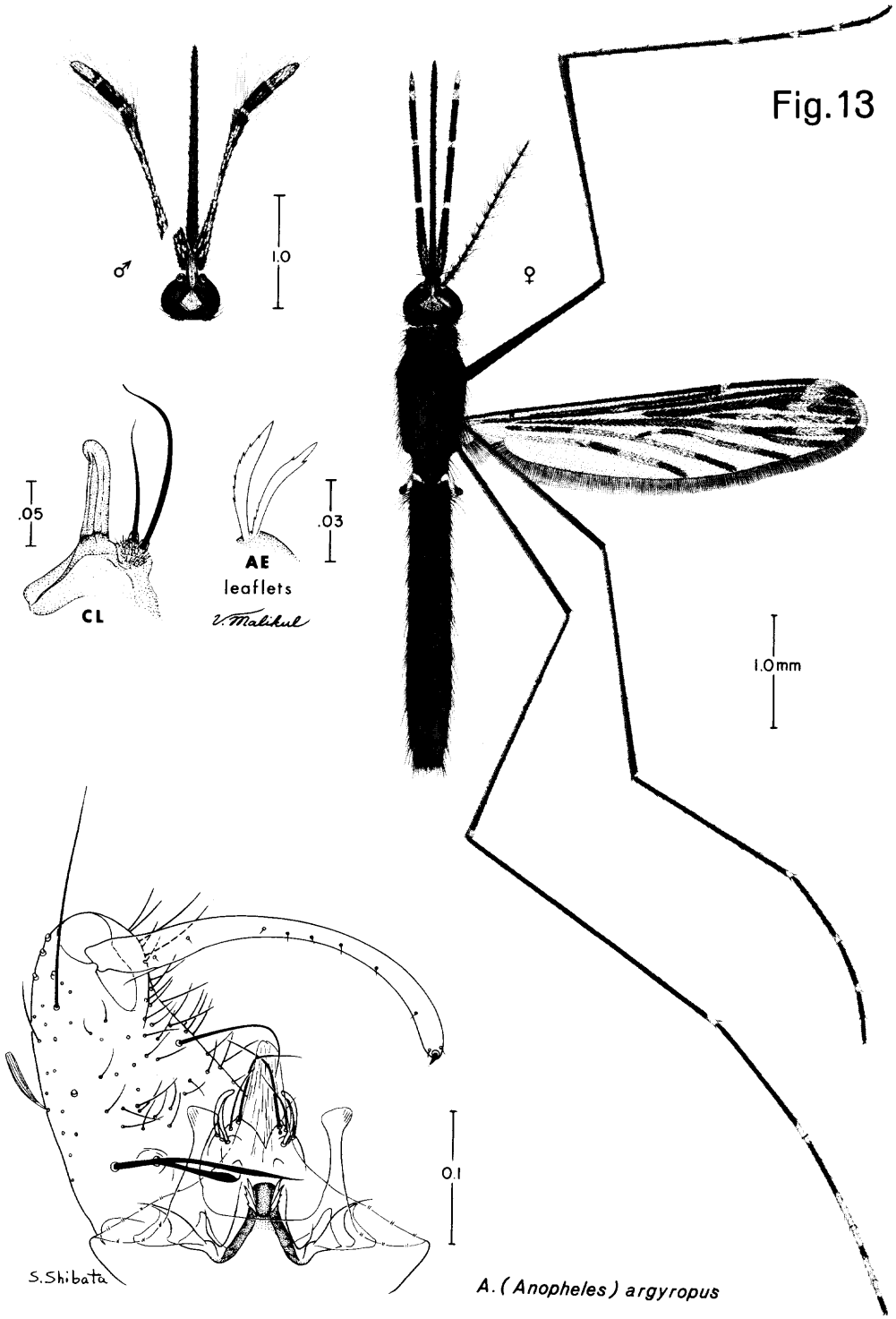
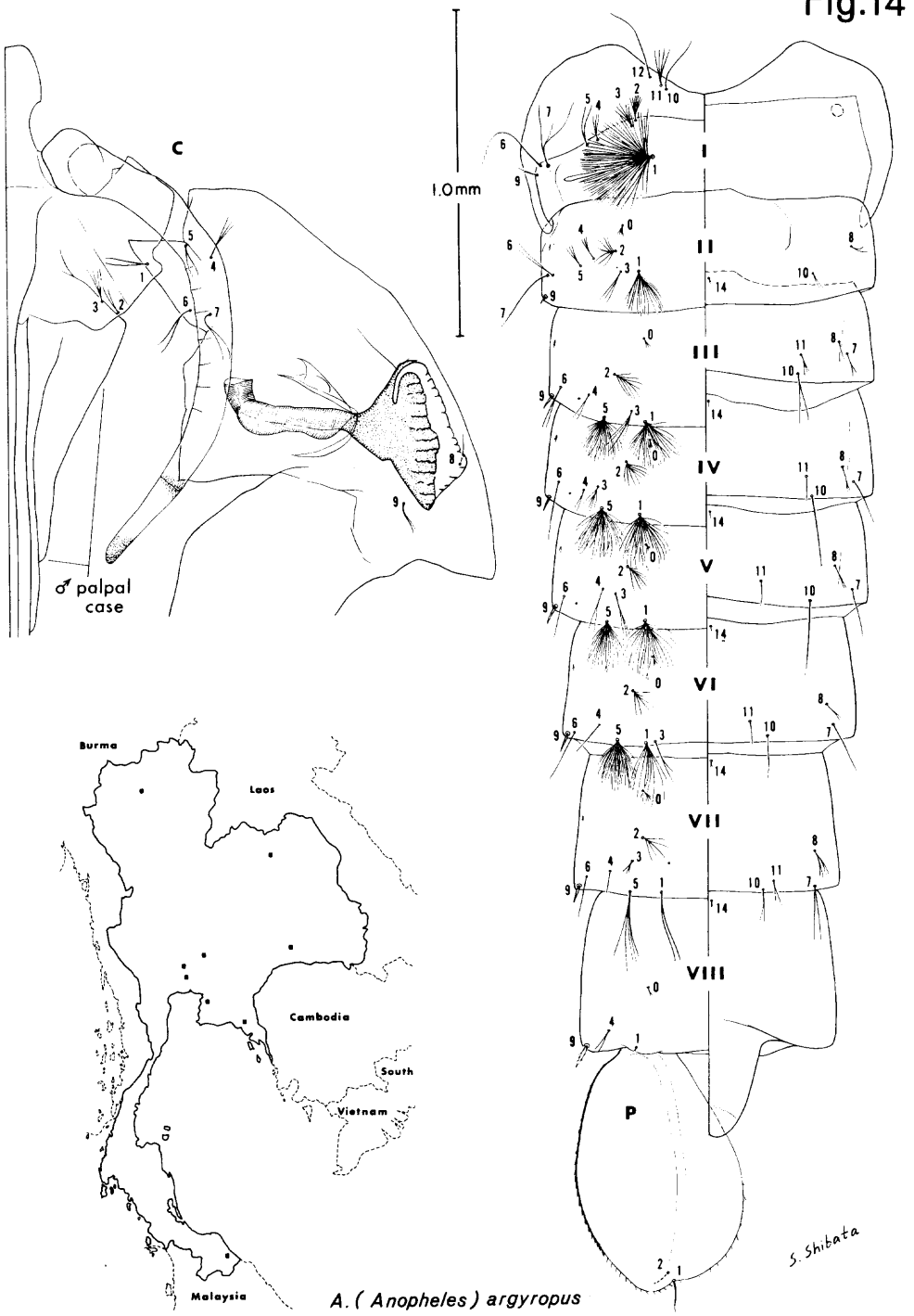
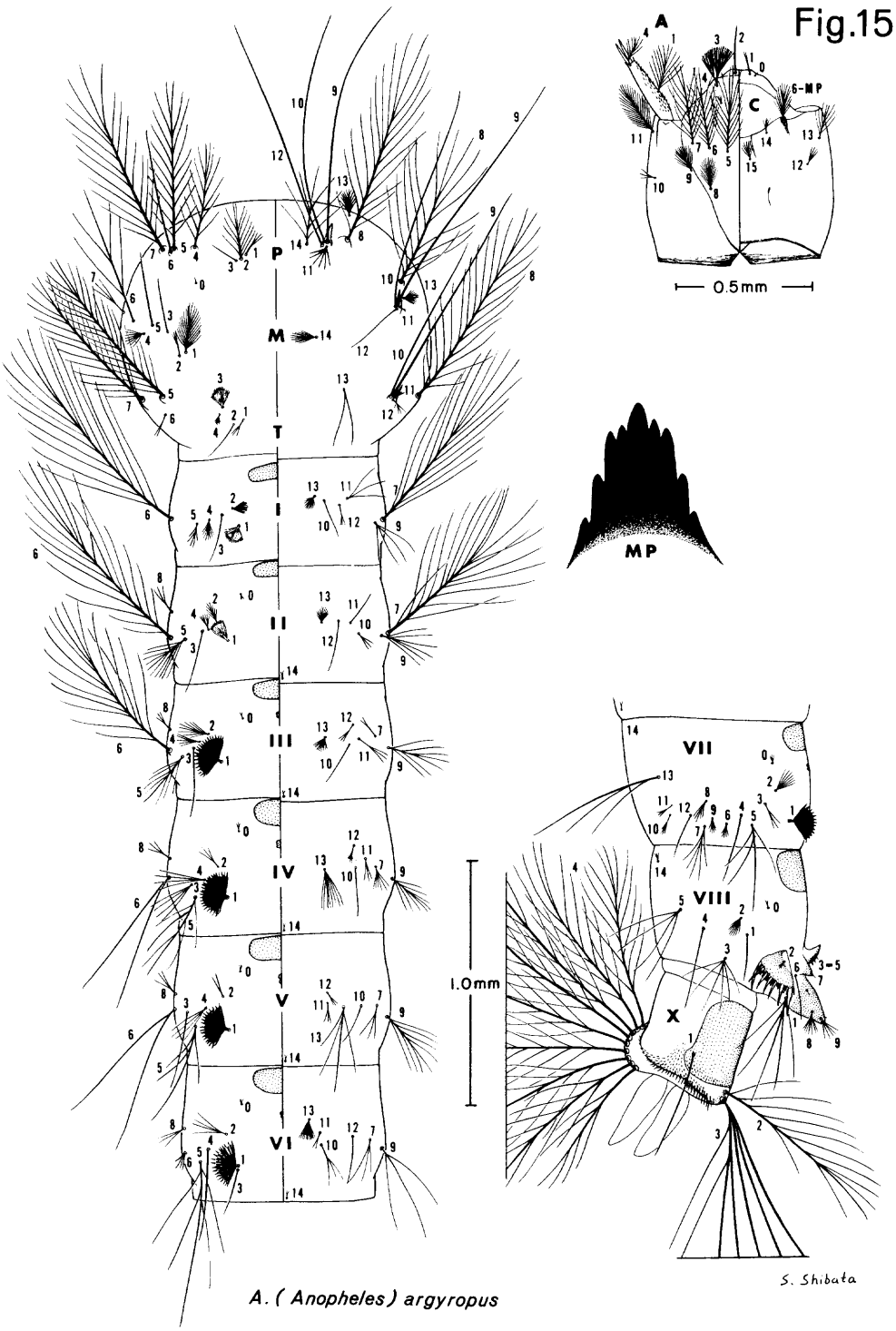

Fig.13
♂
1.0
♀
.05
CL
.03
AE
leaflets
V. Malikul
1.0mm
0.1
S. Shibata
A. (Anopheles) argyropus

Fig.14



A. (Anopheles) argyropus

Fig.15



A. (Anopheles) argyropus

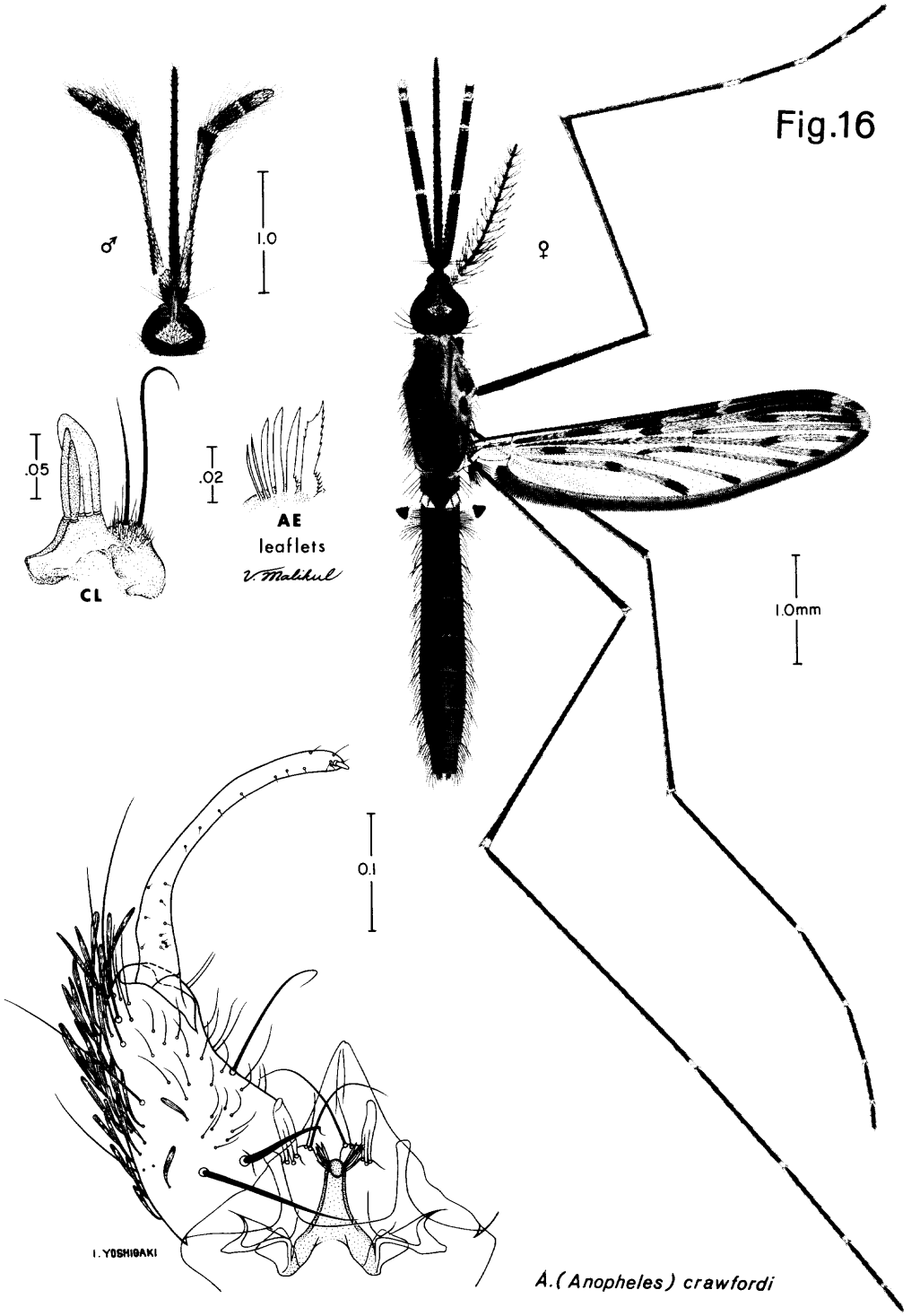
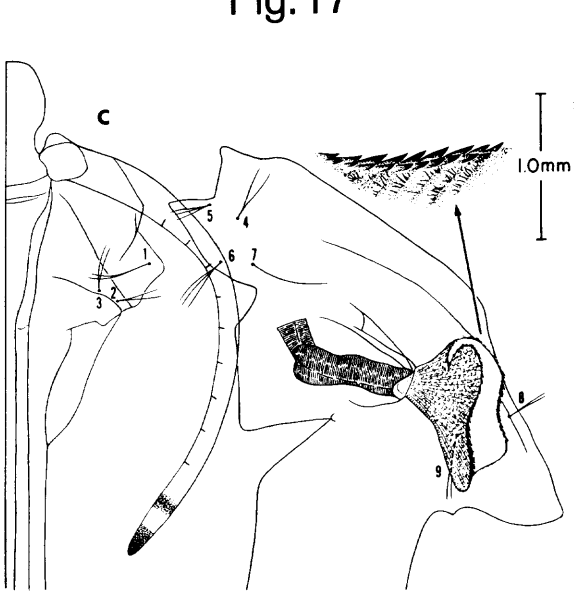
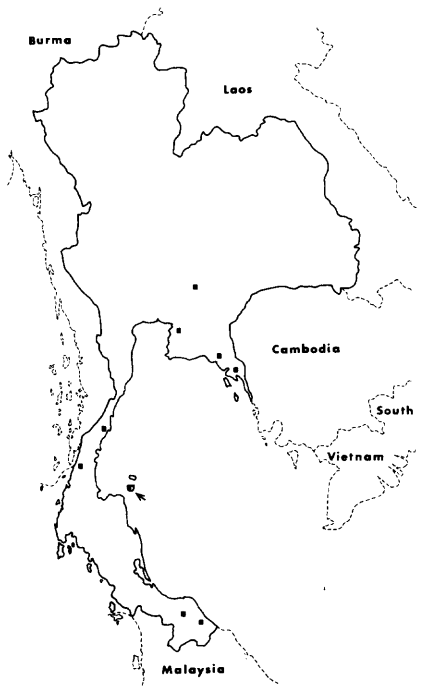
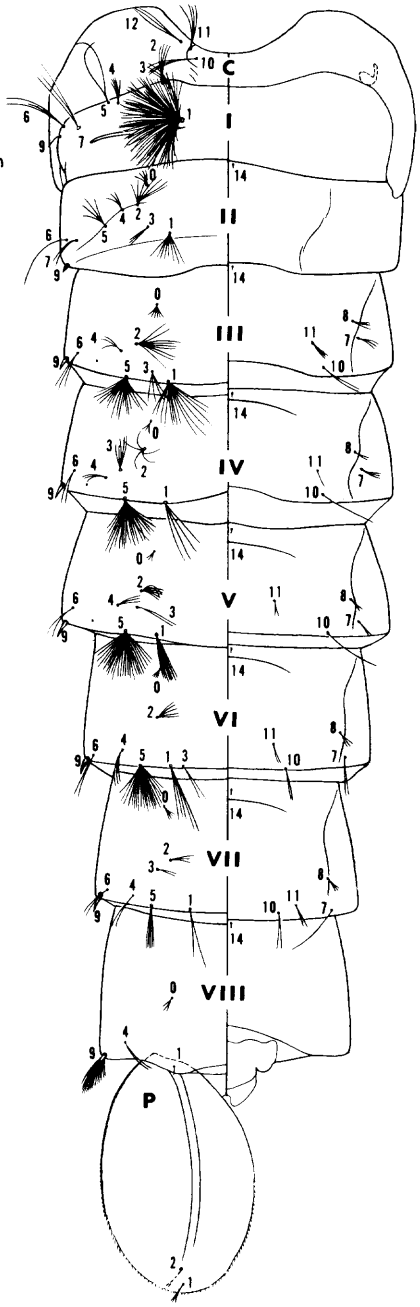

Fig.16
♂
1.0
♀
.05
.02
AE
leaflets
CL
1.0mm
0.1
I. YOSHIGAKI
A.(Anopheles) crawfordi

Fig. 17



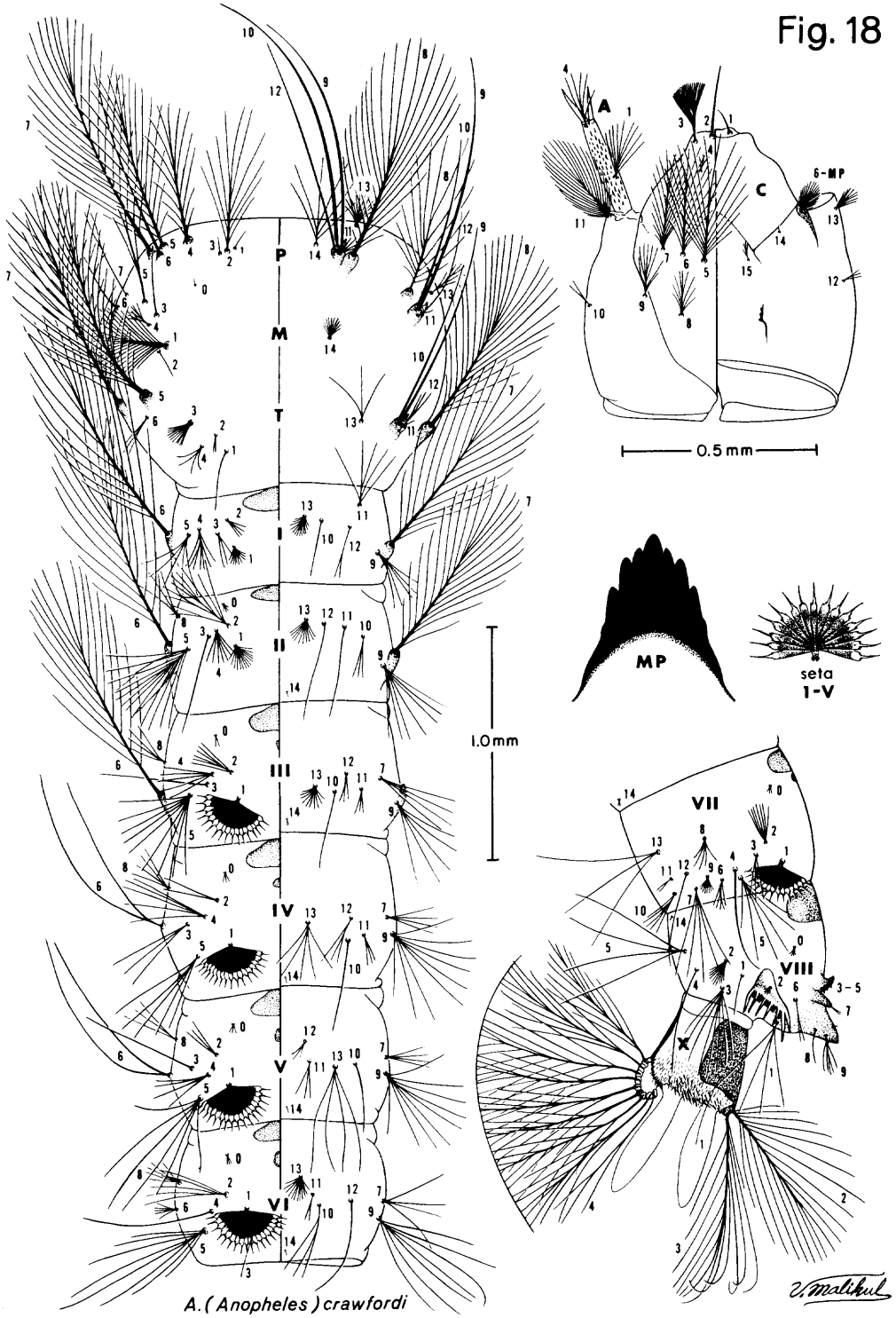




A. (Anopheles) crawfordi

Sonobe

Fig. 18



A. (Anopheles) crawfordi

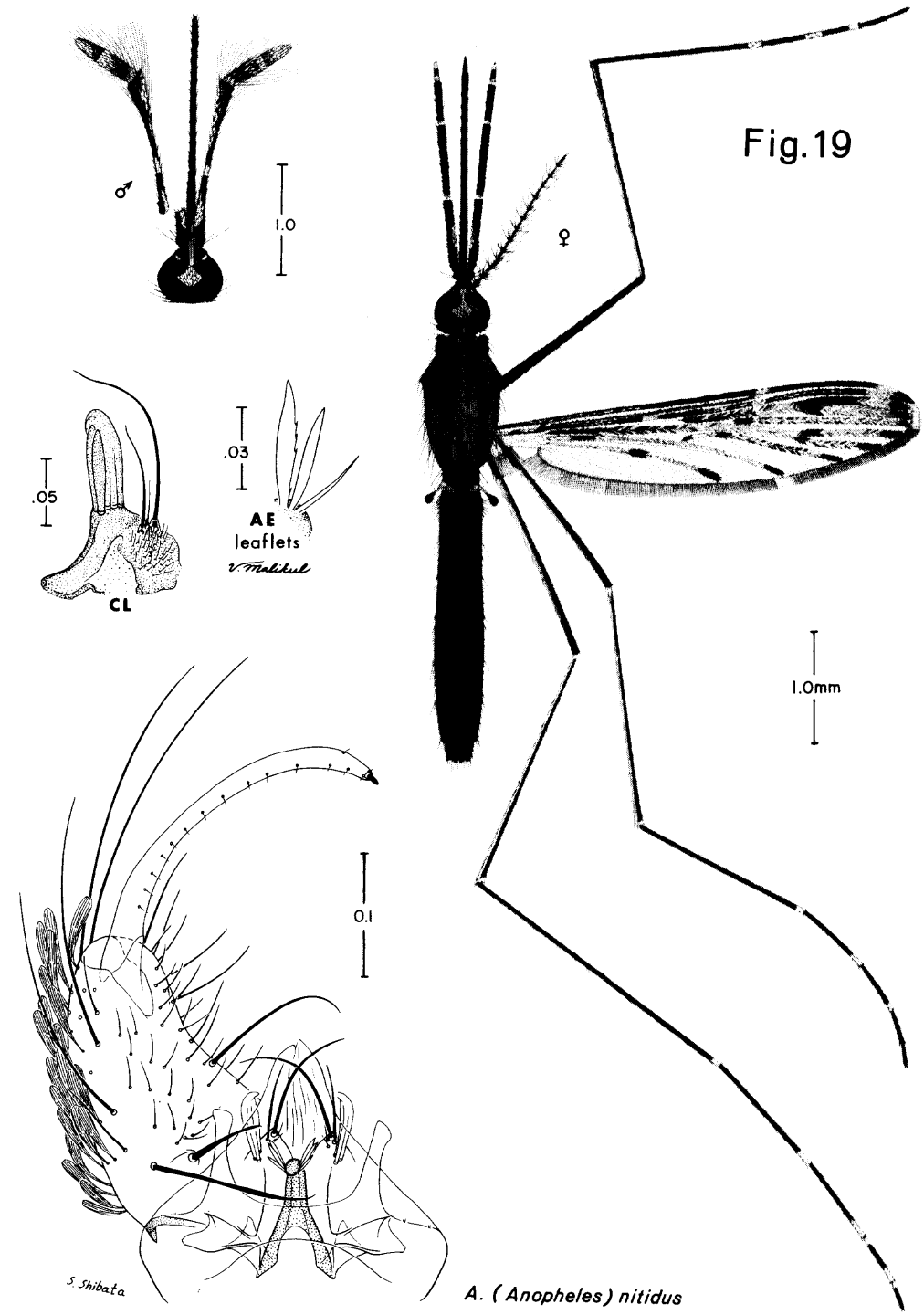

♂
1.0
.05
CL
.03
AE
leaflets
V. Malikul
♀
1.0mm
0.1
S. Shibata
A. (Anopheles) nitidus

Fig.19

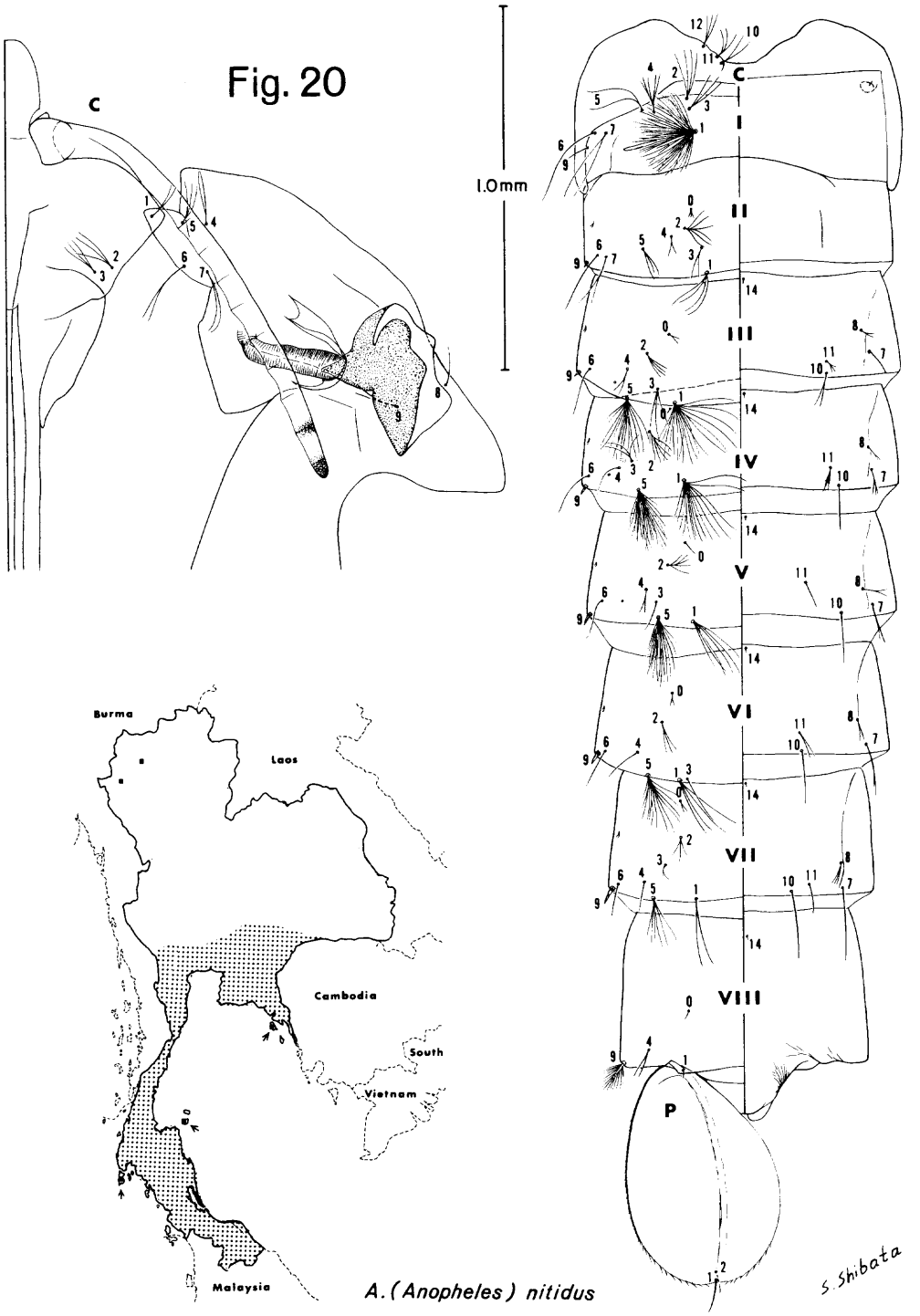
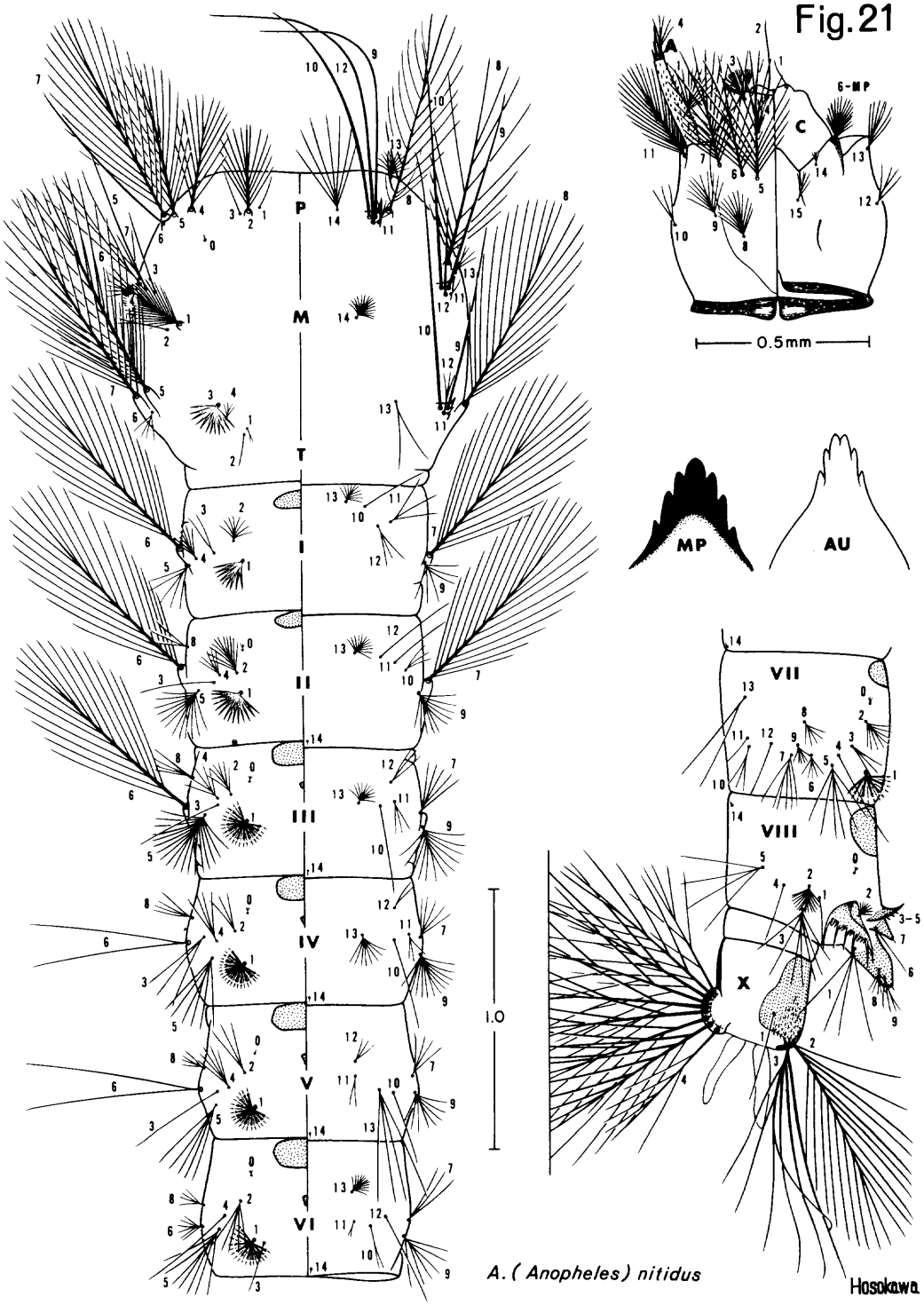
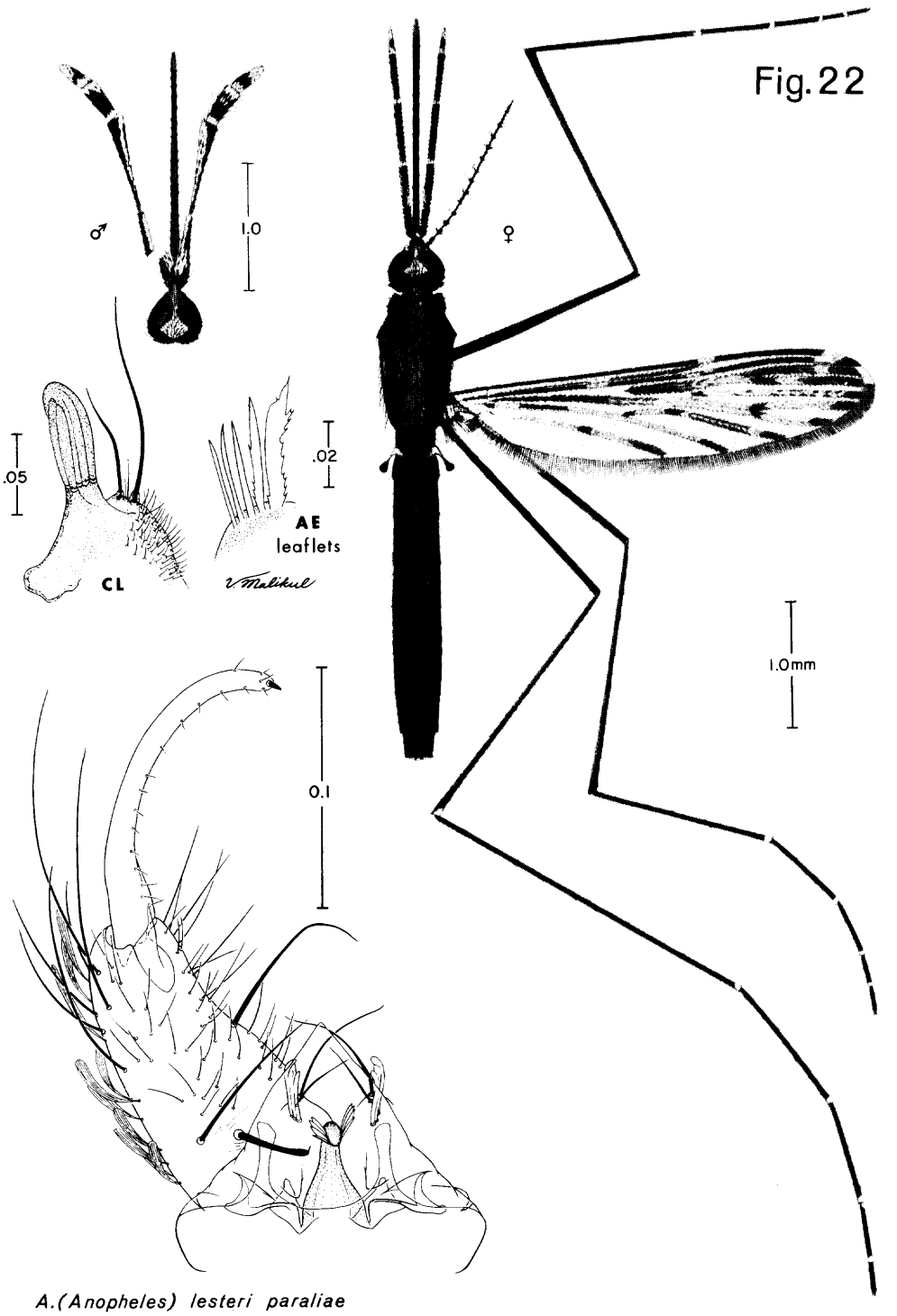

Fig. 20
c
1.0mm
C
I
II
III
IV
V
VI
VII
VIII
P
Burma
Laos
Cambodia
South
Vietnam
Malaysia
A. (Anopheles) nitidus
S. Shibata

Fig.21

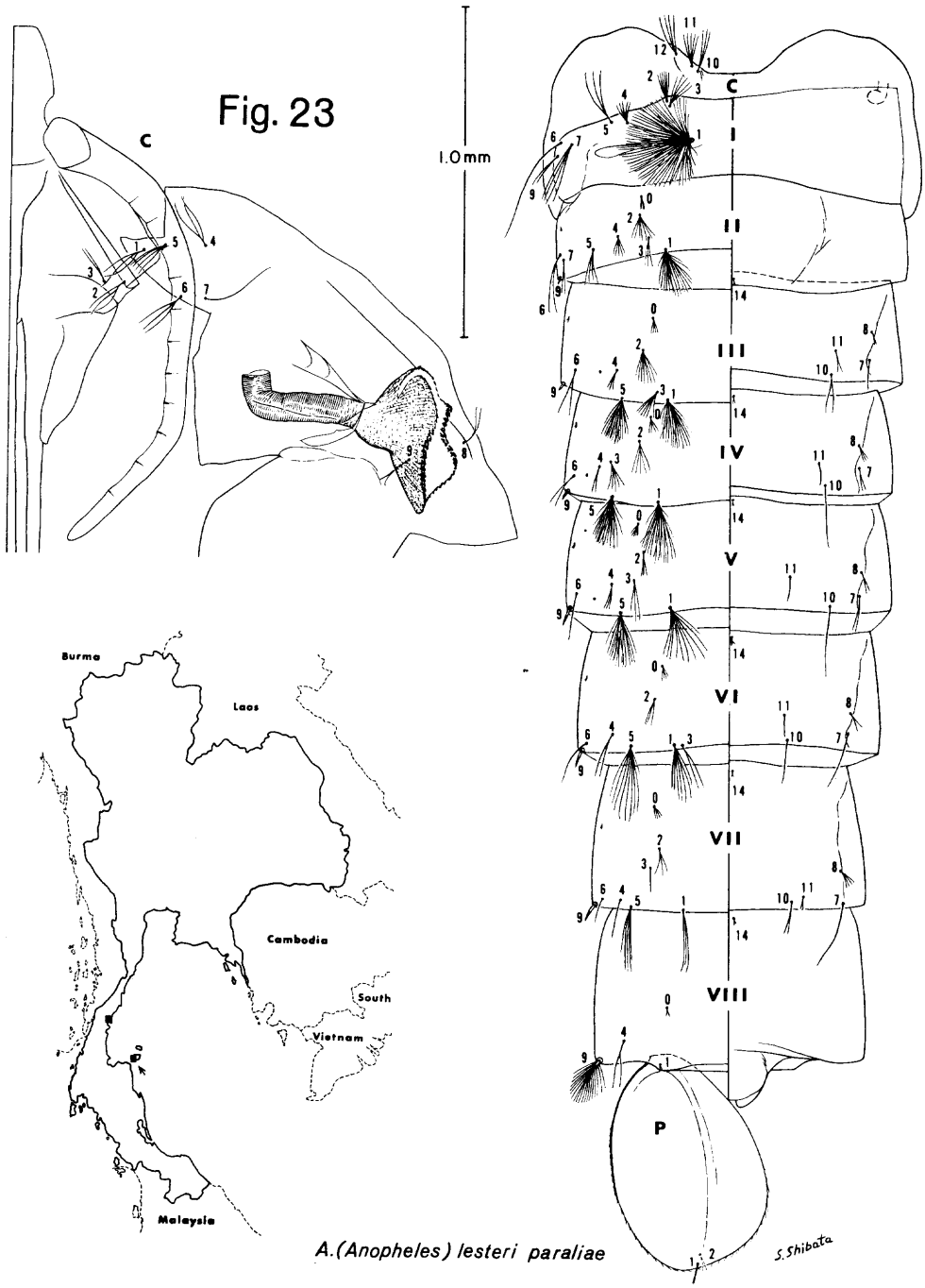


A. (Anopheles) nitidus

Hosokawa



A.(Anopheles) lesteri paraliae


Fig. 23
C
1.0mm
C
I
II
III
IV
V
VI
VII
VIII
P
Burma
Laos
Cambodia
South
Vietnam
Malaysia
A.(Anopheles) lesteri paraliae
S.Shibata

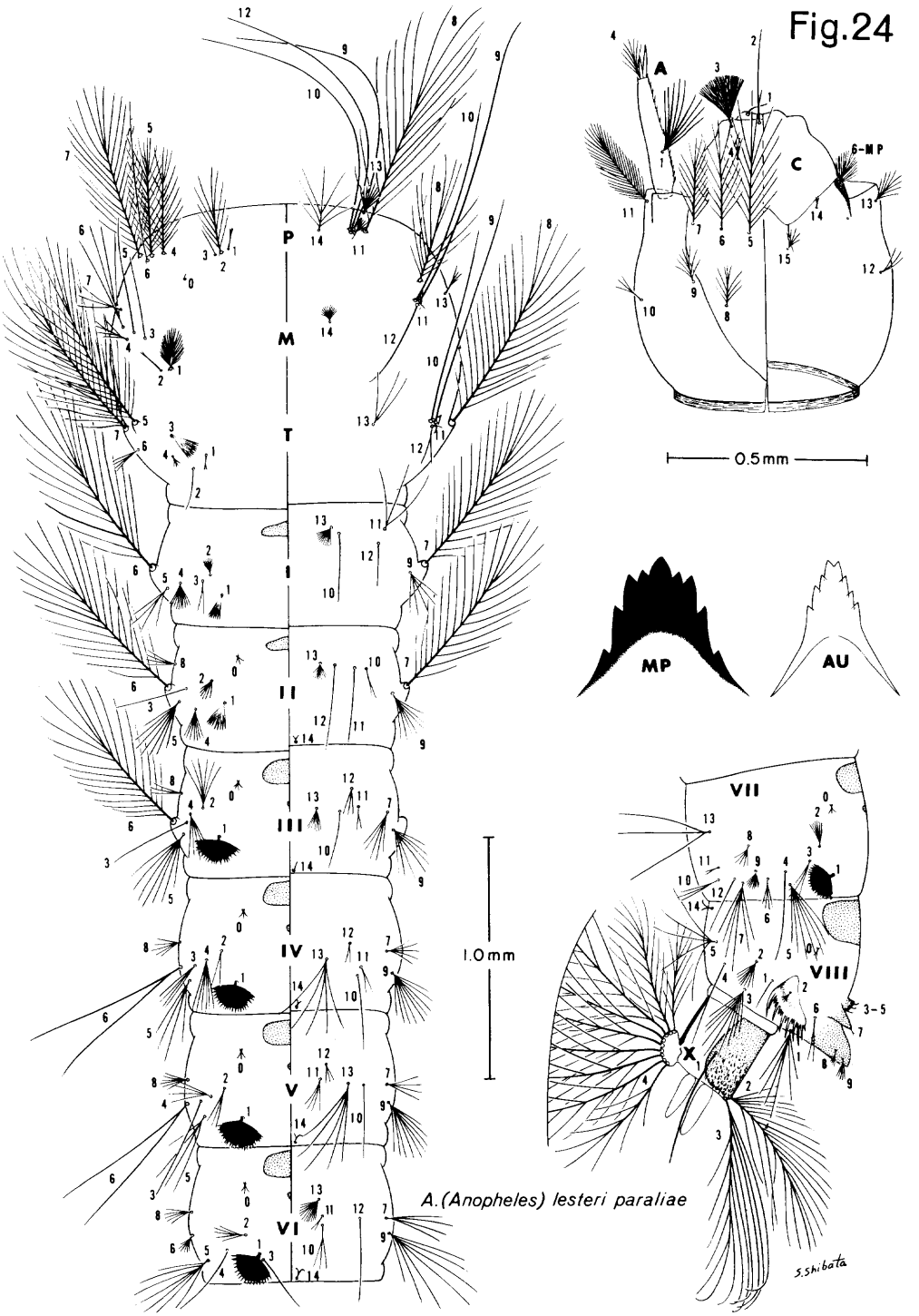
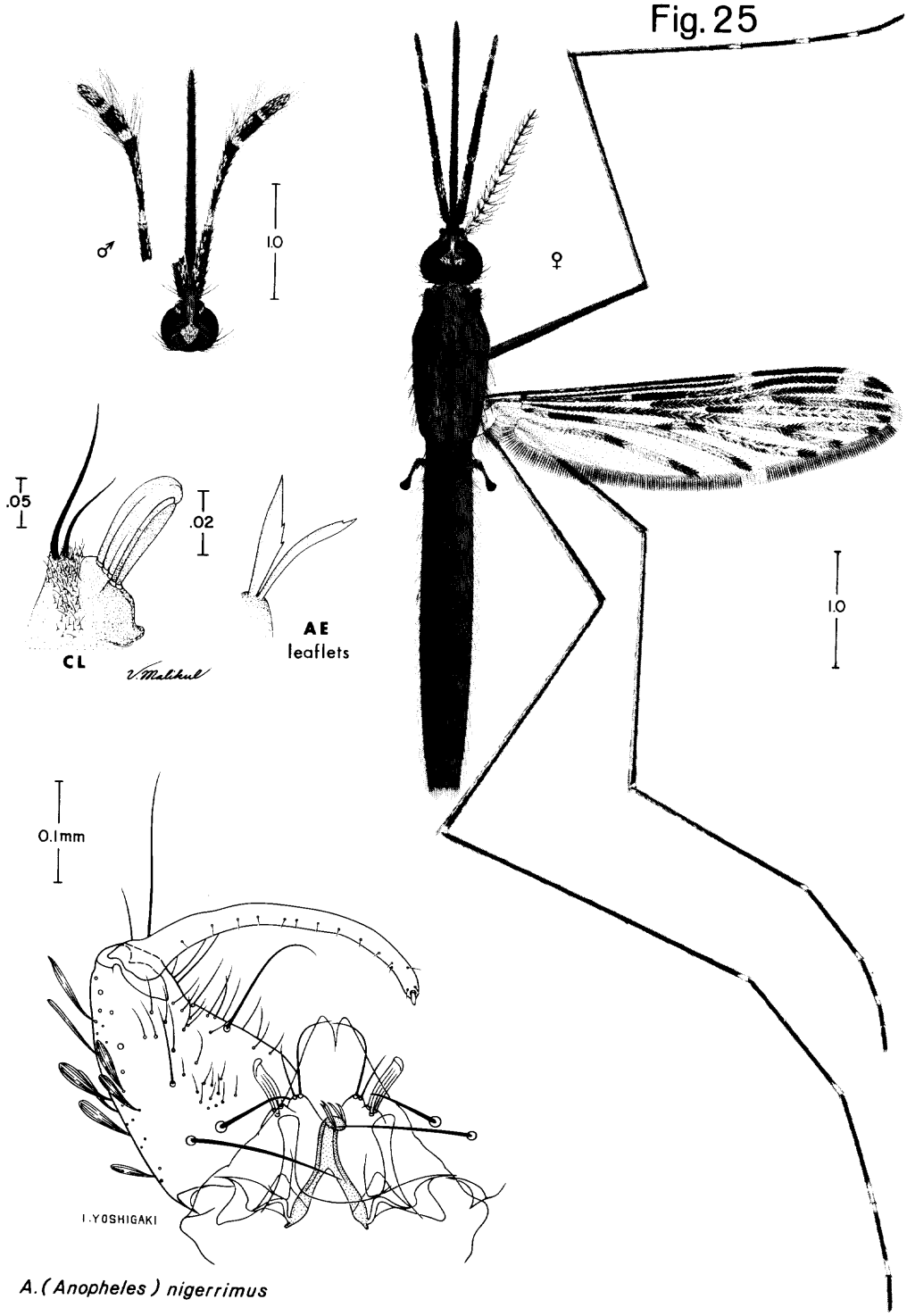
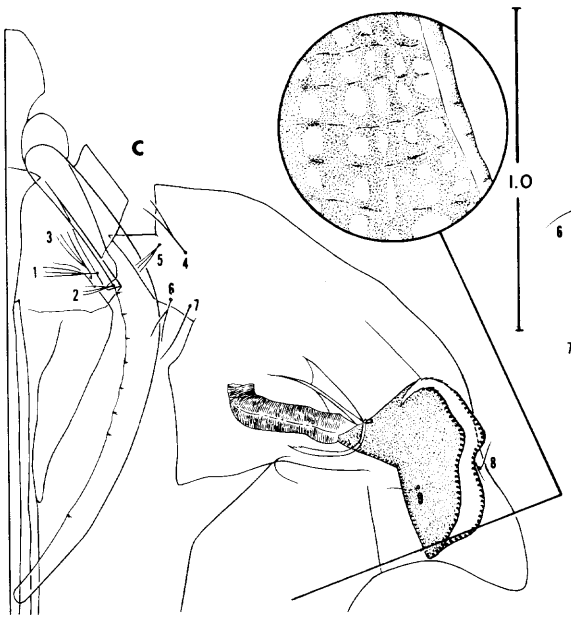

Fig.24
A
C
6-MP
0.5mm
MP
AU
P
M
T
I
II
III
IV
V
VI
VII
VIII
X
1.0mm
A.(Anopheles) lesteri paraliae
S.Shibata

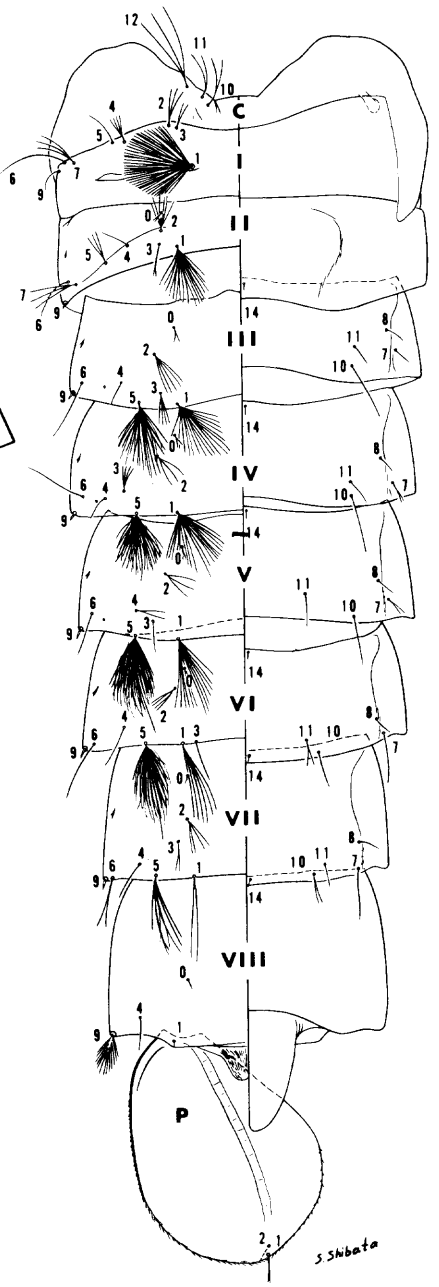
Fig. 25

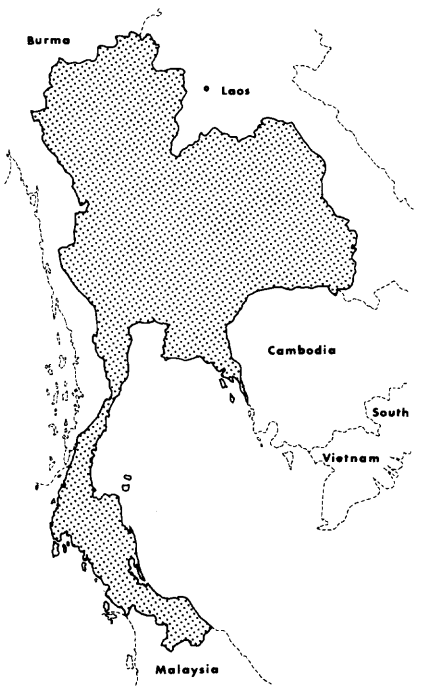


A. (Anopheles) nigerrimus

Fig. 26

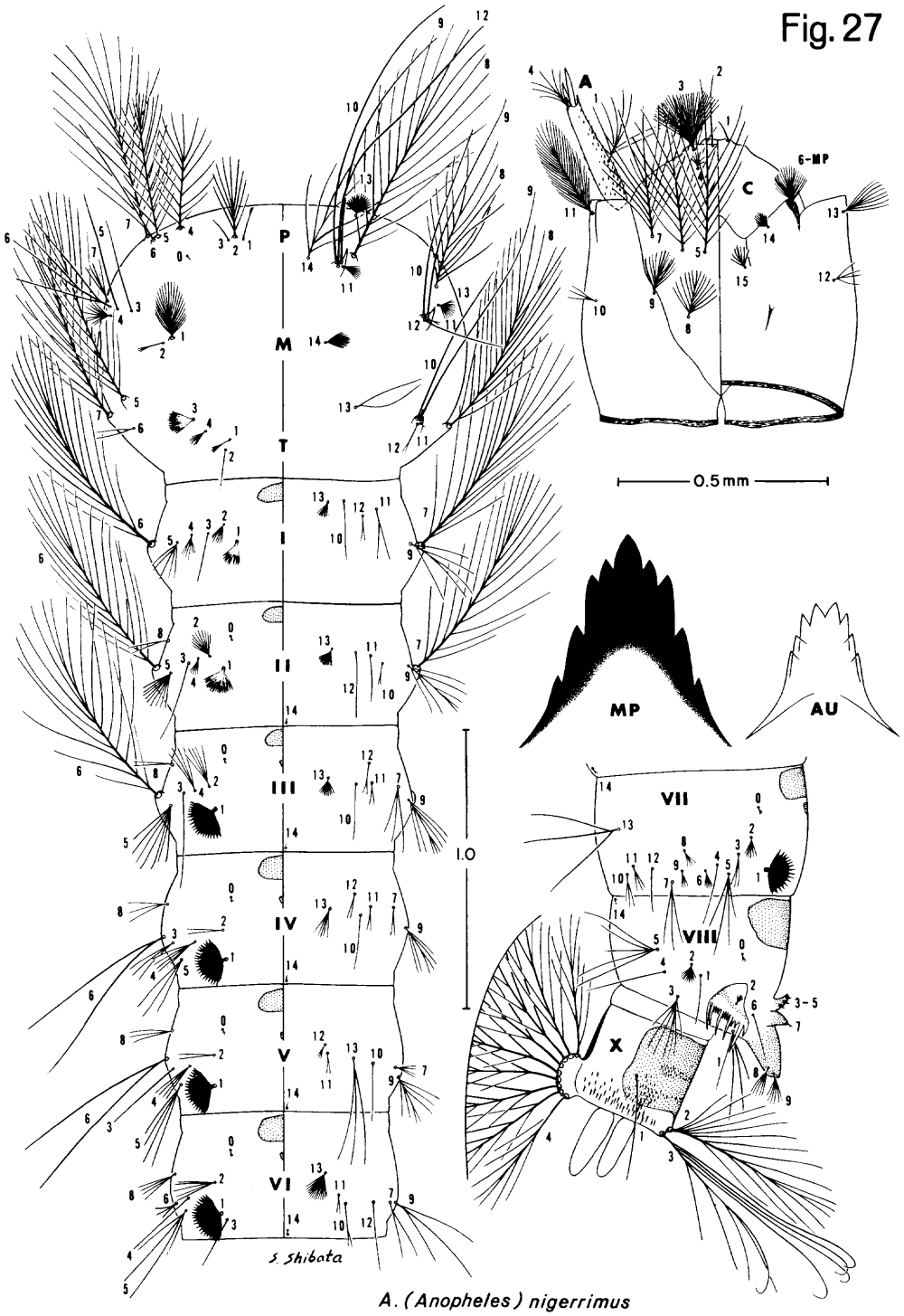






A. (Anopheles) nigerrimus

Fig. 27



A. (Anopheles) nigerrimus

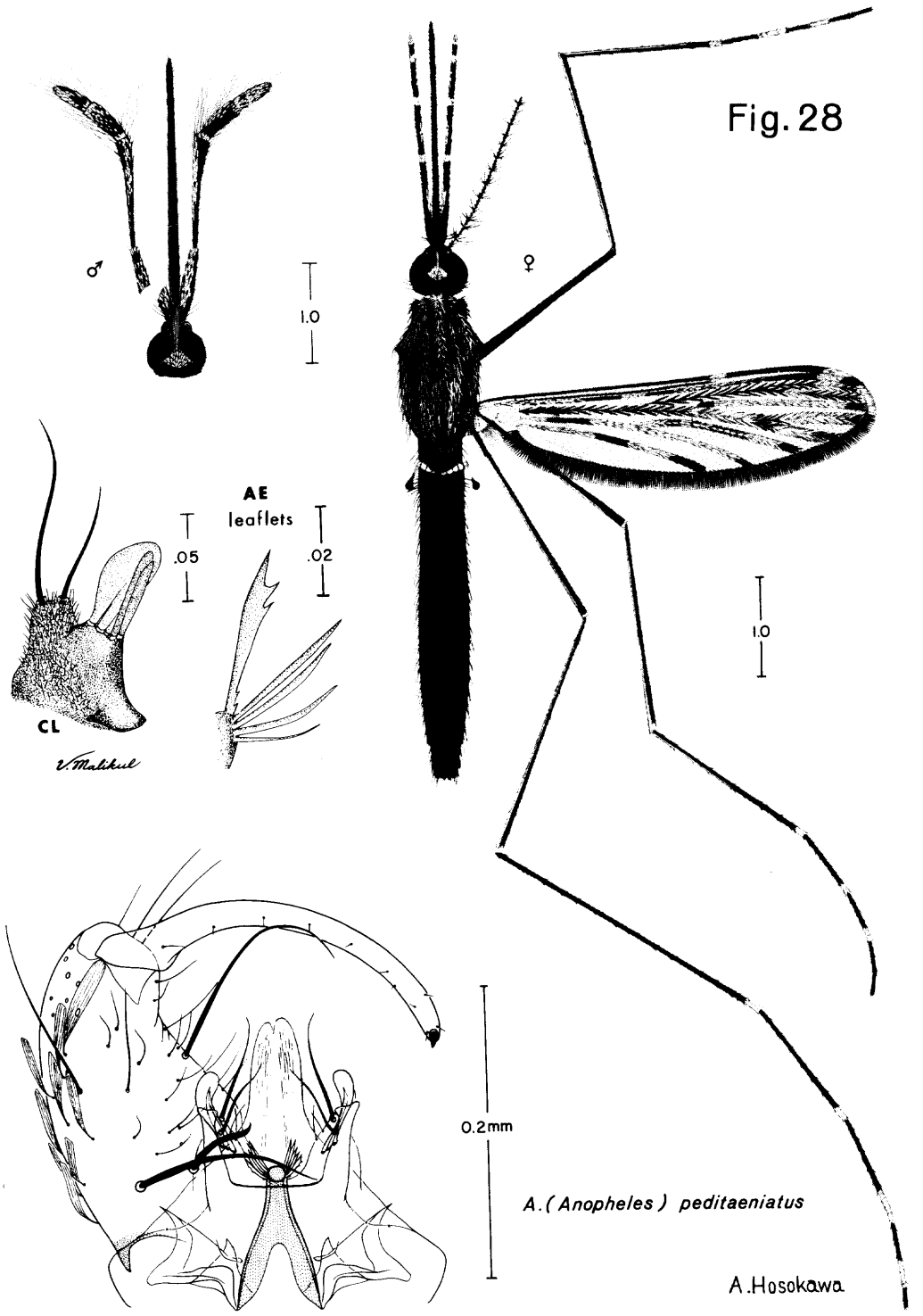
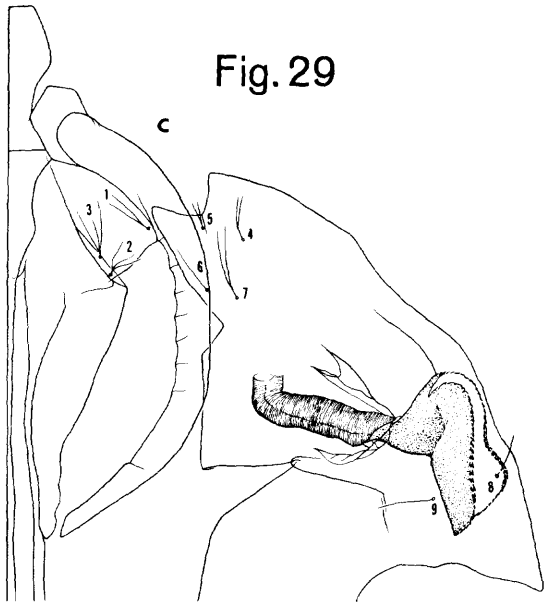
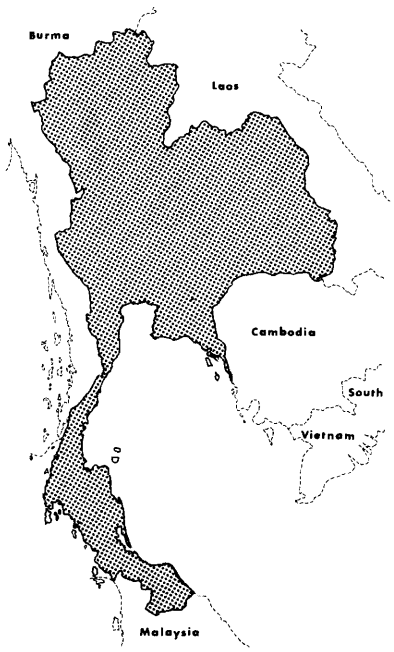
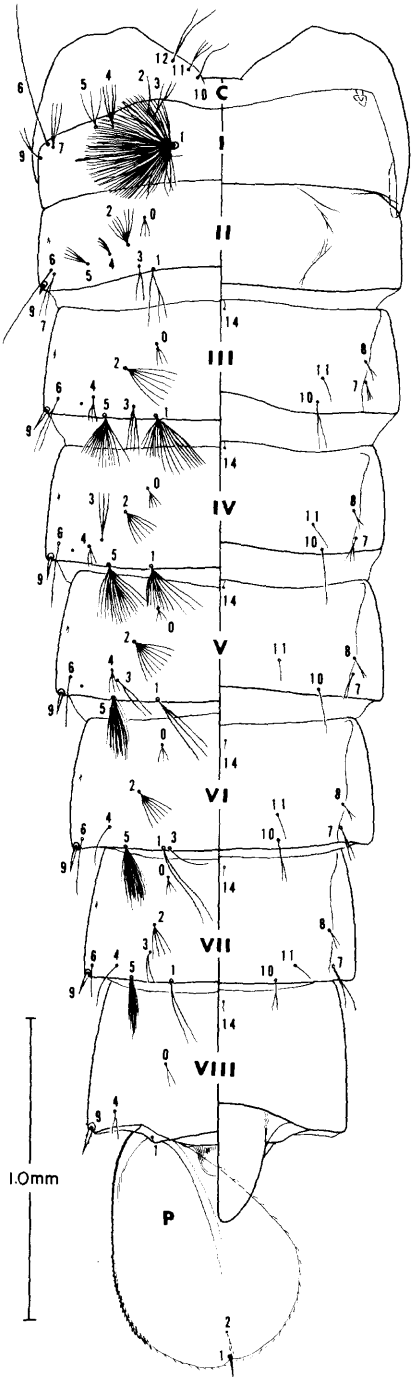

Fig. 28
♂
1.0
♀
AE
leaflets
.05
.02
CL
1.0
0.2mm
A.(Anopheles) peditaeniatus
A.Hosokawa

Fig. 29



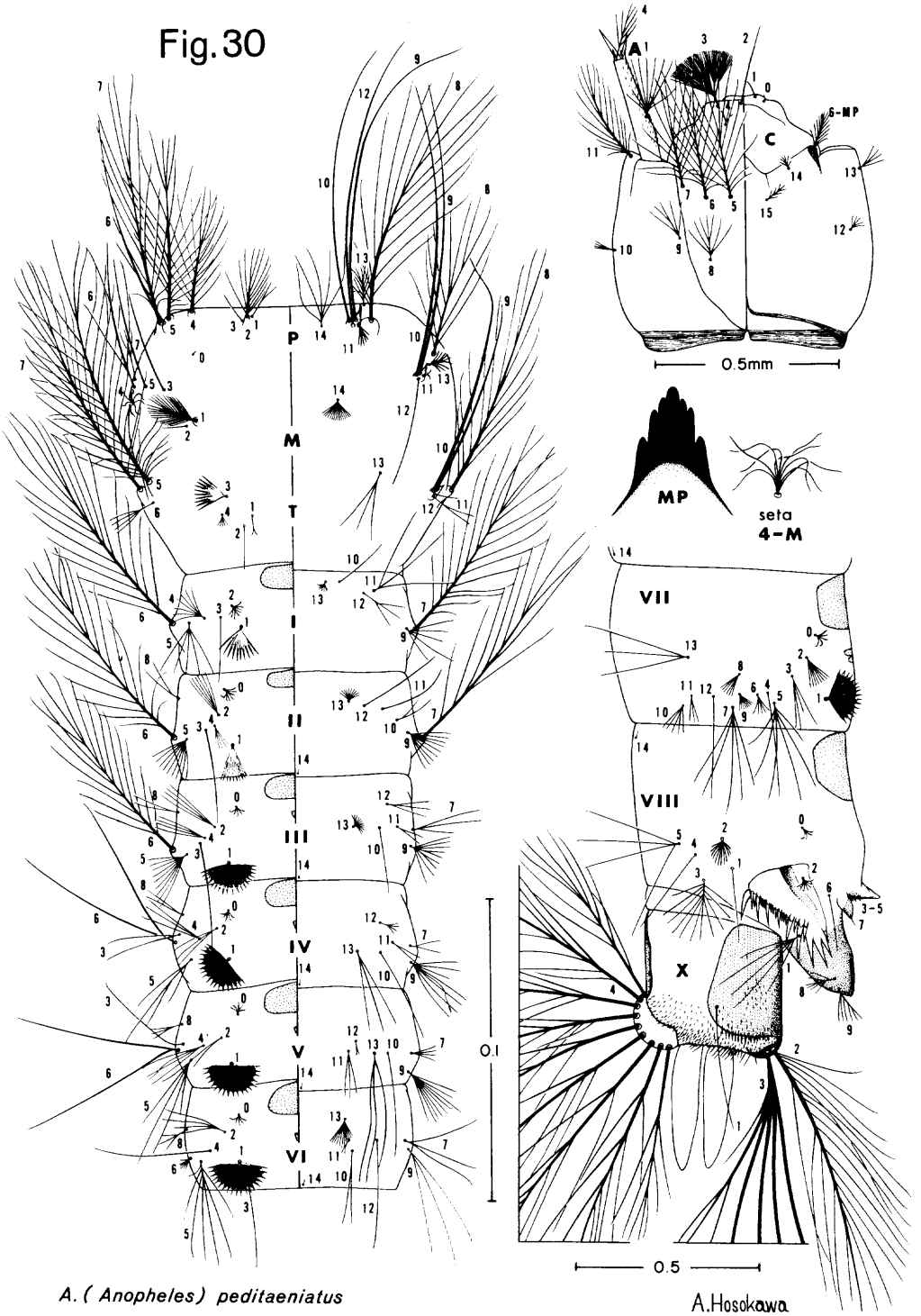




A.(Anopheles) peditaeniatus

A. Hosokawa

Fig.30



A. (Anopheles) peditaeniatus

A.Hosokawa

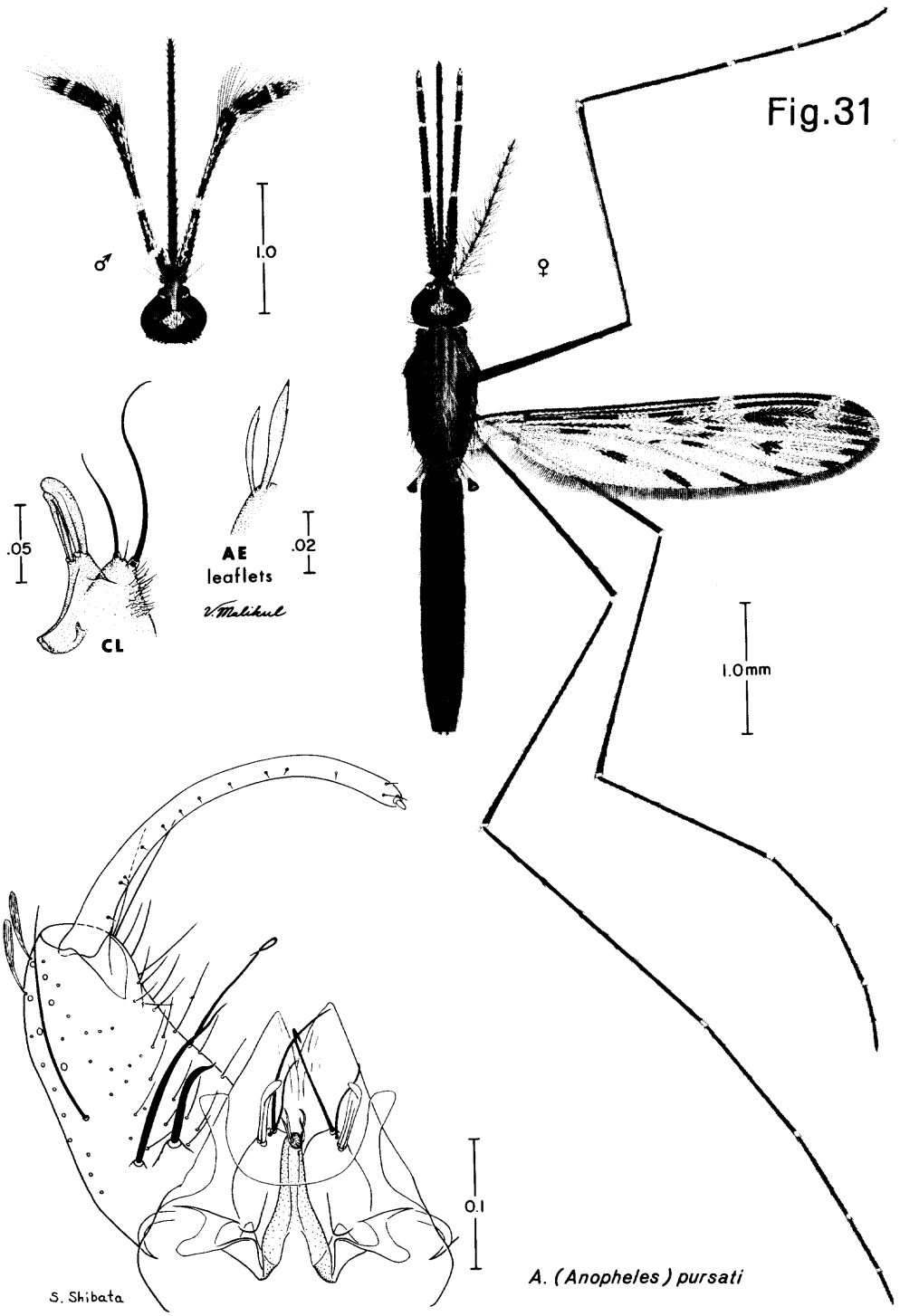
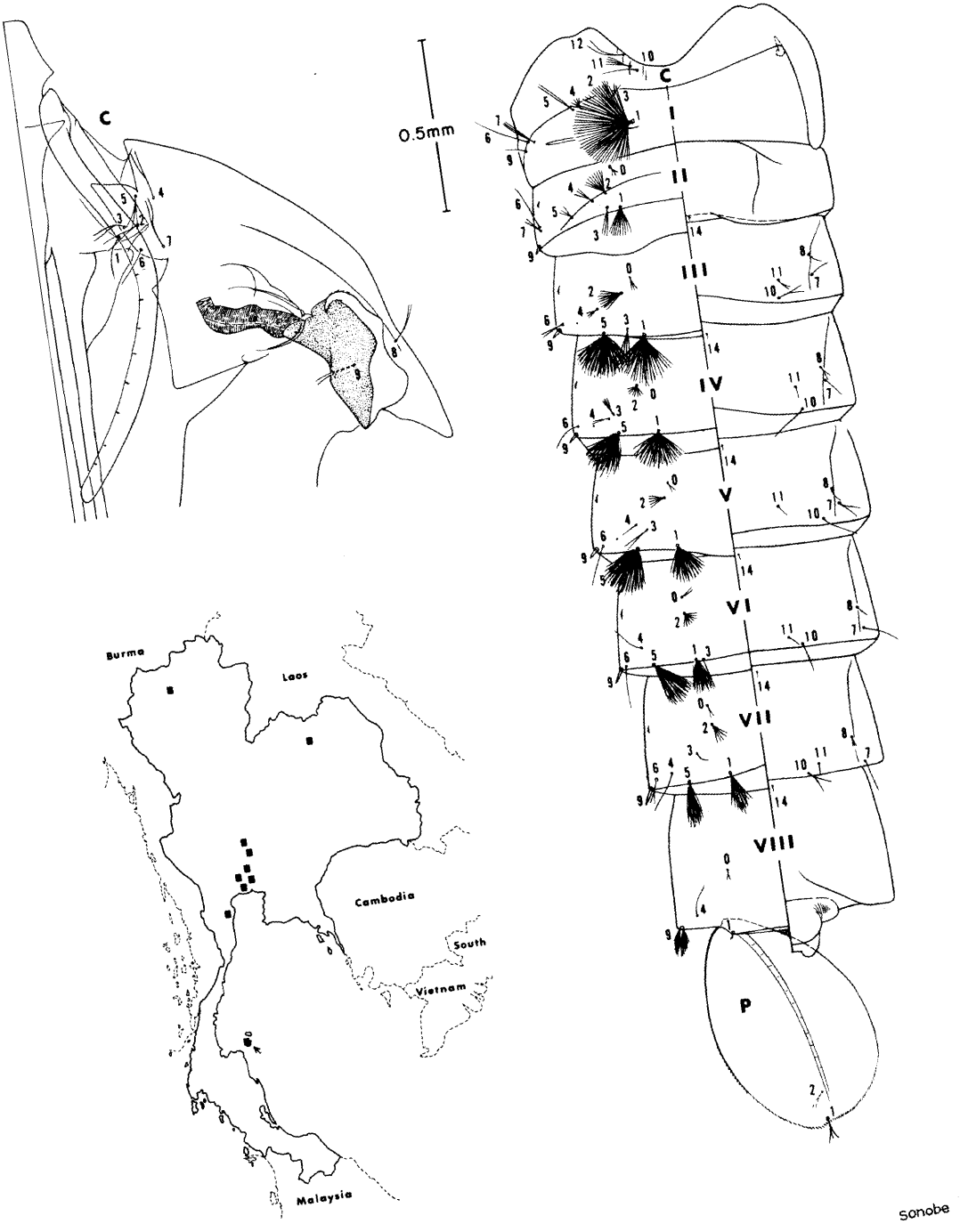

Fig.31
♂
1.0
♀
.05
CL
AE
leaflets
.02
V. Malikul
1.0mm
0.1
S. Shibata
A. (Anopheles) pursati

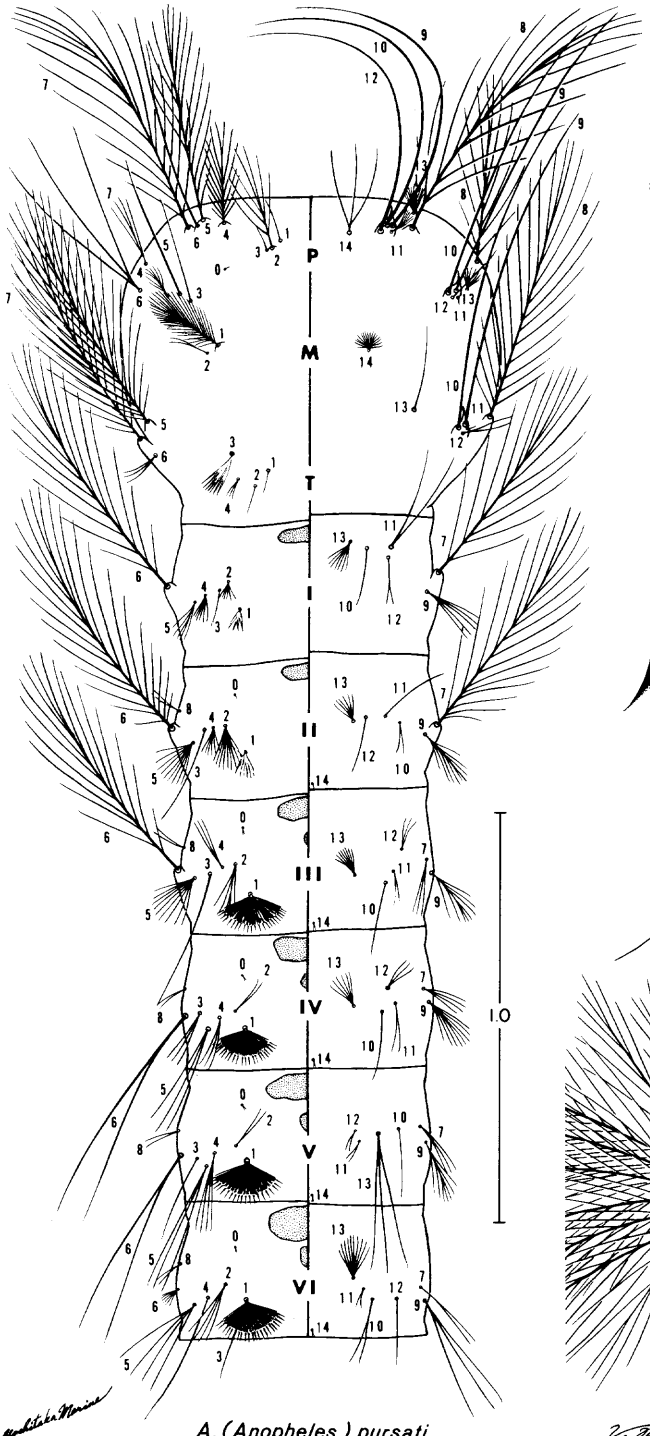
Fig. 32

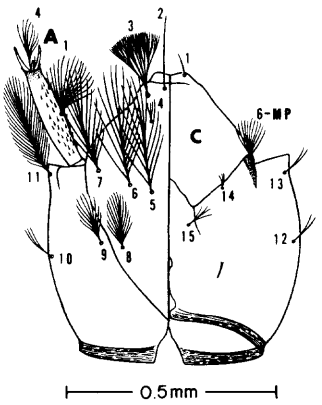


Sonobe

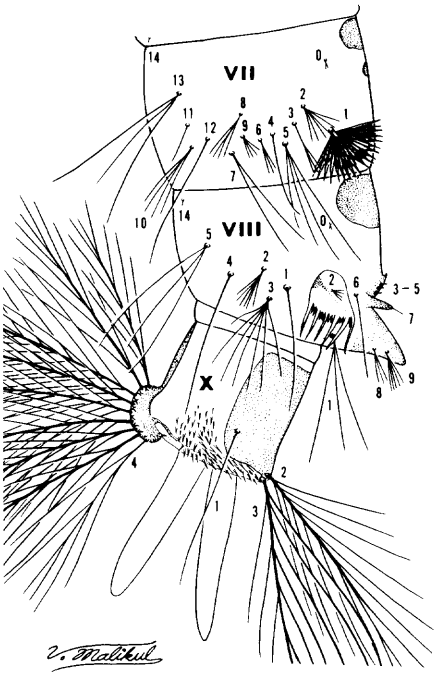
A. (Anopheles) pursati

Fig. 33









A. (Anopheles) pursati

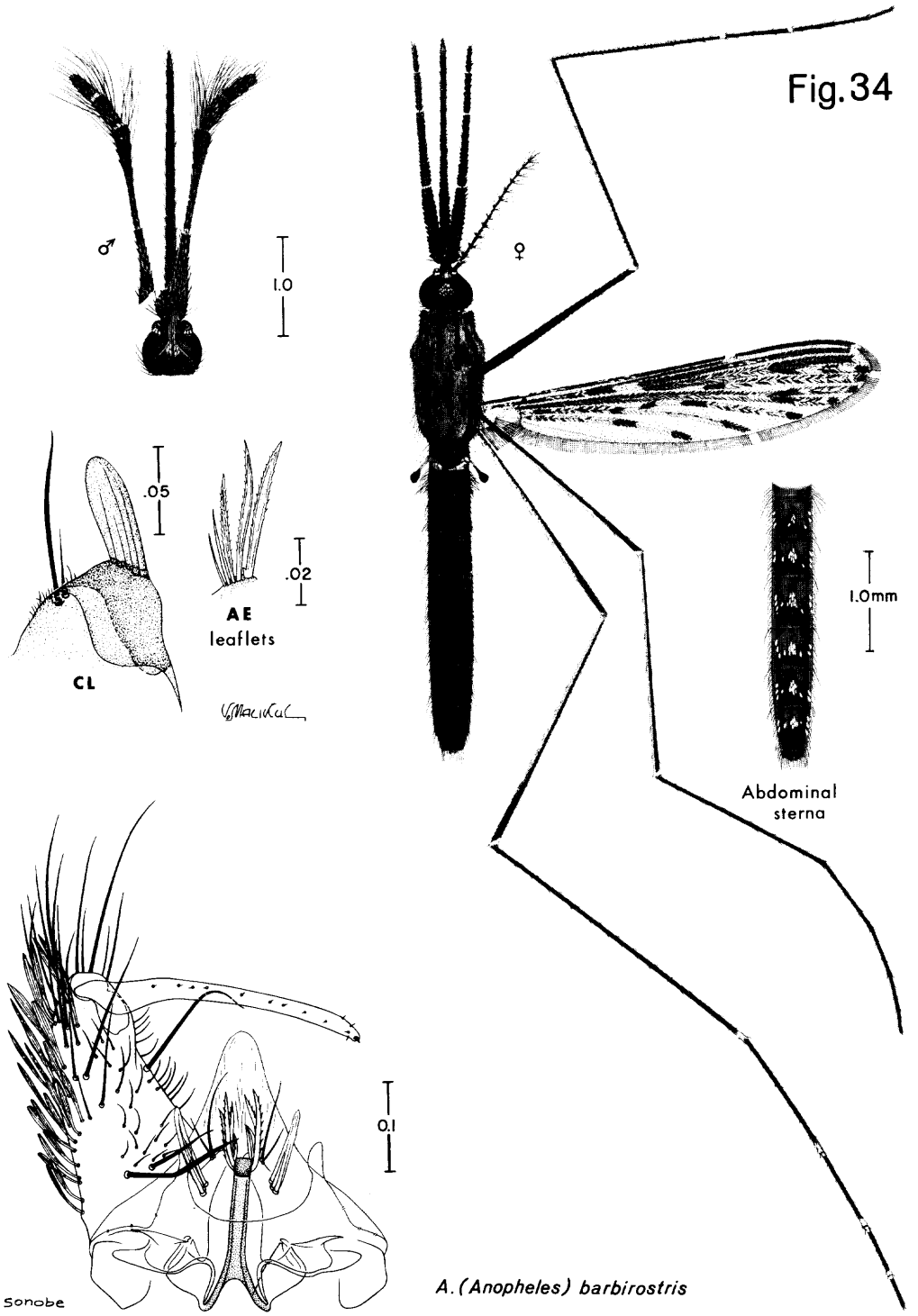
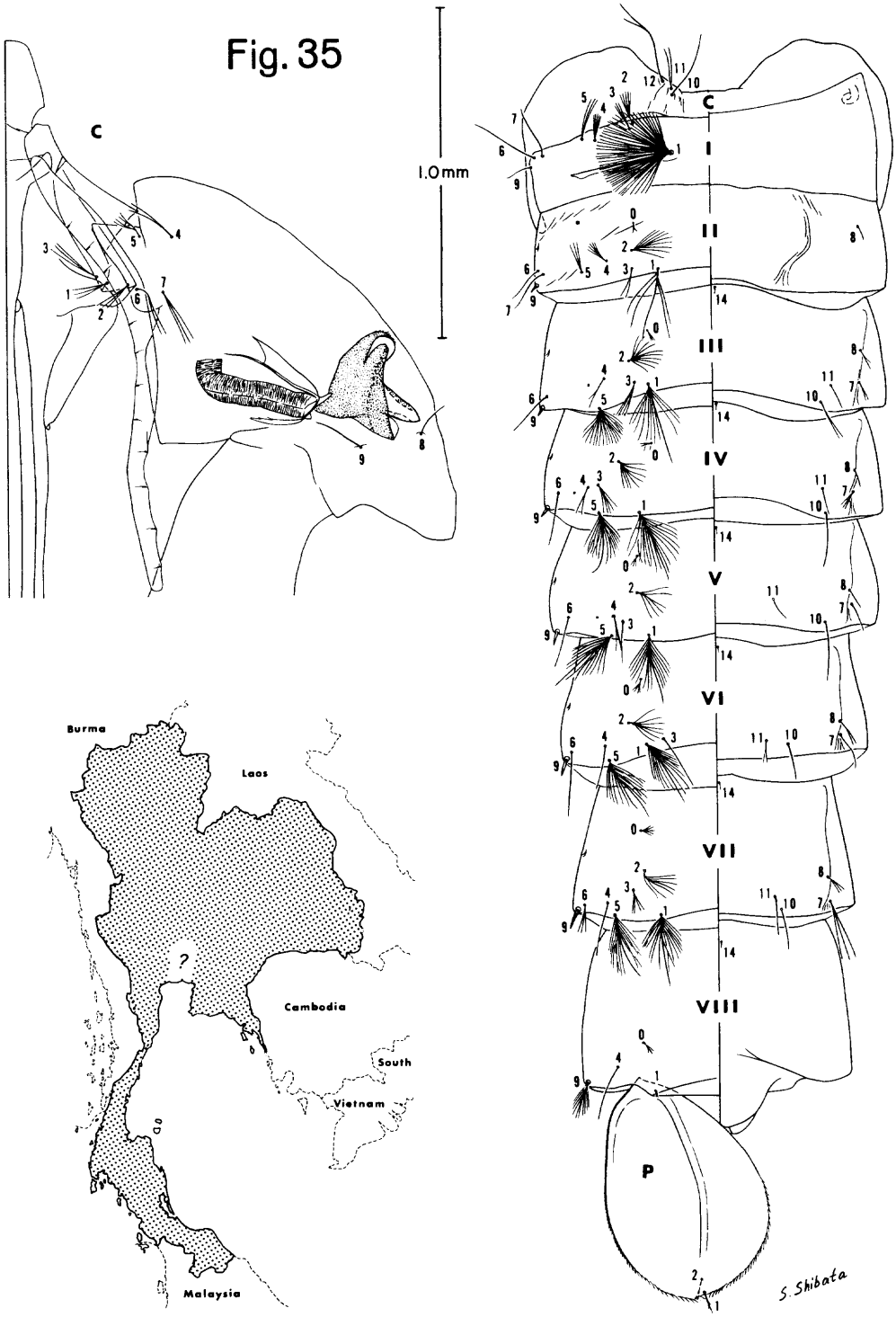
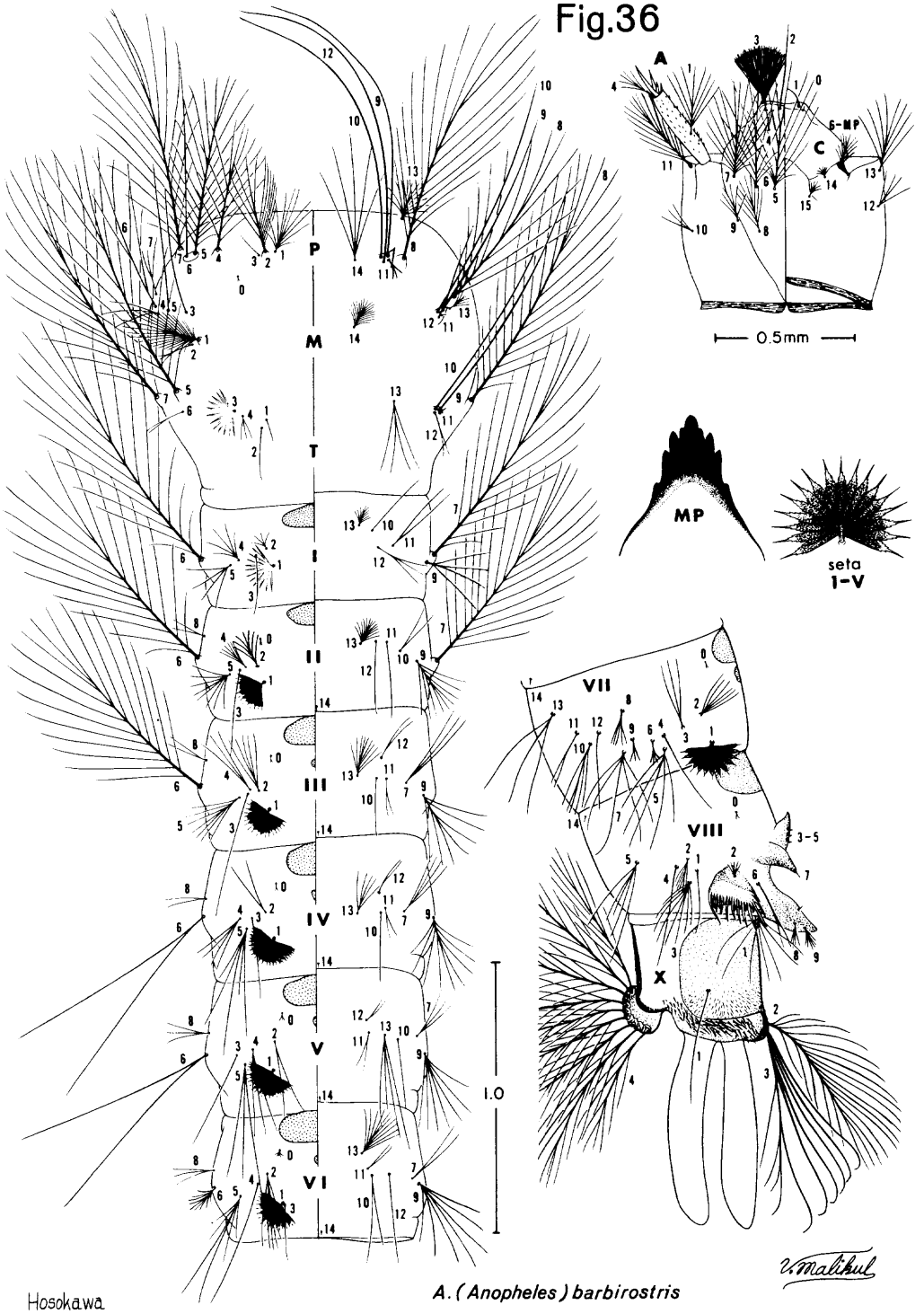

Fig.34
♂
1.0
♀
.05
.02
AE
leaflets
CL
1.0mm
Abdominal
sterna
0.1
Sonobe
A.(Anopheles) barbirostris

Fig. 35



A. (Anopheles) barbirostris

Fig.36



A. (Anopheles) barbirostris

Hosokawa

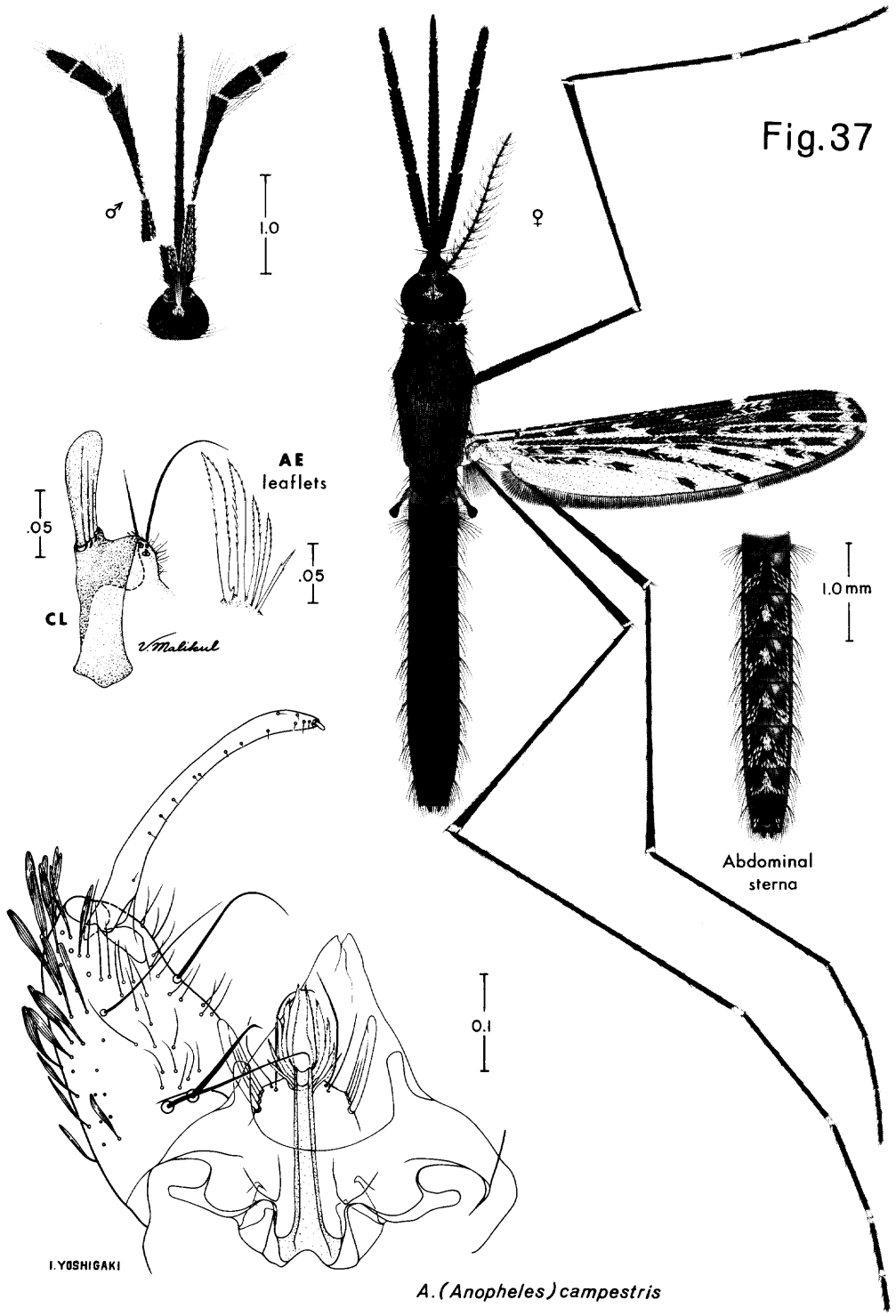
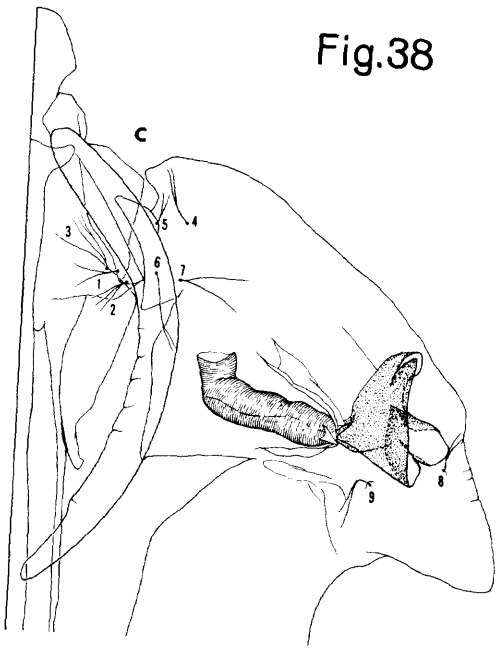
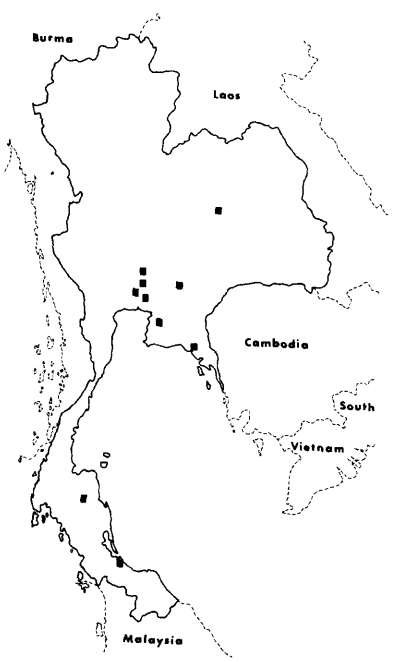

Fig.37
♂
1.0
♀
AE
leaflets
.05
.05
CL
Malikul
1.0 mm
Abdominal
sterna
0.1
I. YOSHIGAKI
A. (Anopheles) campestris

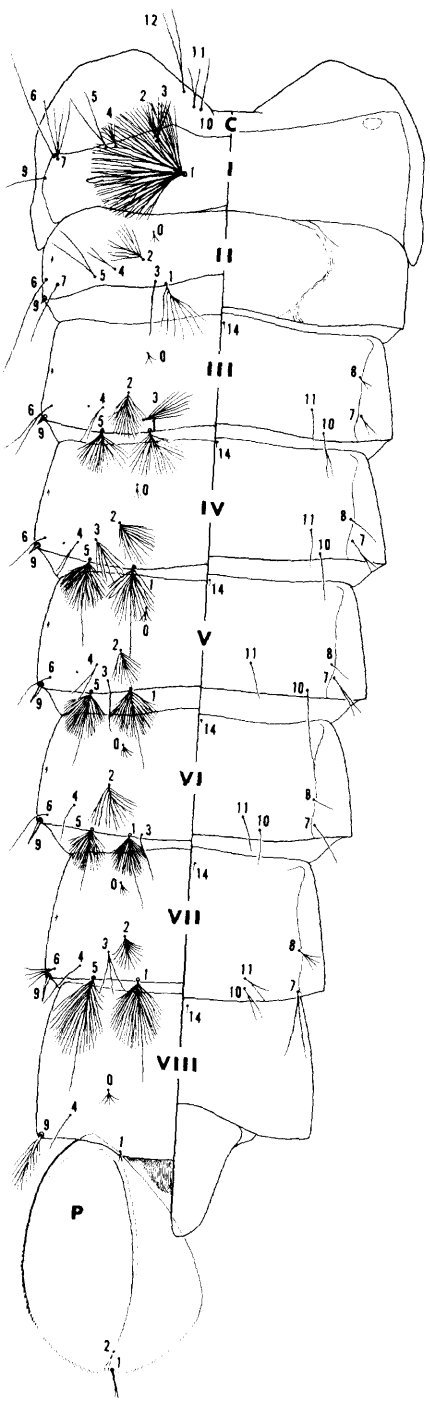
Fig.38





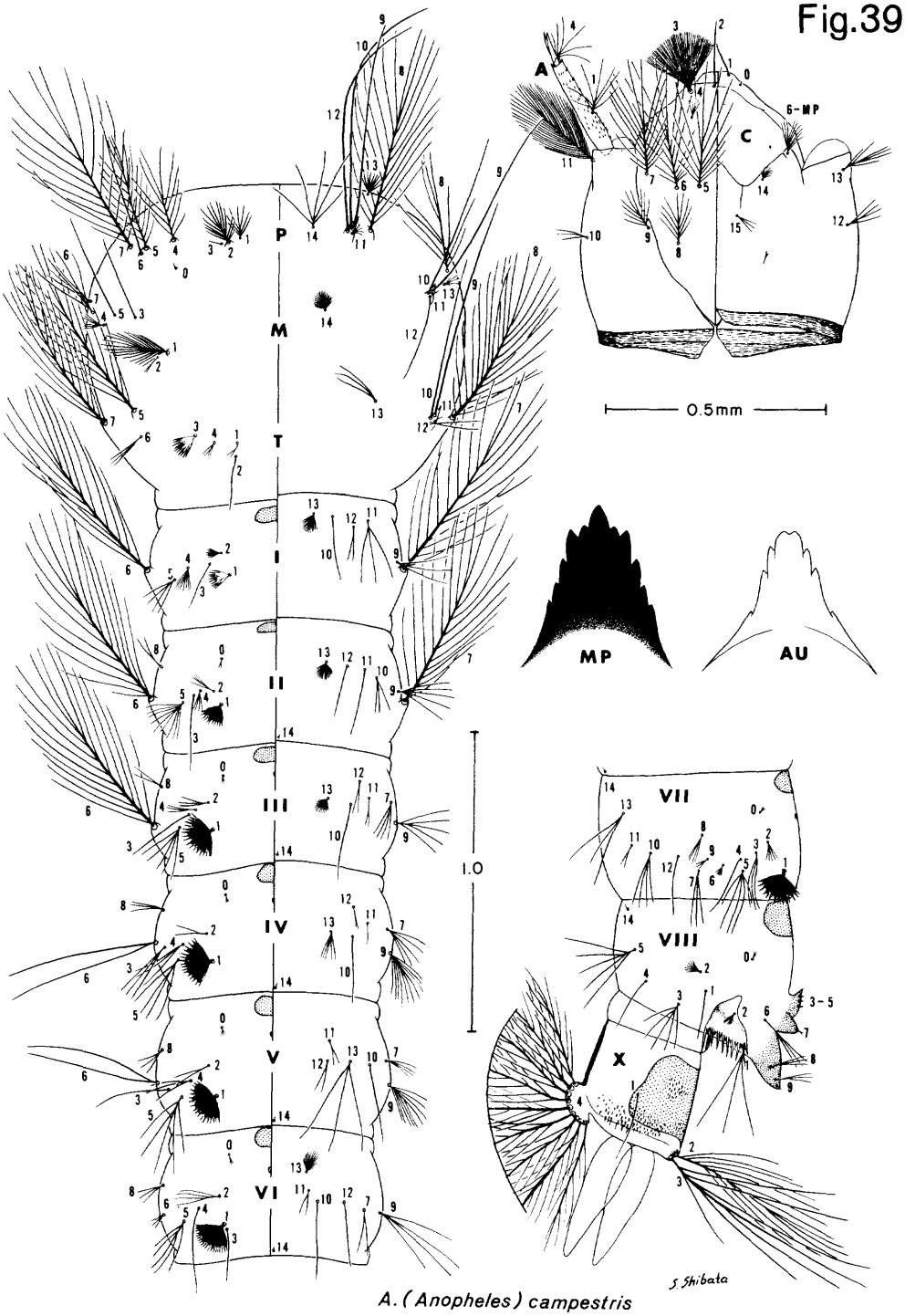
A. (Anopheles) campestris

1.0mm

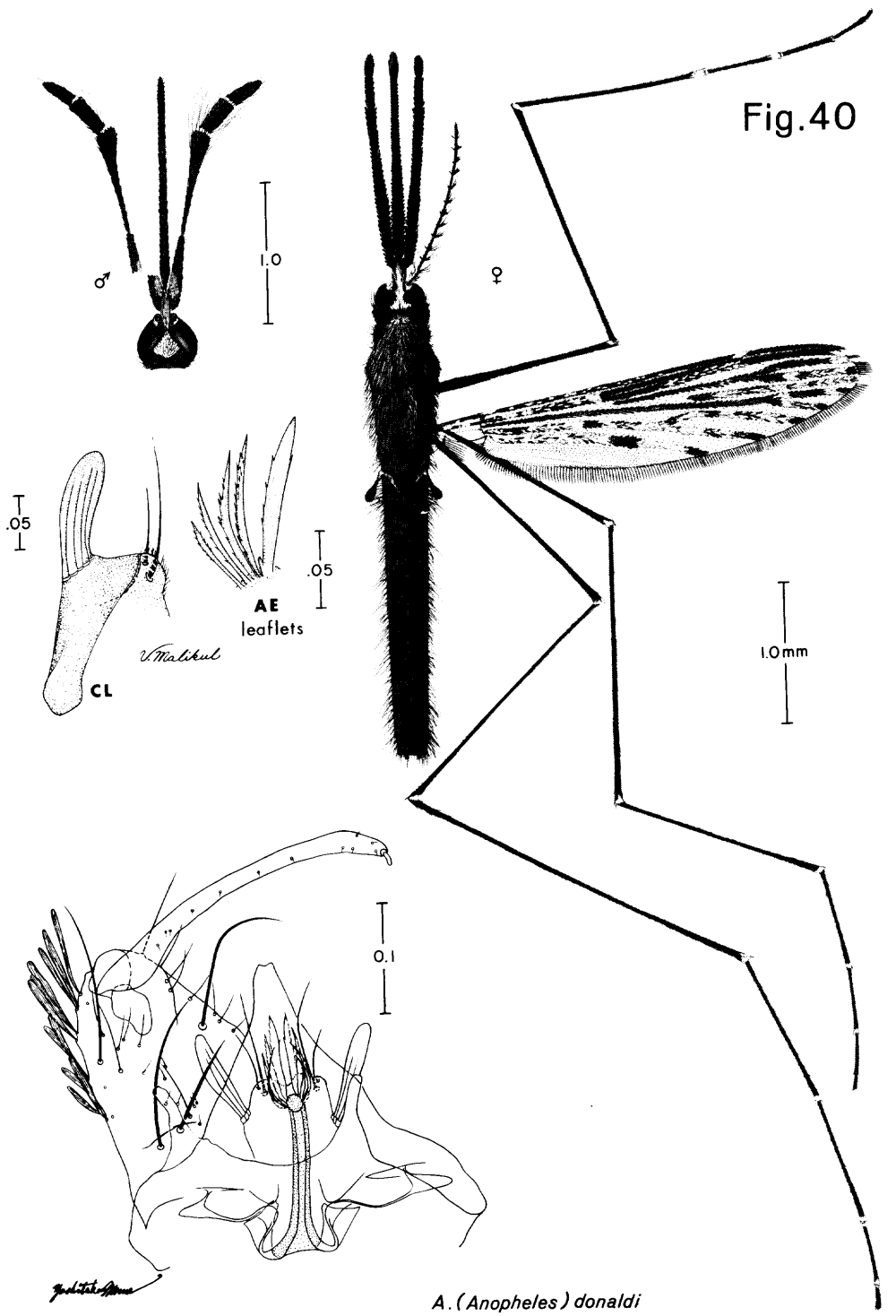


Hosokawa

Fig.39

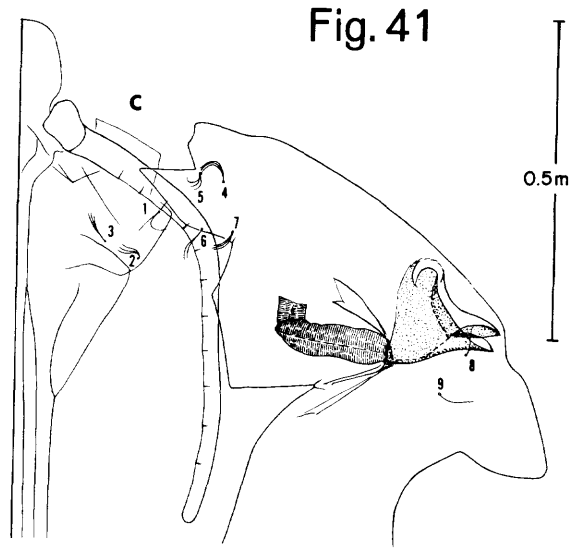


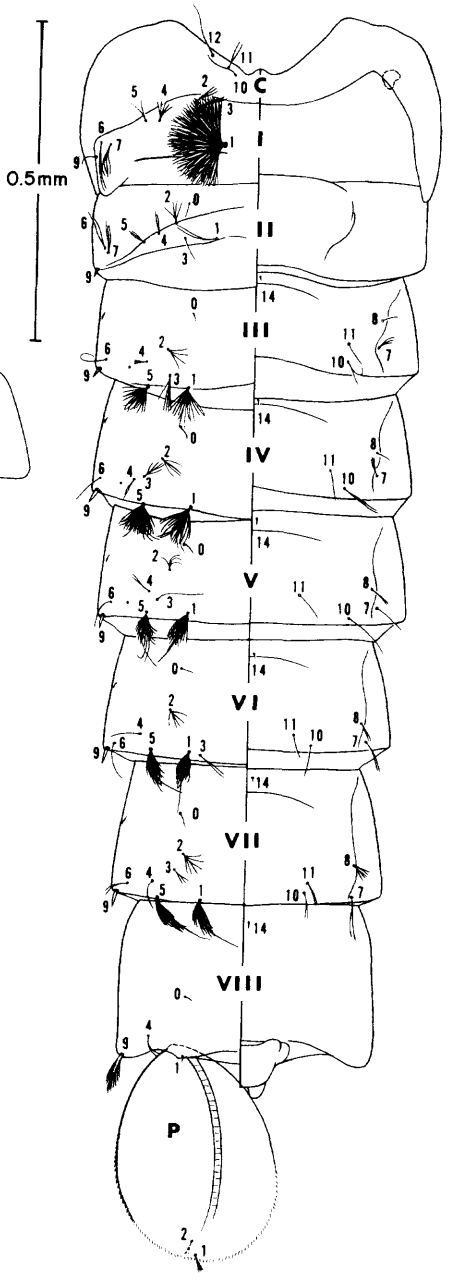
A. (Anopheles) campestris

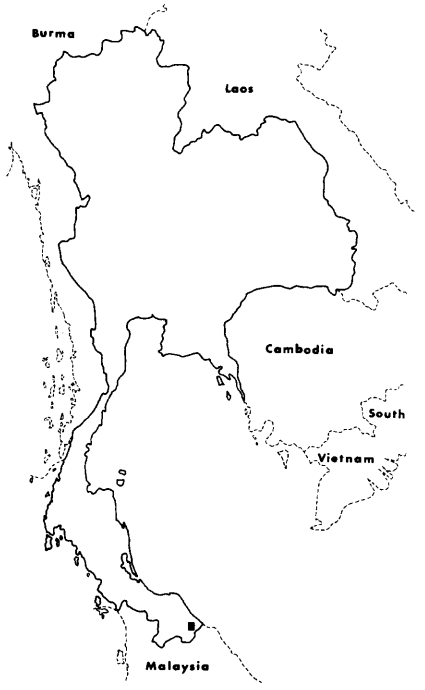


A. (Anopheles) donaldi

Fig. 41

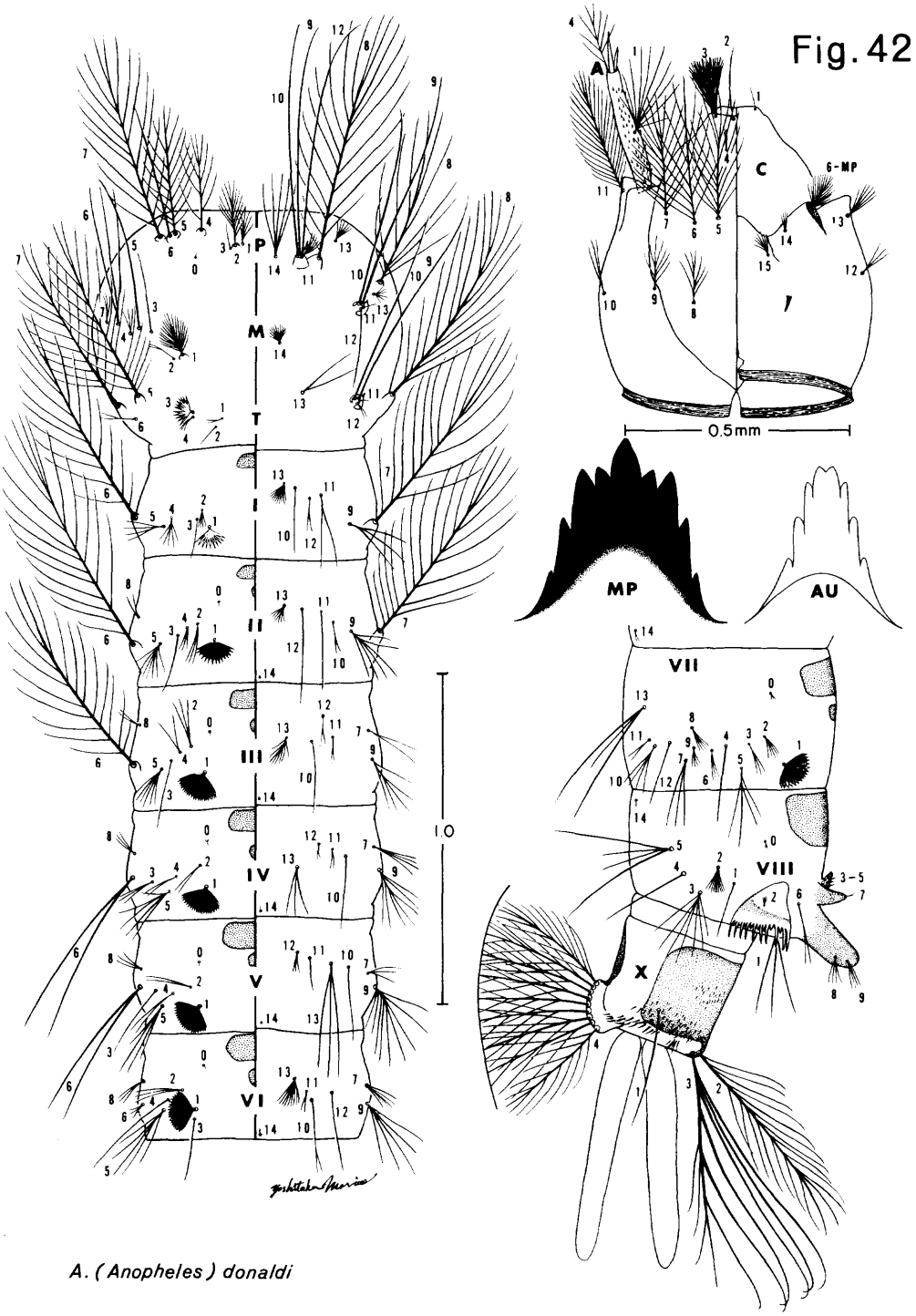






A. (Anopheles) donaldi

Sonobe



A. (Anopheles) donaldi

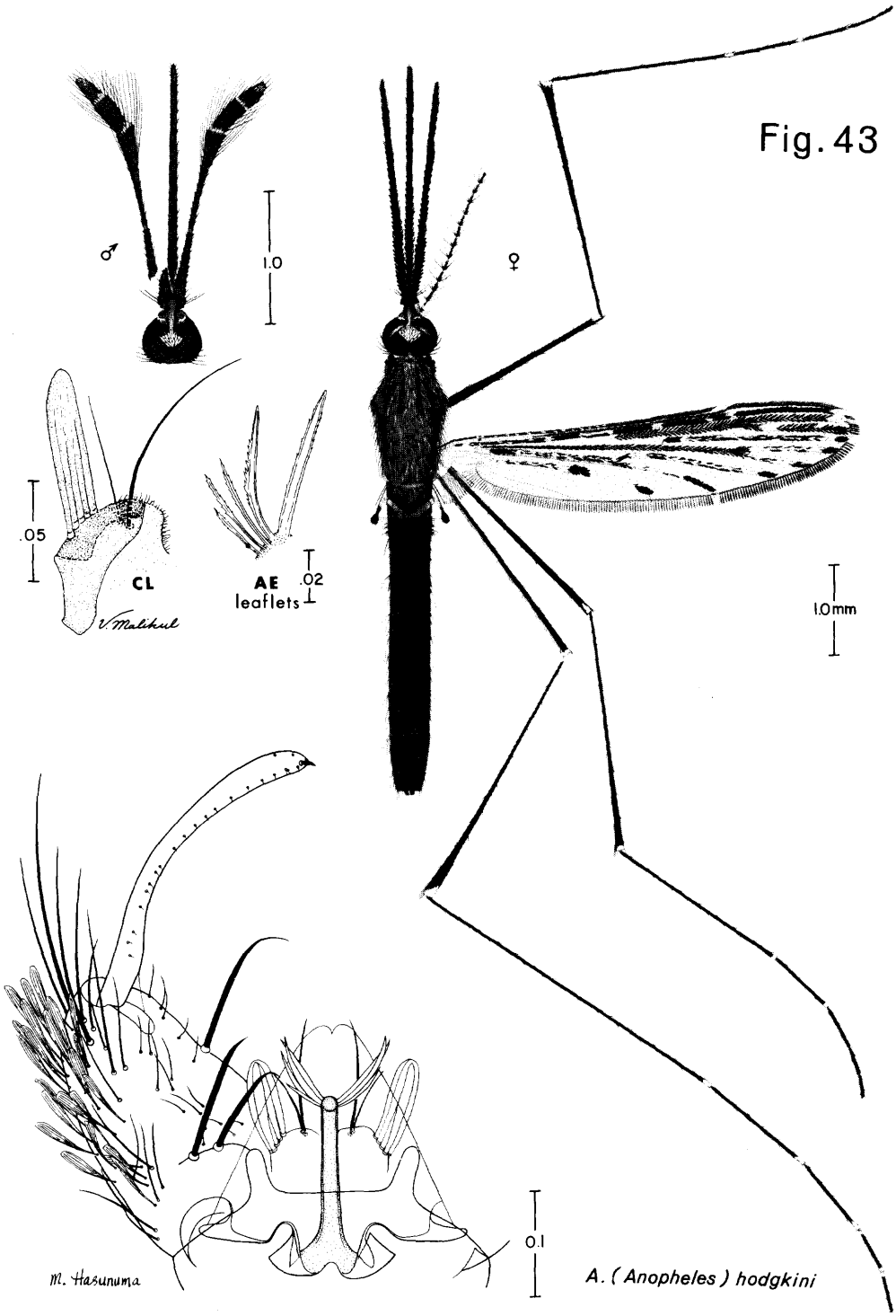
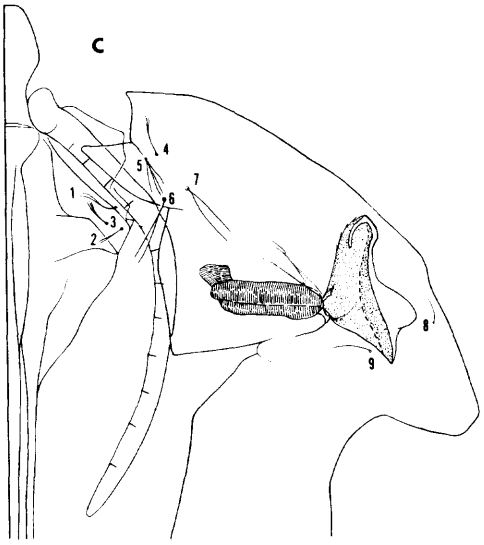
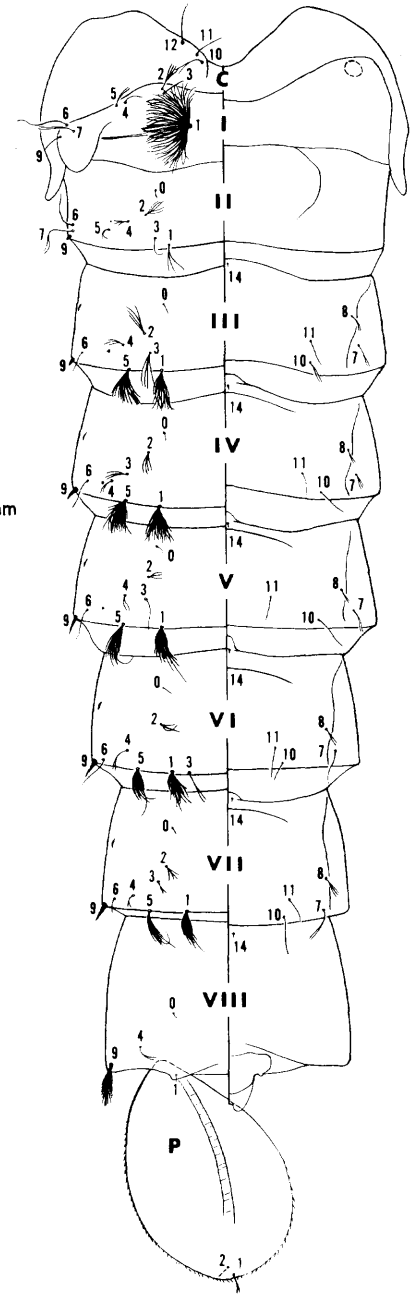
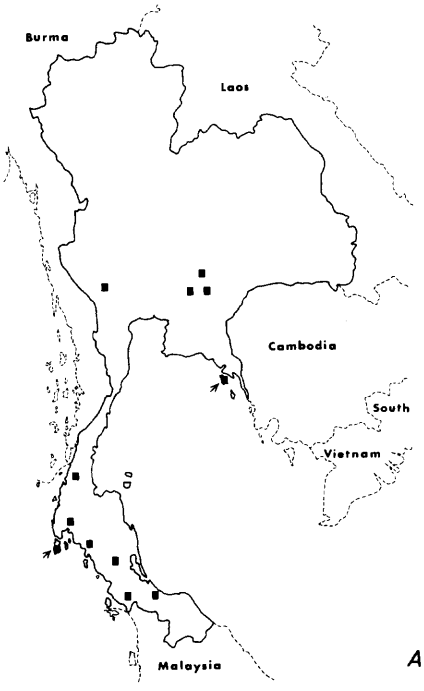

Fig. 43
♂
1.0
♀
.05
CL
V. Malikul
AE
leaflets
.02
1.0mm
0.1
M. Hazunuma
A. (Anopheles) hodgkini

Fig. 44





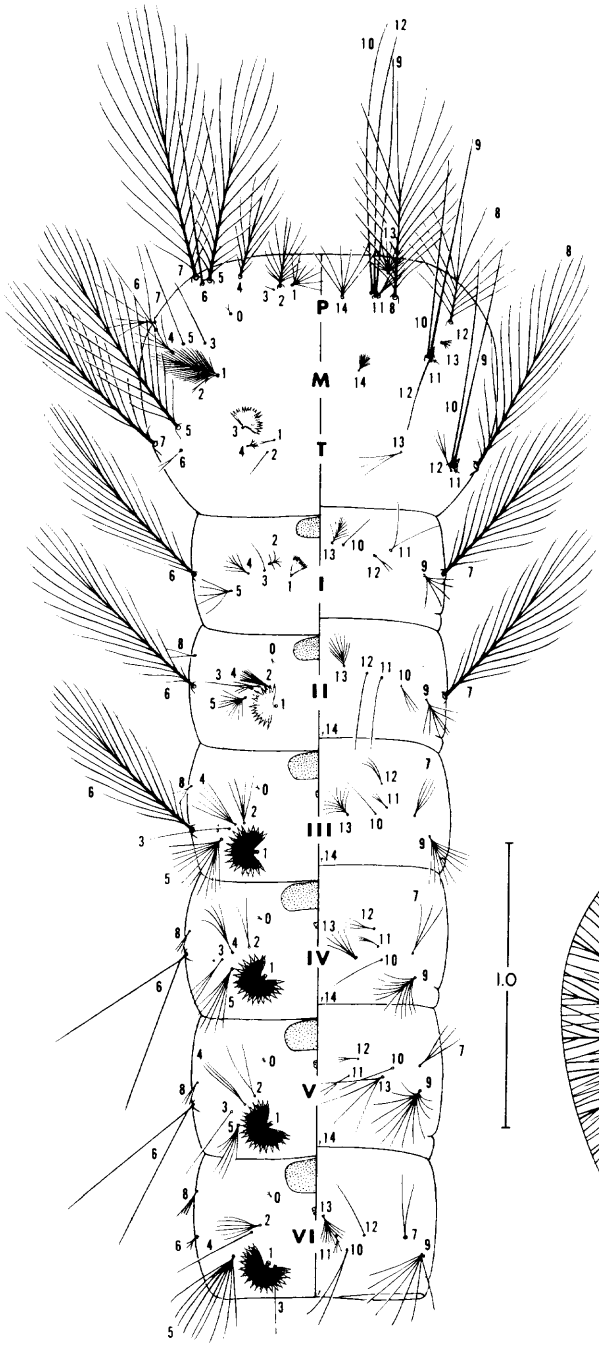
0.5mm

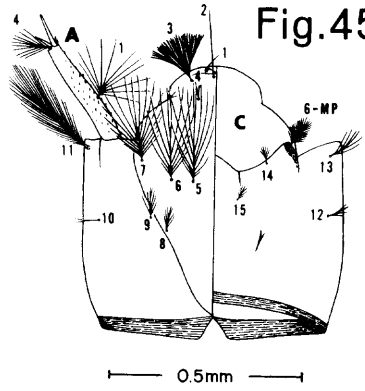


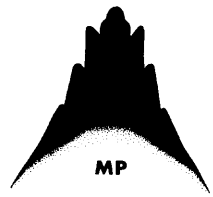
A.(Anopheles) hodgkini

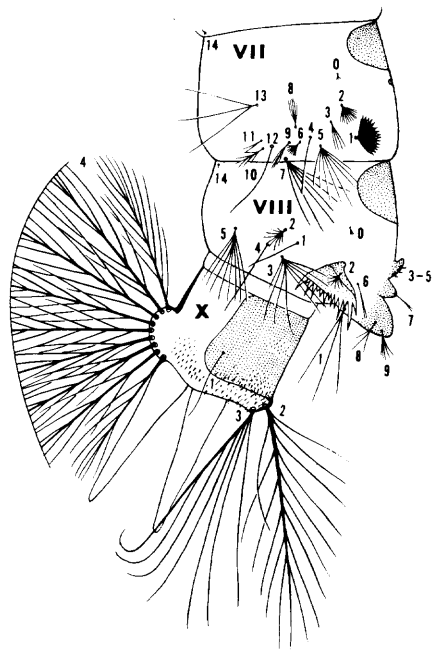
Sonobe

Fig.45









A.(Anopheles) hodgkini

Sənobe

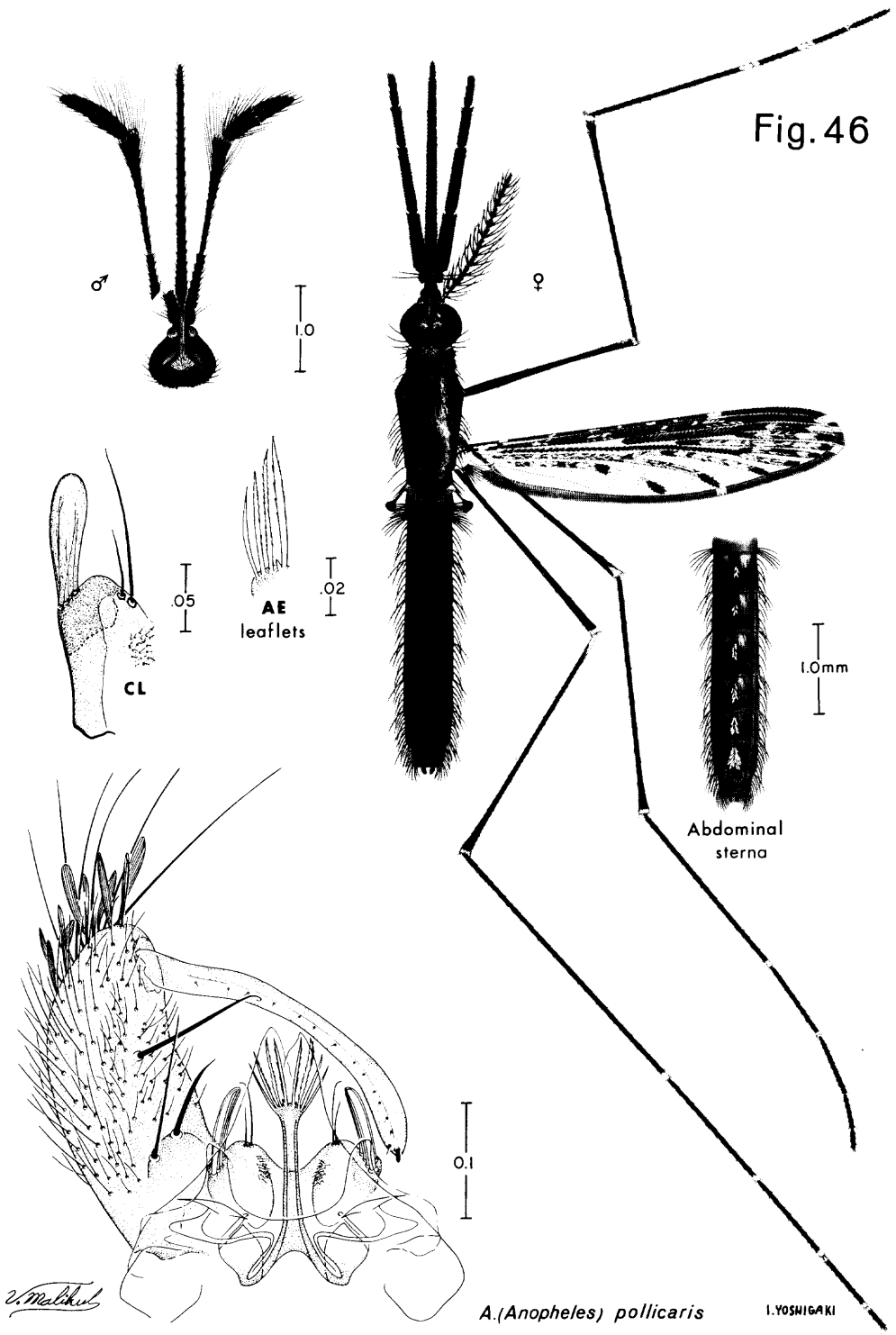
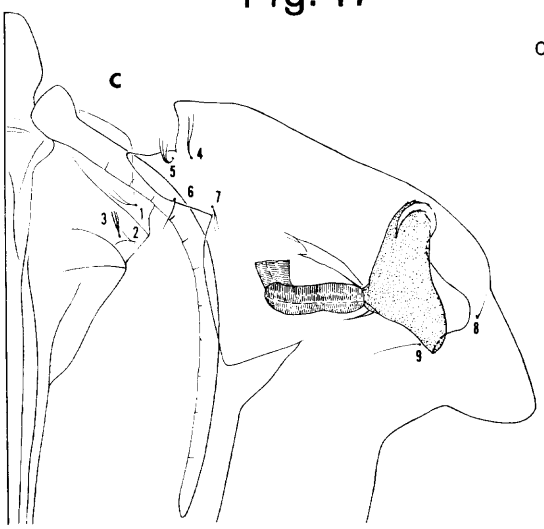
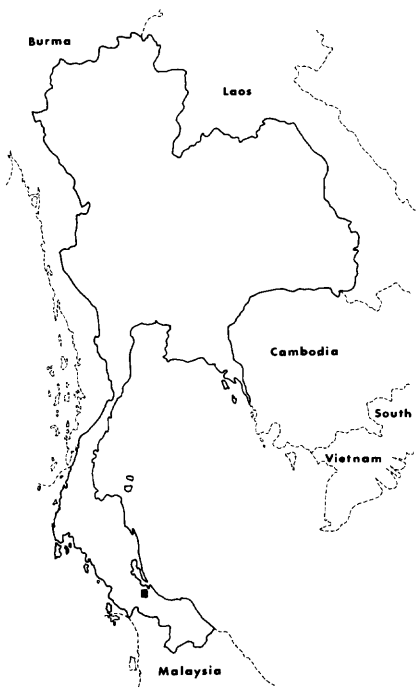
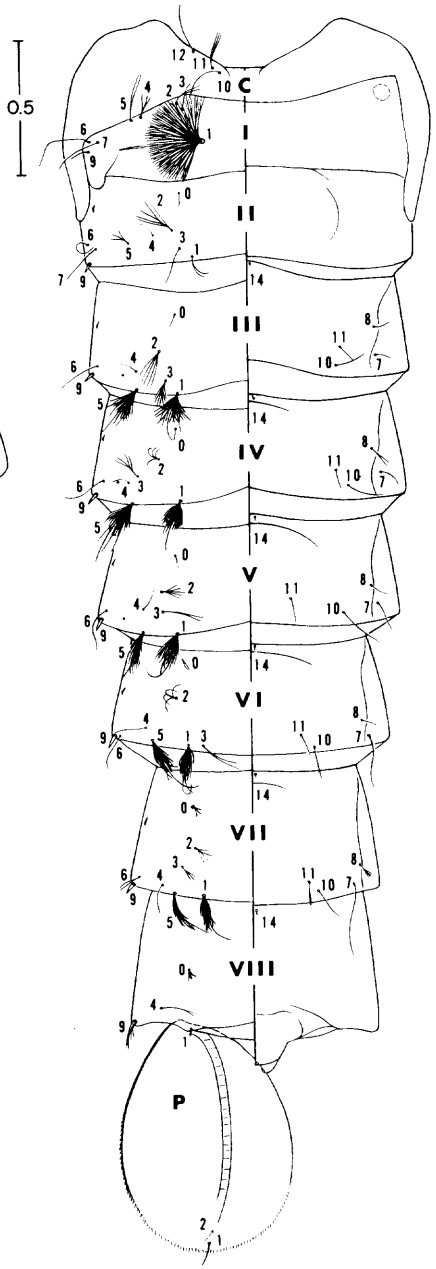

Fig. 46
♂
♀
1.0
.05
CL
AE
leaflets
.02
1.0mm
Abdominal
sterna
0.1
A.(Anopheles) pollicaris
I.YOSHIGAKI

Fig.47

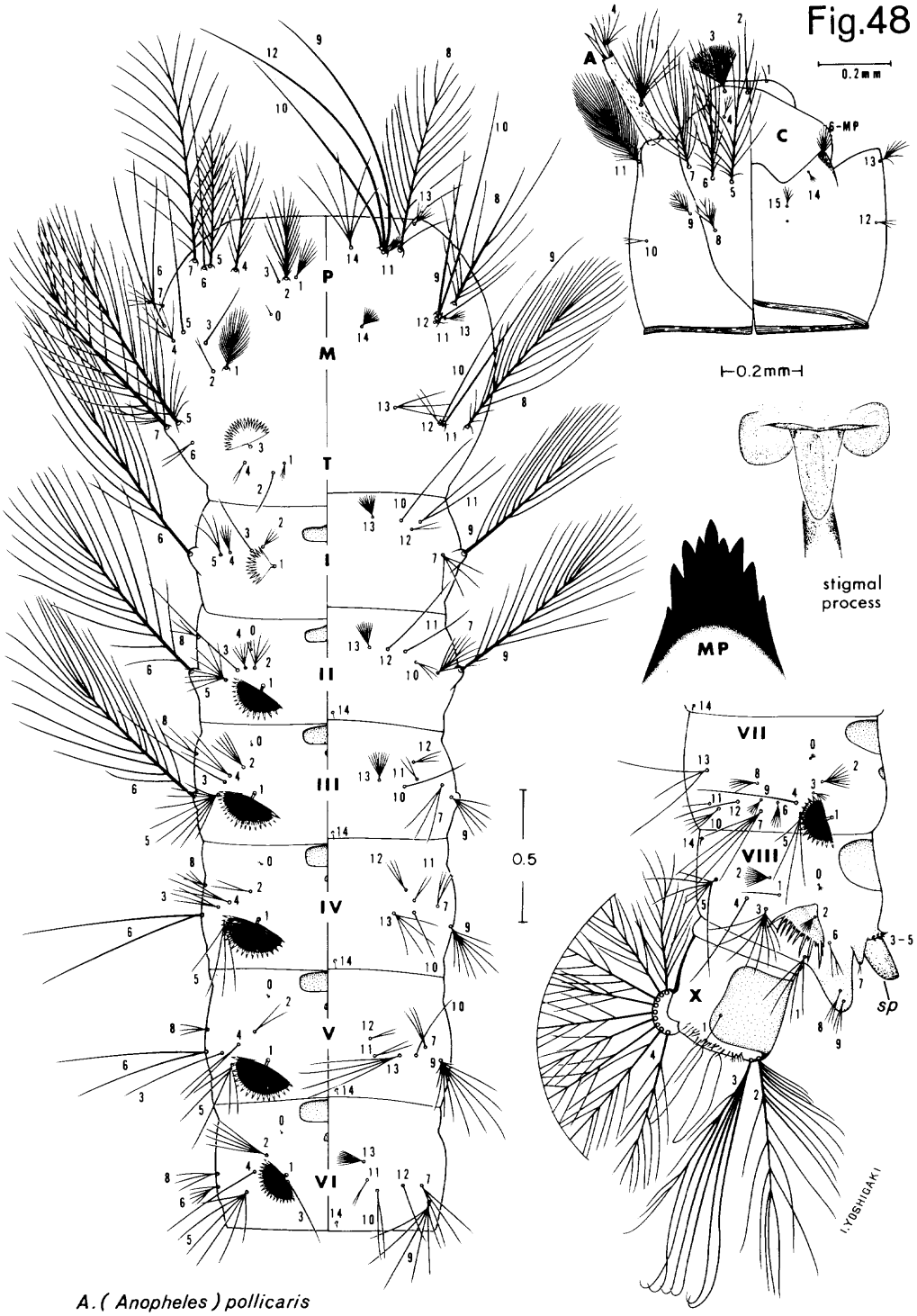






A. (Anopheles) pollicaris

Sonobe



A. (Anopheles) pollicaris

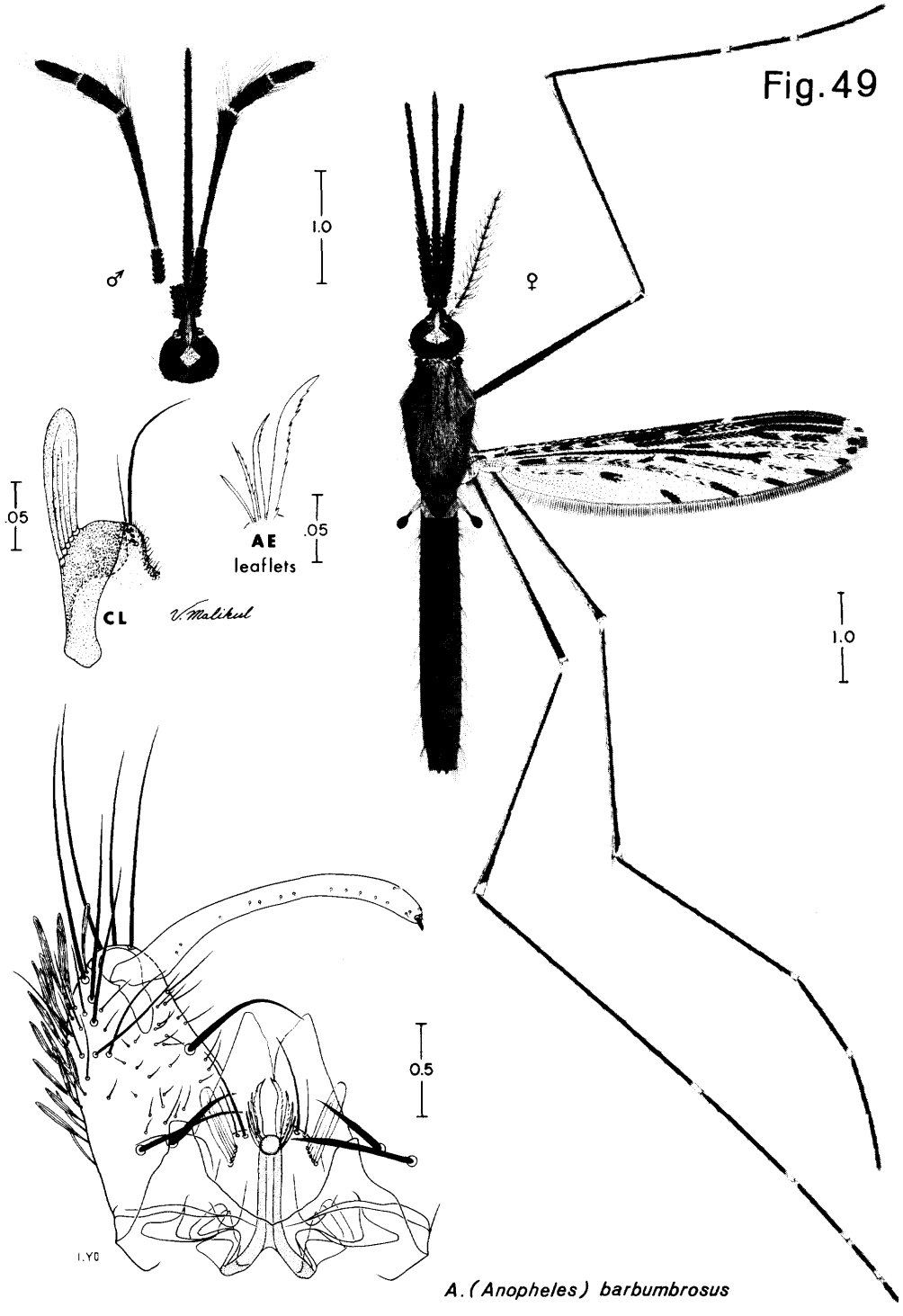
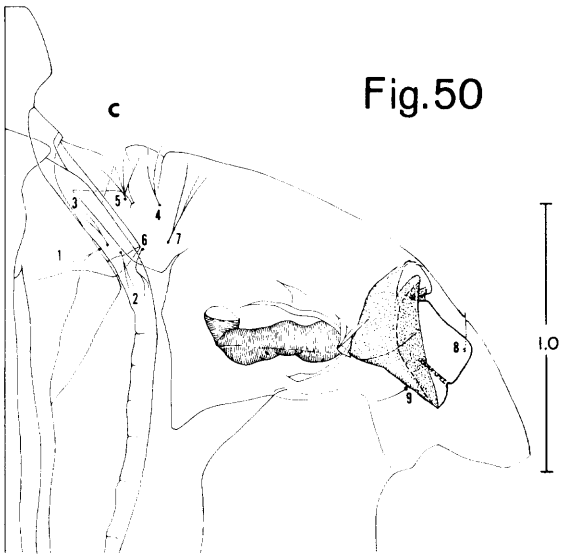
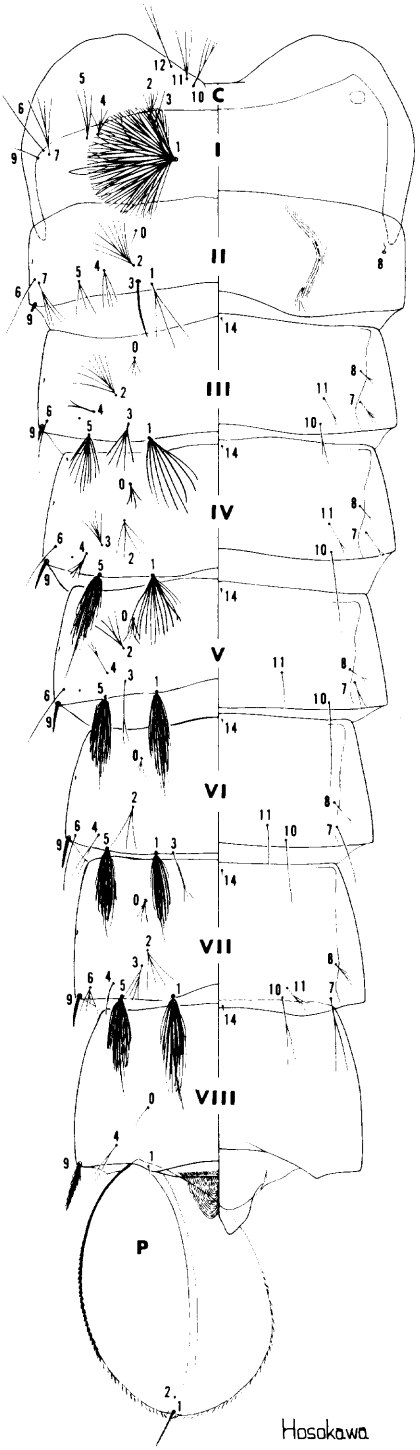
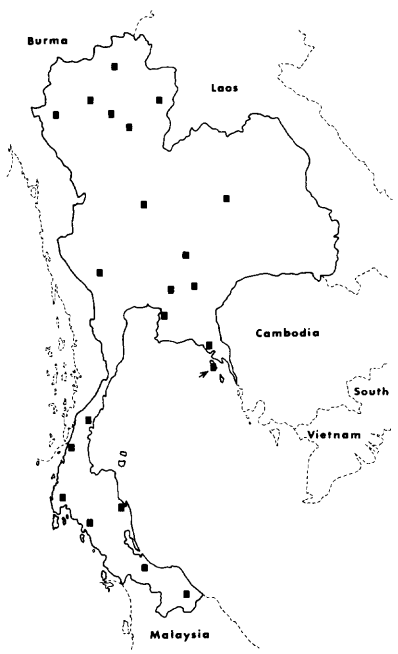

Fig. 49
♂
1.0
.05
CL
V. Malikul
AE
leaflets
.05
♀
1.0
0.5
I.YO
A. (Anopheles) barbumbrosus

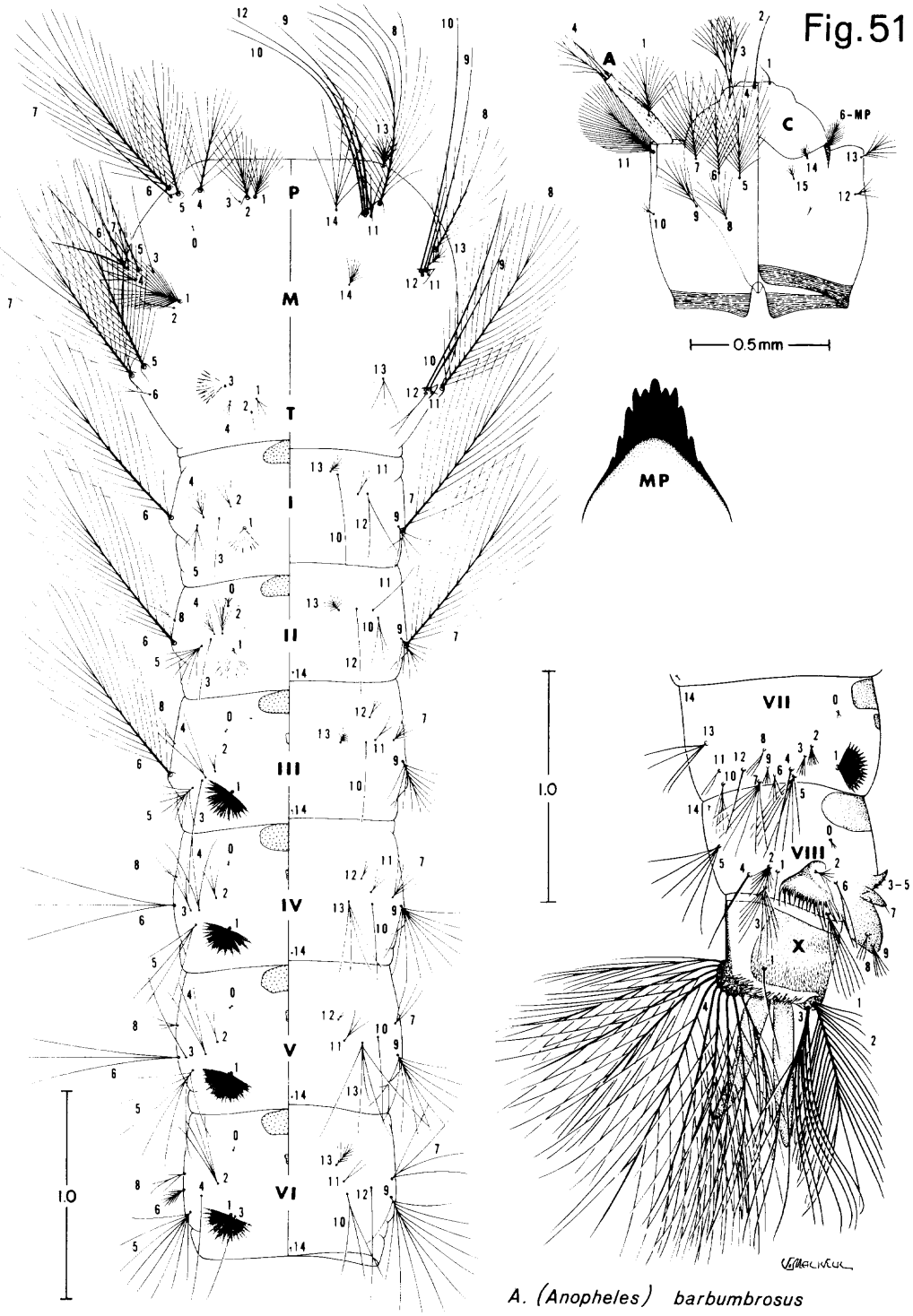
Fig.50

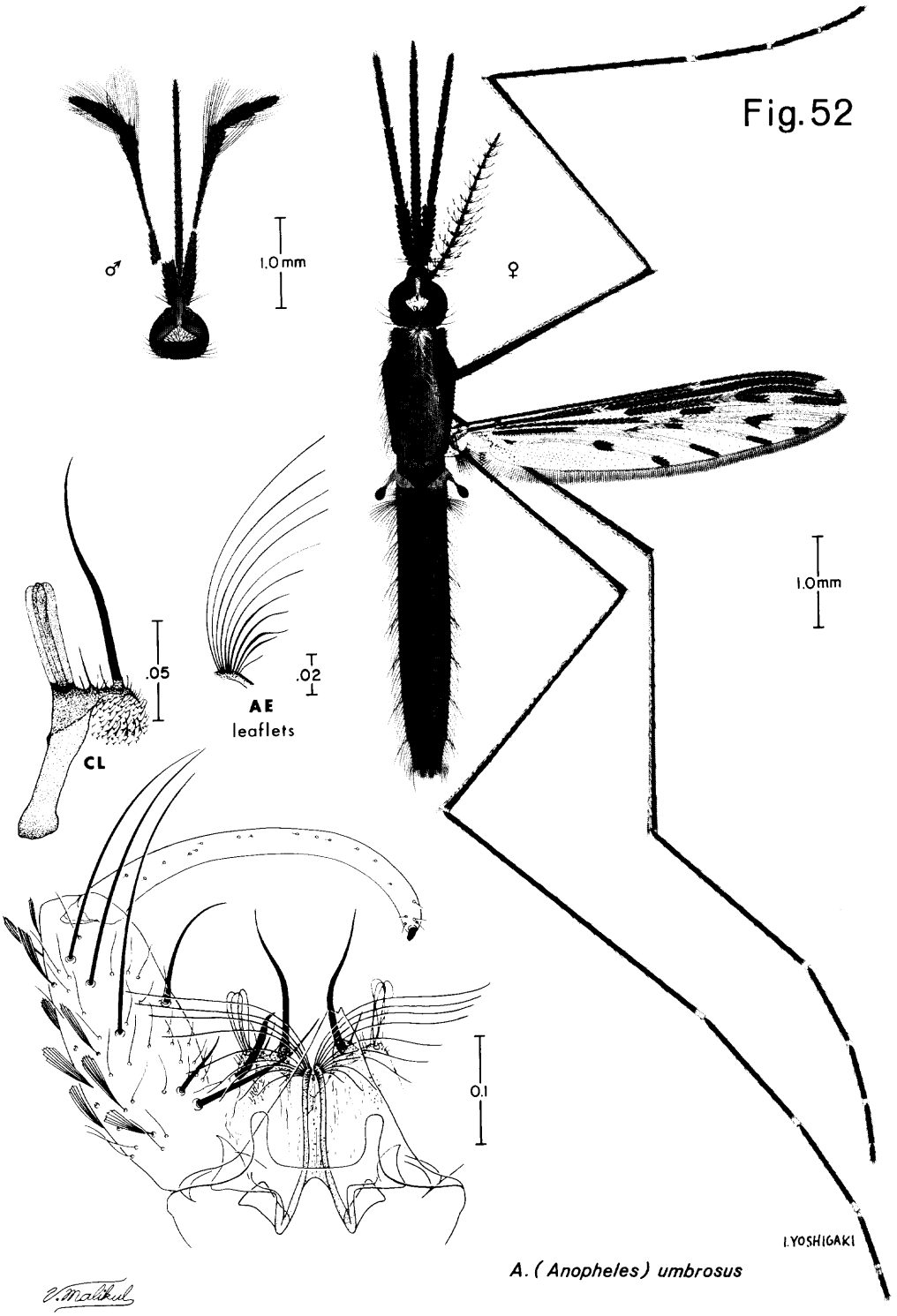




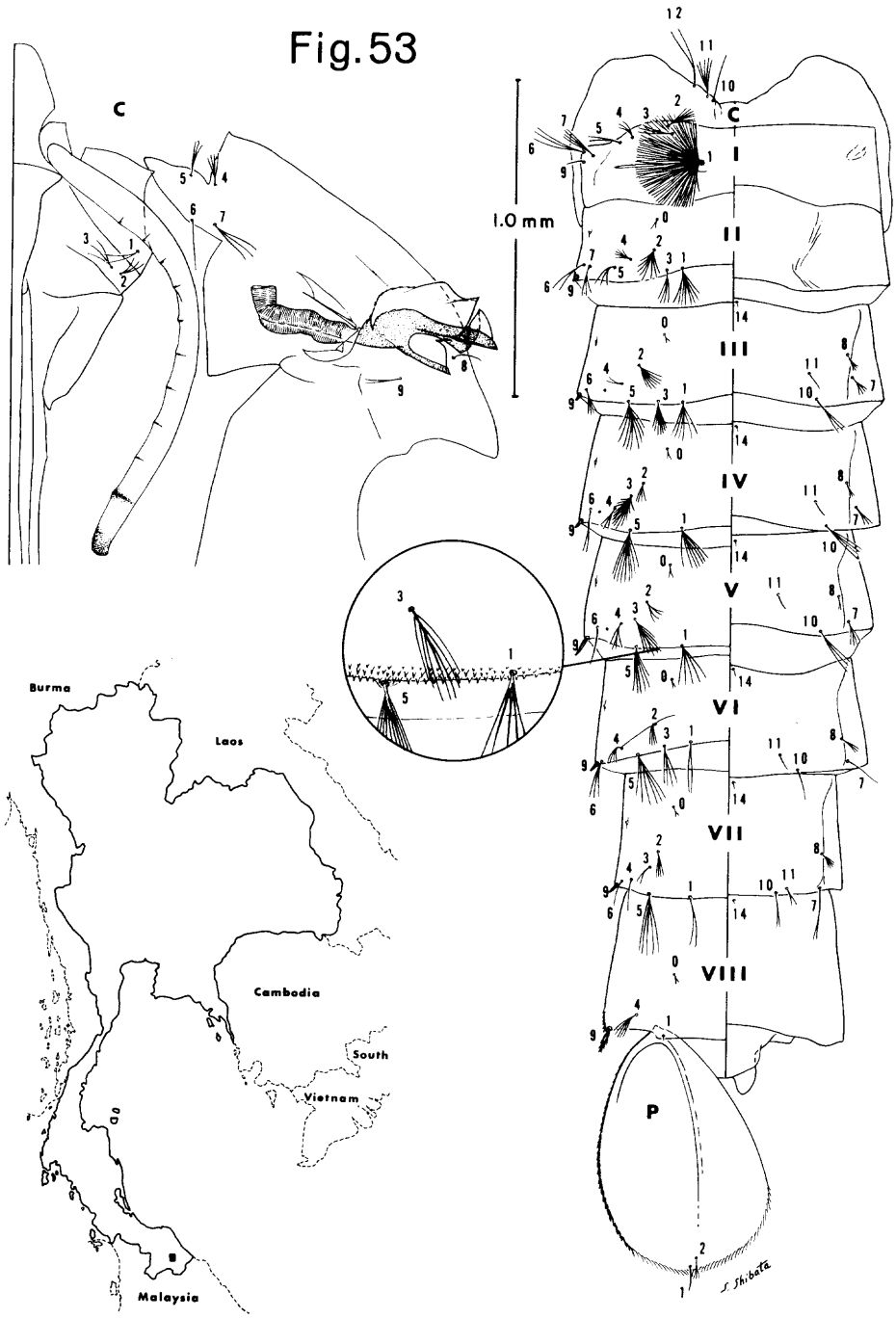


A. (Anopheles) barbumbrosus


Fig.51
A
C
6-MP
0.5mm
MP
P
M
T
I
II
III
IV
V
VI
VII
VIII
X
1.0
1.0
A. (Anopheles) barbumbrosus

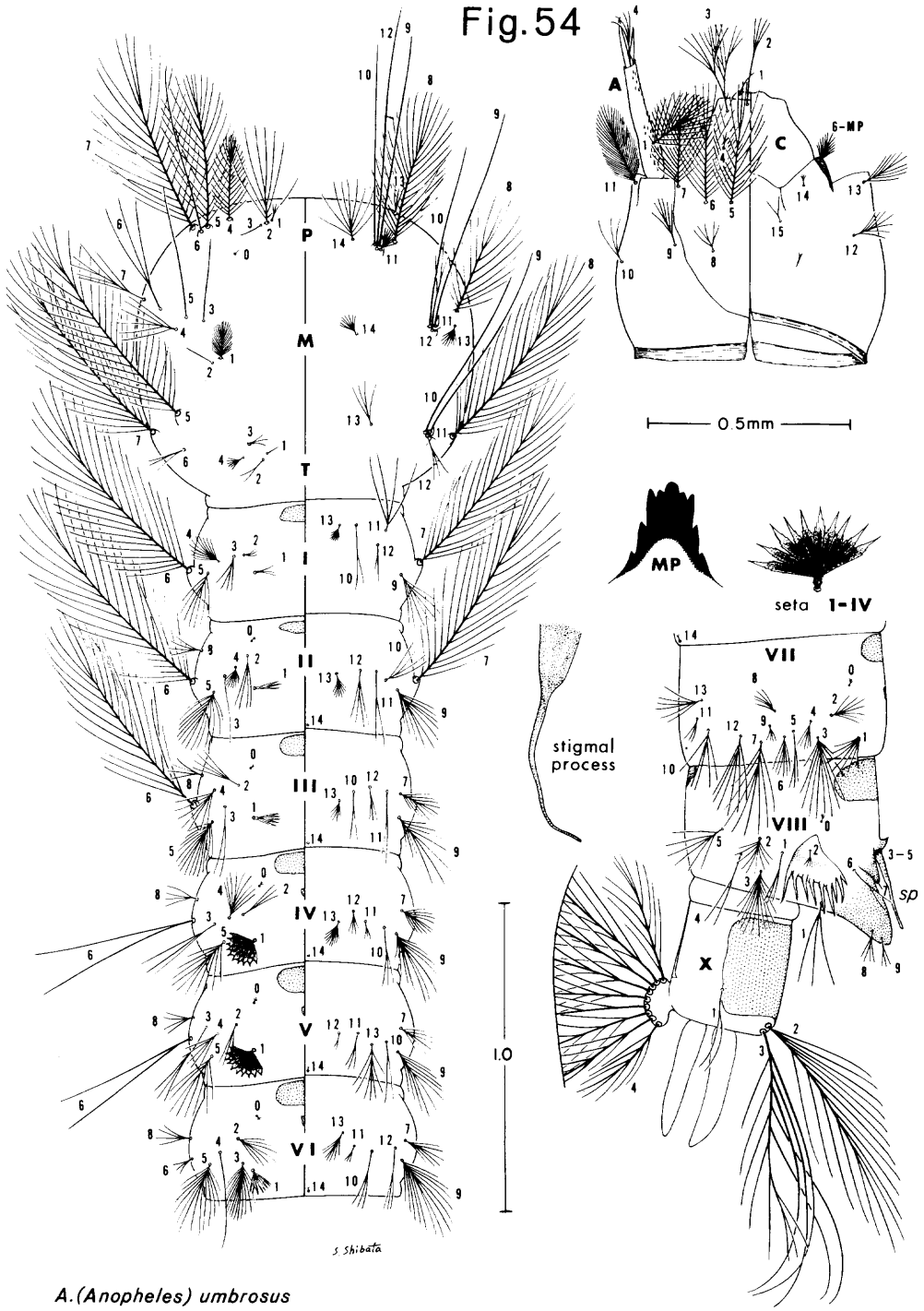


A. (Anopheles) umbrosus



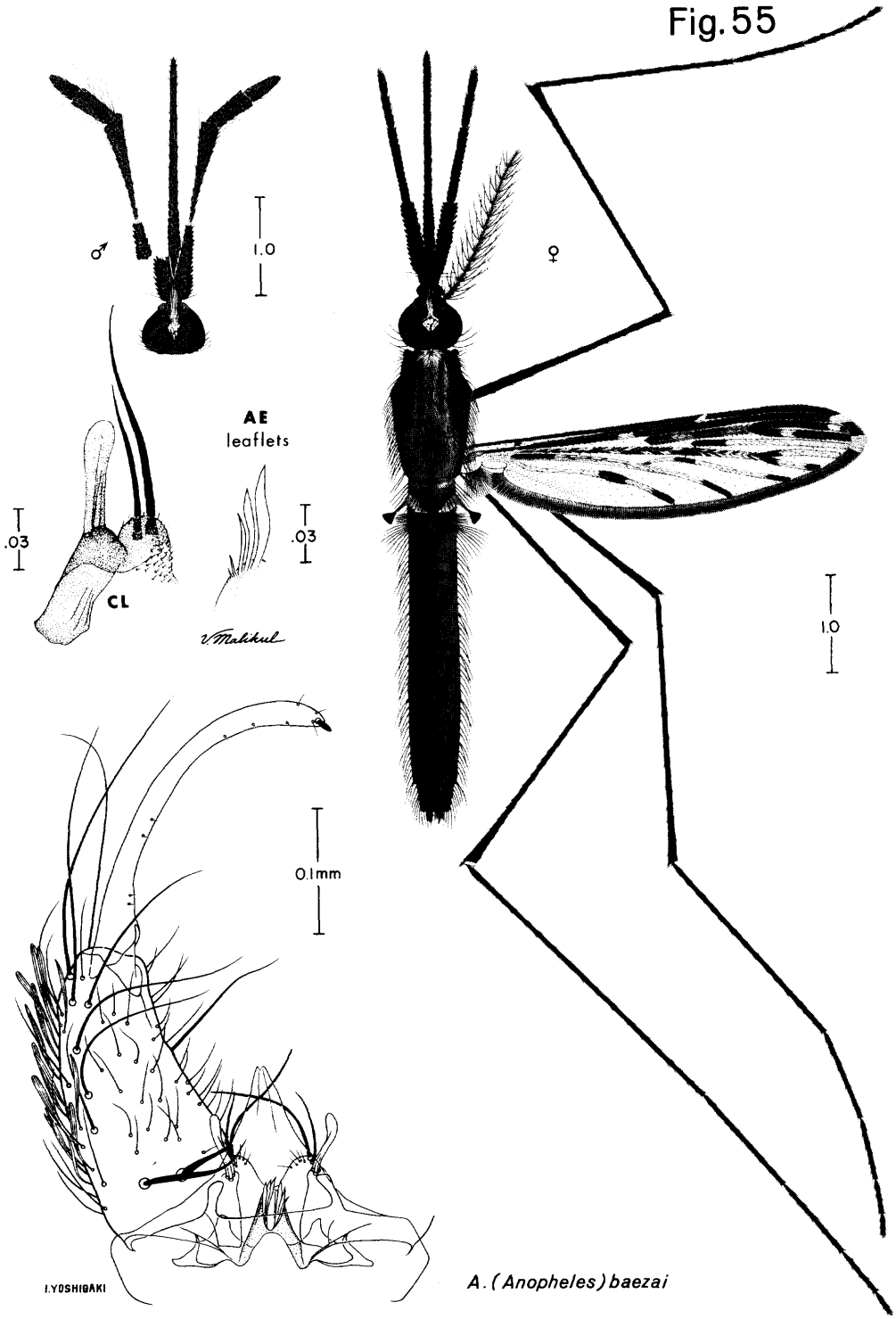
A. (Anopheles) umbrosus

Fig.54



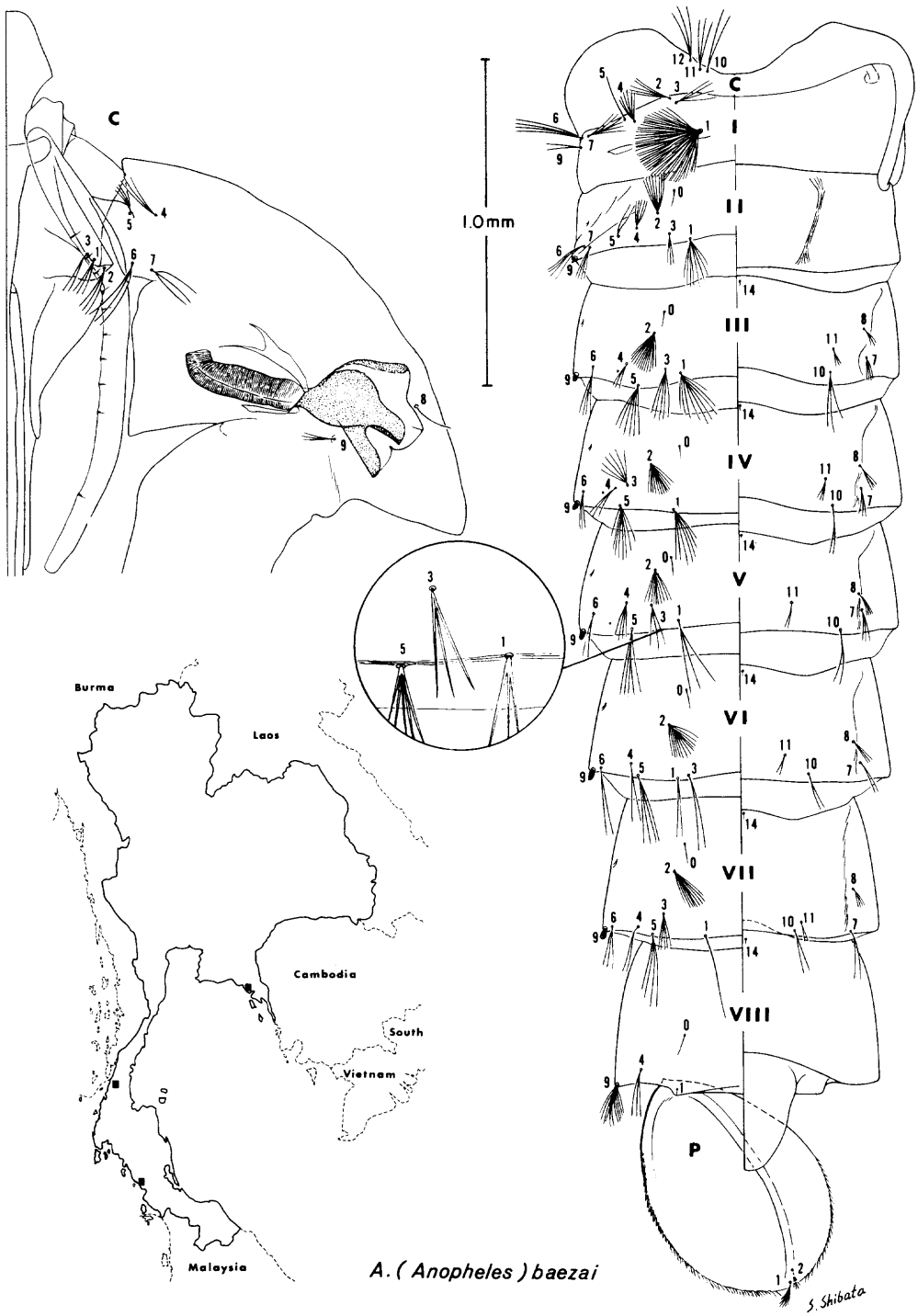
A.(Anopheles) umbrosus

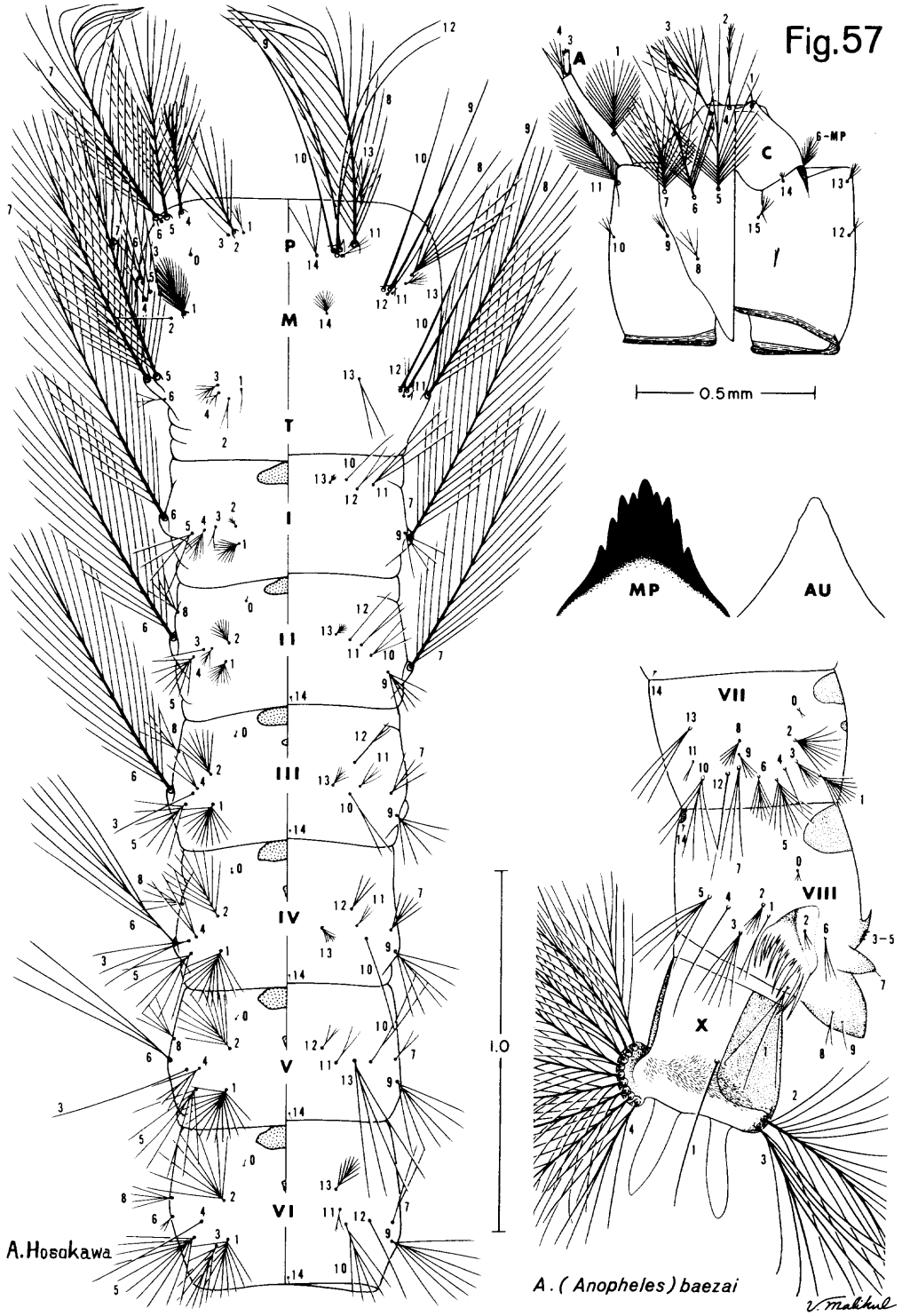
Fig. 55

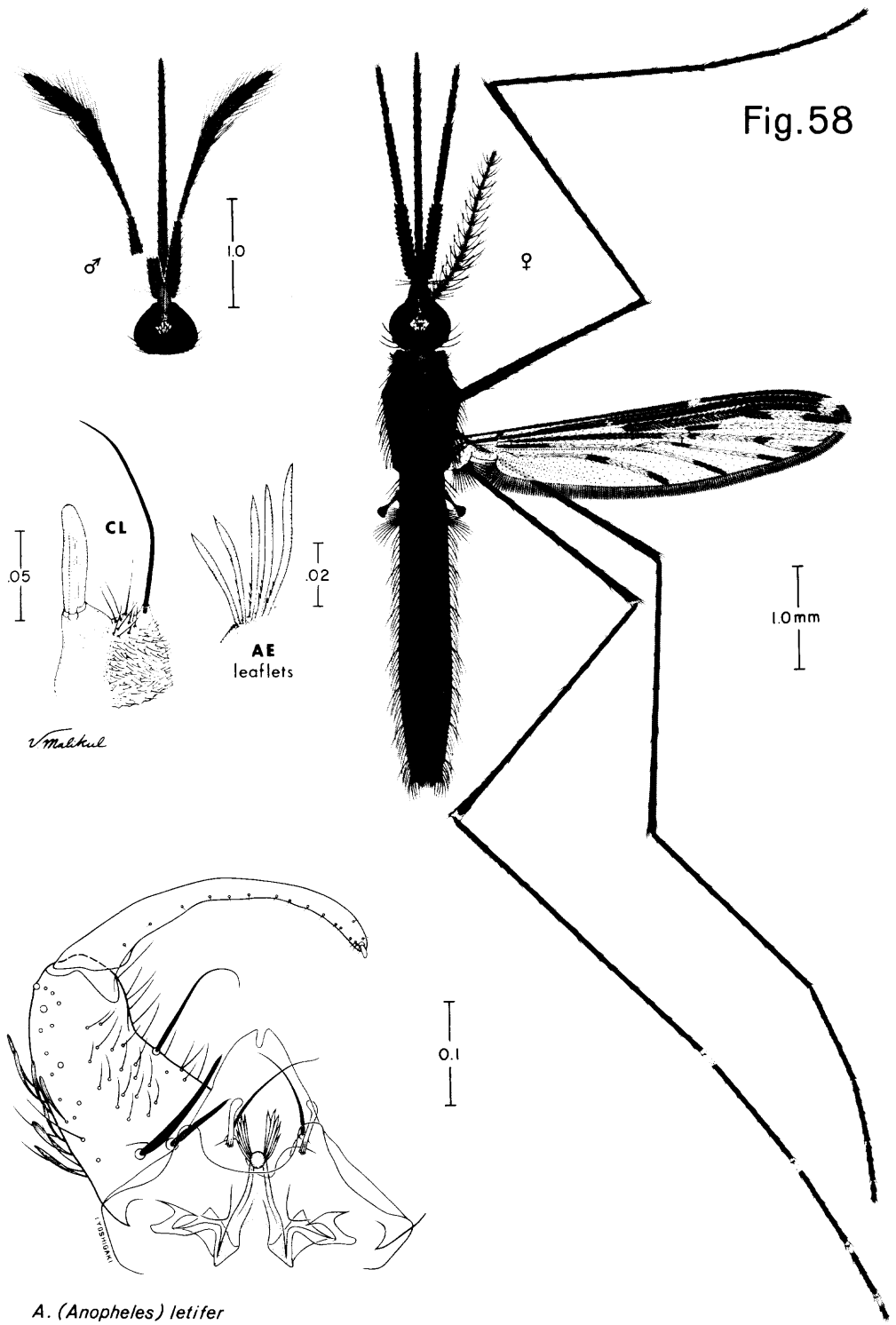


A. (Anopheles) baezai

Fig.56

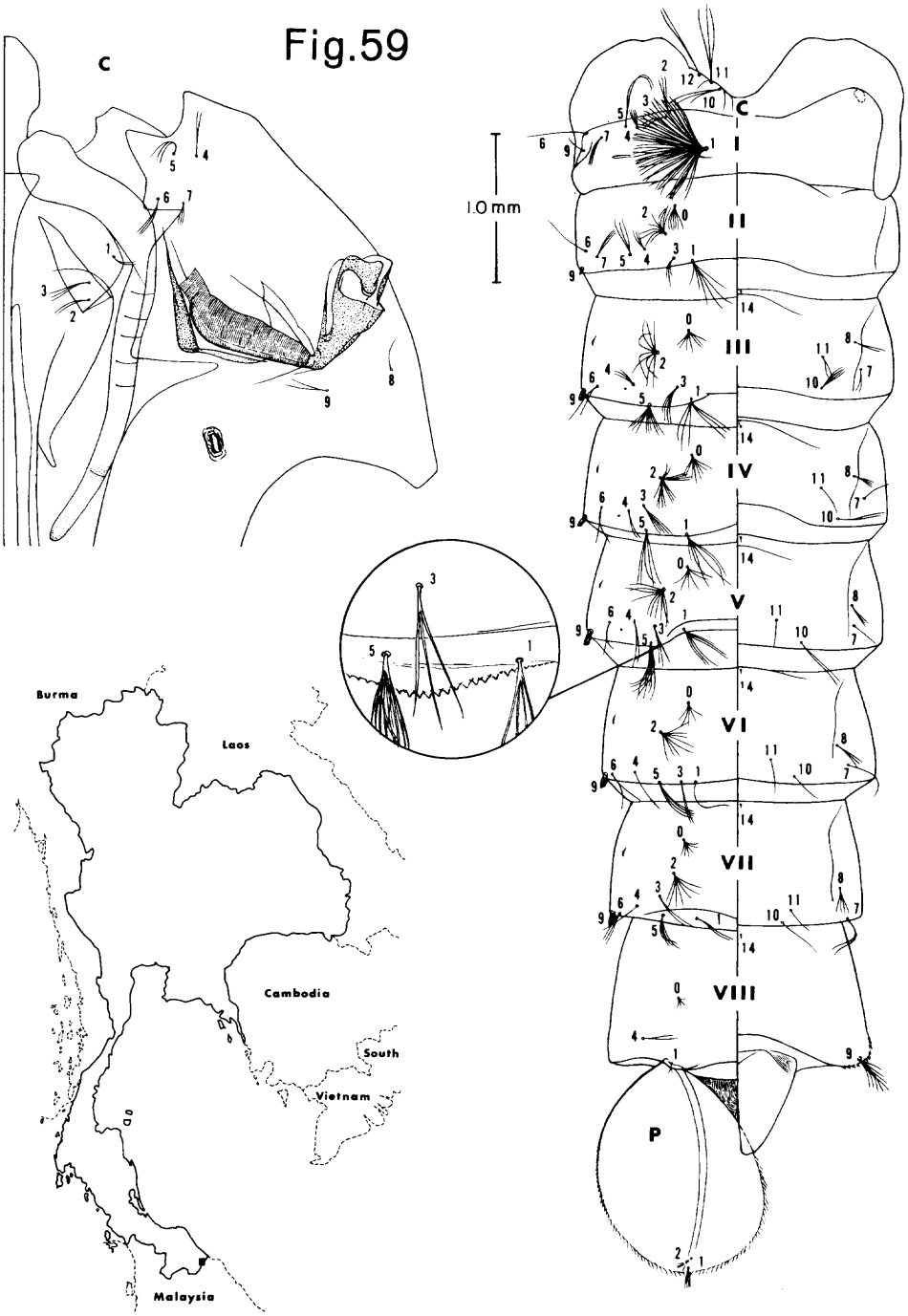

C
1.0mm
I
II
III
IV
V
VI
VII
VIII
P
Burma
Laos
Cambodia
South
Vietnam
Malaysia
A. (Anopheles) baezai
S. Shibata


Fig.57
A
C
6-MP
0.5mm
MP
AU
P
M
T
I
II
III
IV
V
VI
VII
VIII
X
3-5
1.0
A.Hosokawa
A. (Anopheles) baezai



A. (Anopheles) letifer

Fig.59



A. (Anopheles) letifer

sonobe

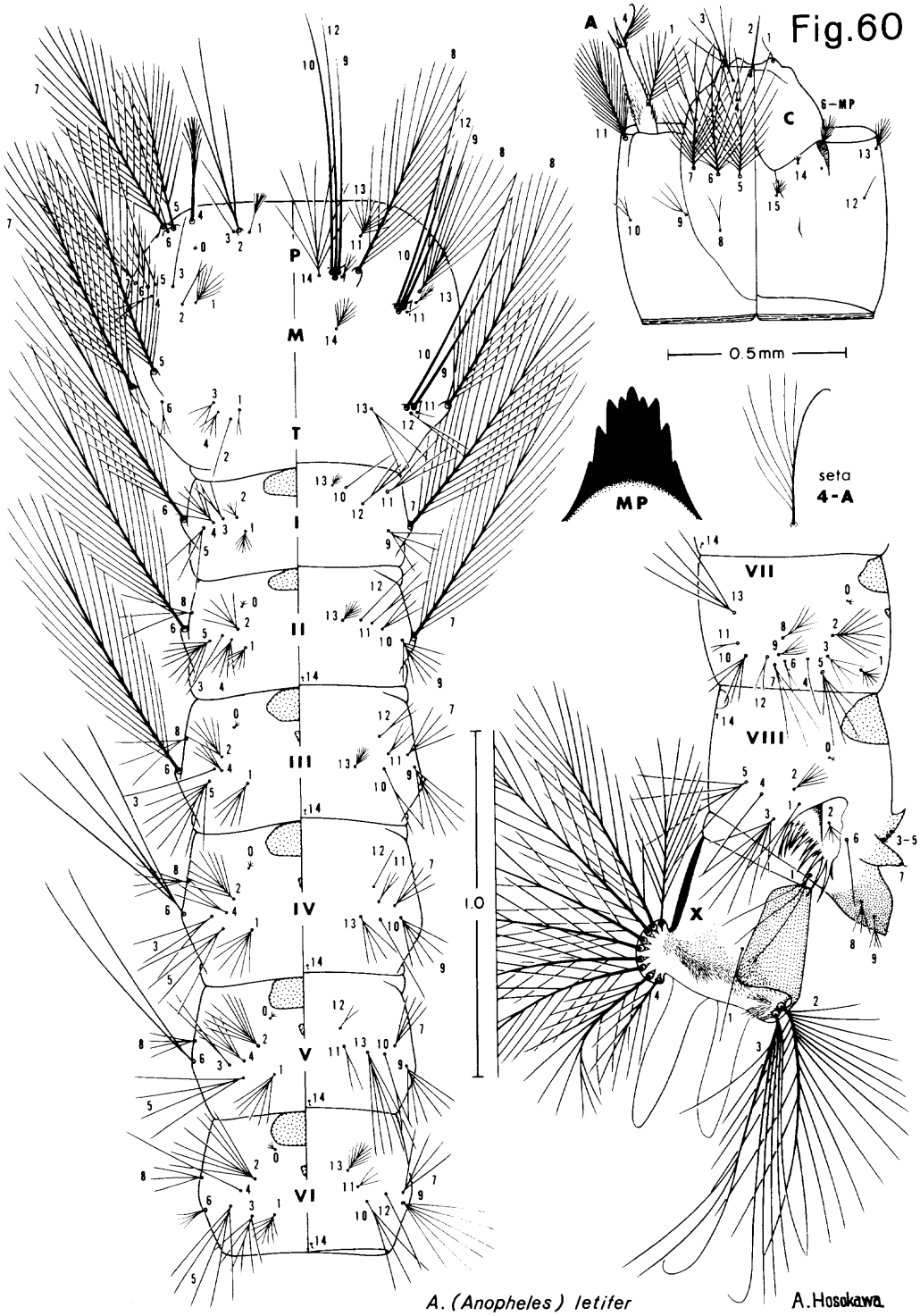
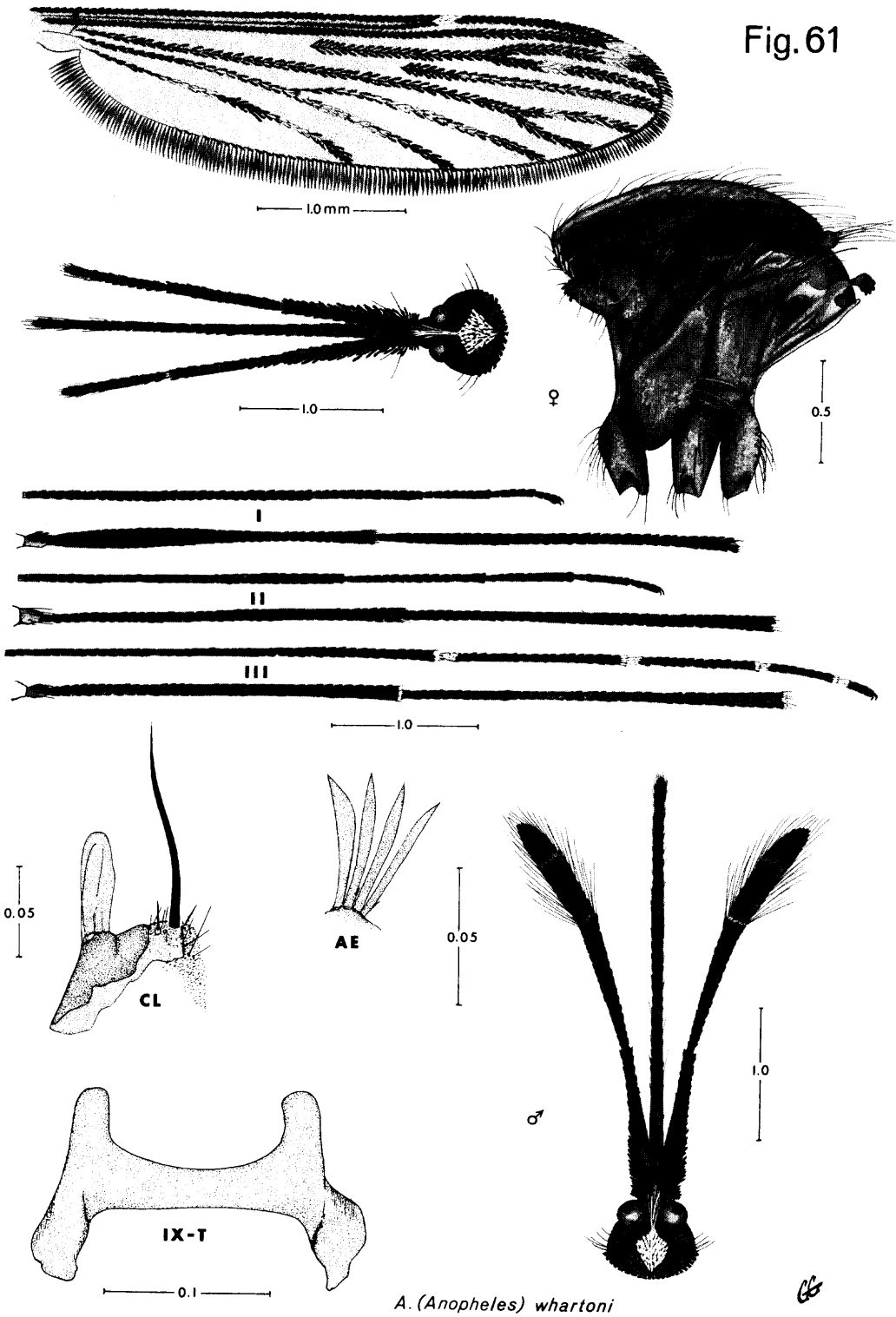
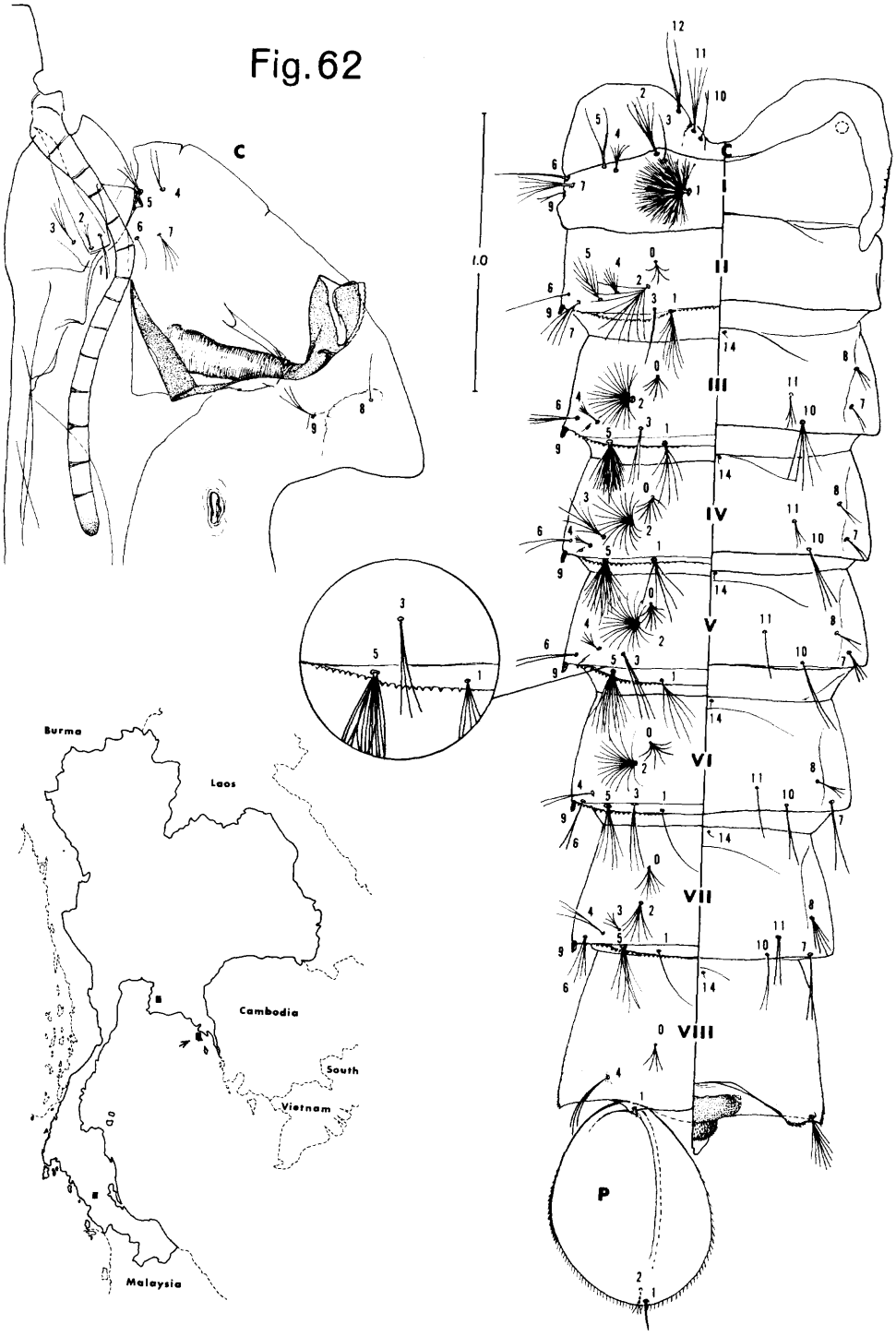

Fig.60
A
C
6-MP
0.5mm
MP
seta
4-A
P
M
T
I
II
III
IV
V
VI
VII
VIII
X
1.0
3-5
A. (Anopheles) letifer
A.Hosokawa

Fig. 61

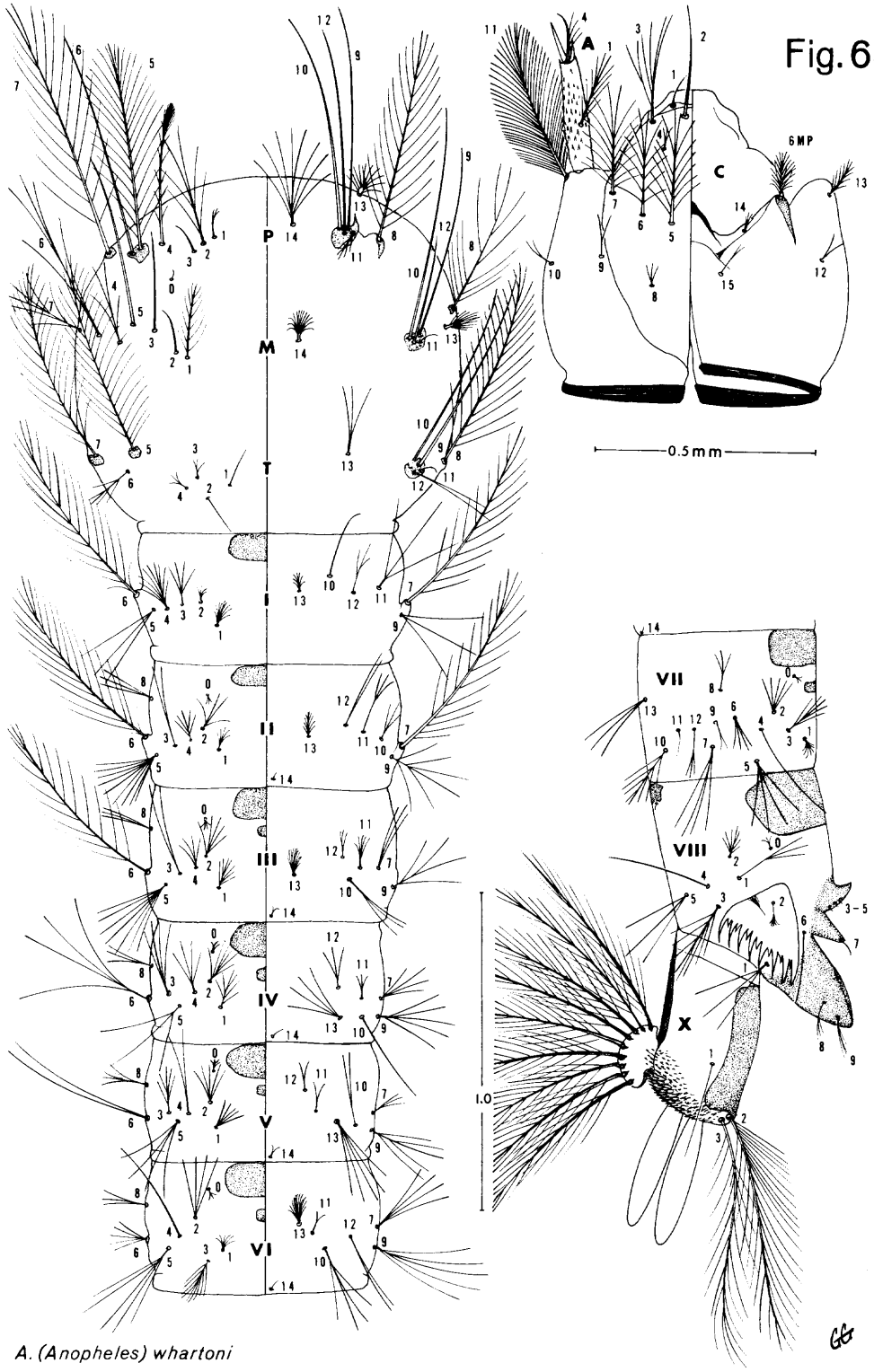


A. (Anopheles) whartoni

Fig. 62



A.(Anopheles) whartoni



A. (Anopheles) whartoni

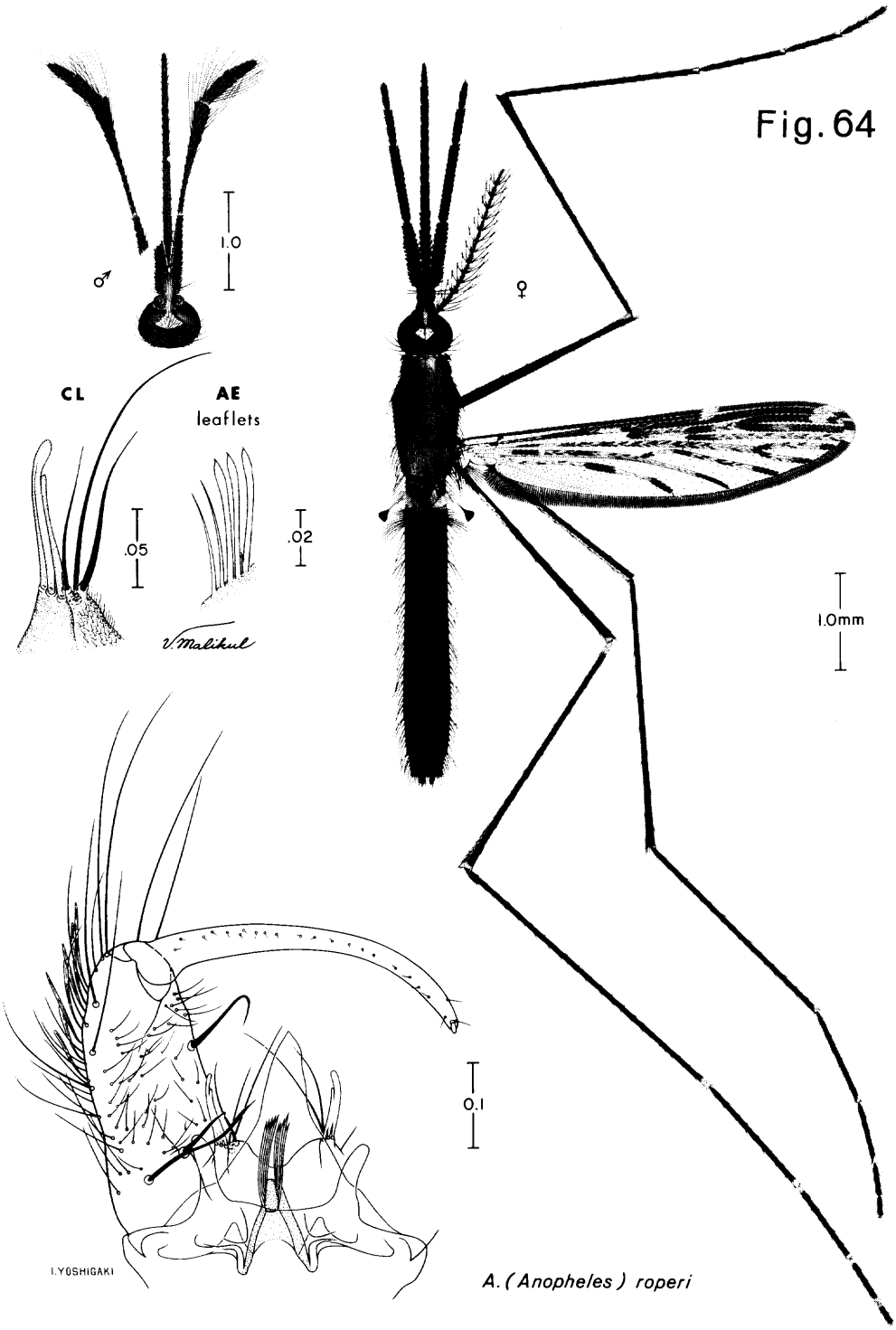
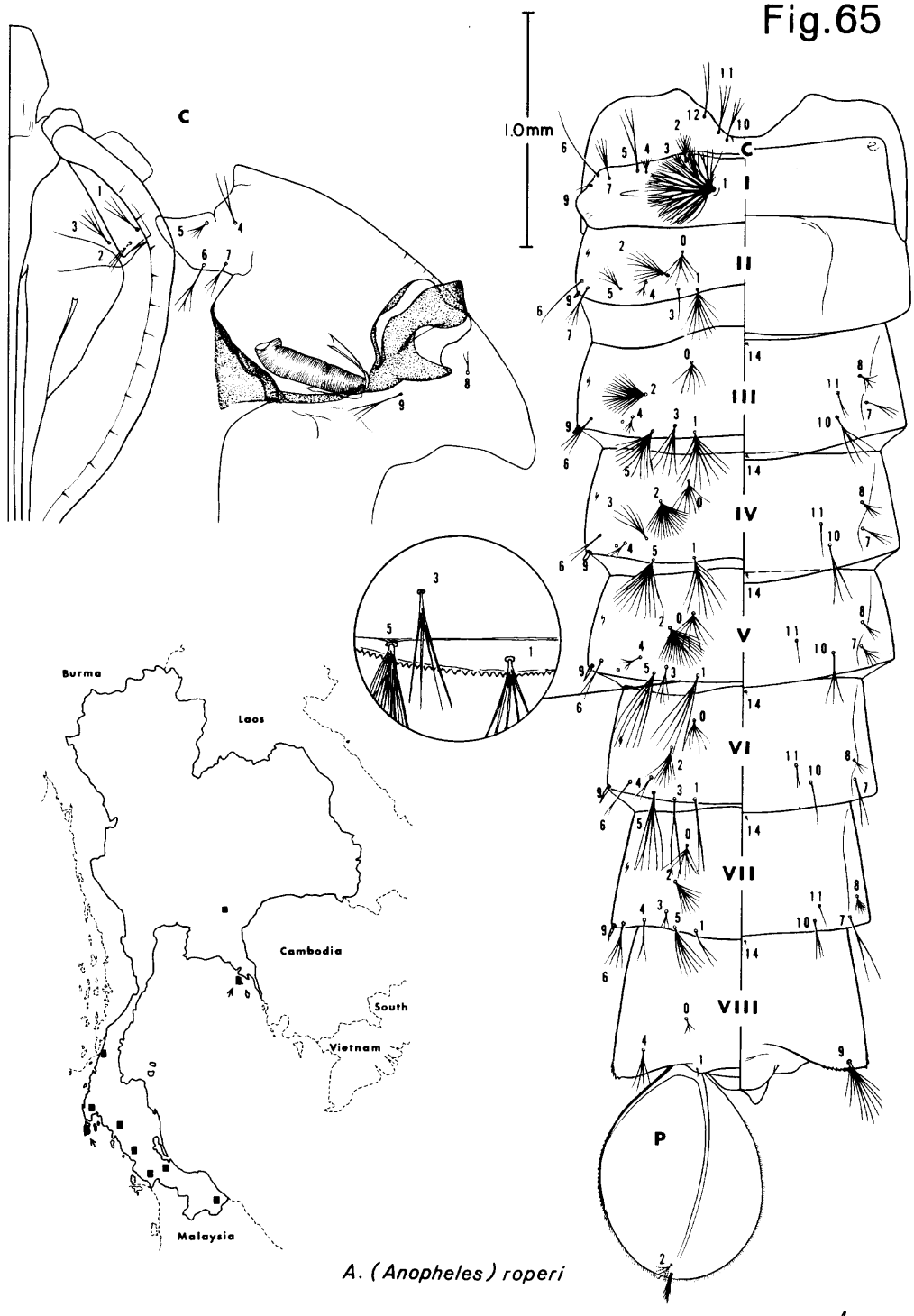

Fig. 64
♂
1.0
CL
AE
leaflets
.05
.02
V. Malikul
♀
1.0mm
0.1
I. YOSHIGAKI
A. (Anopheles) roperi

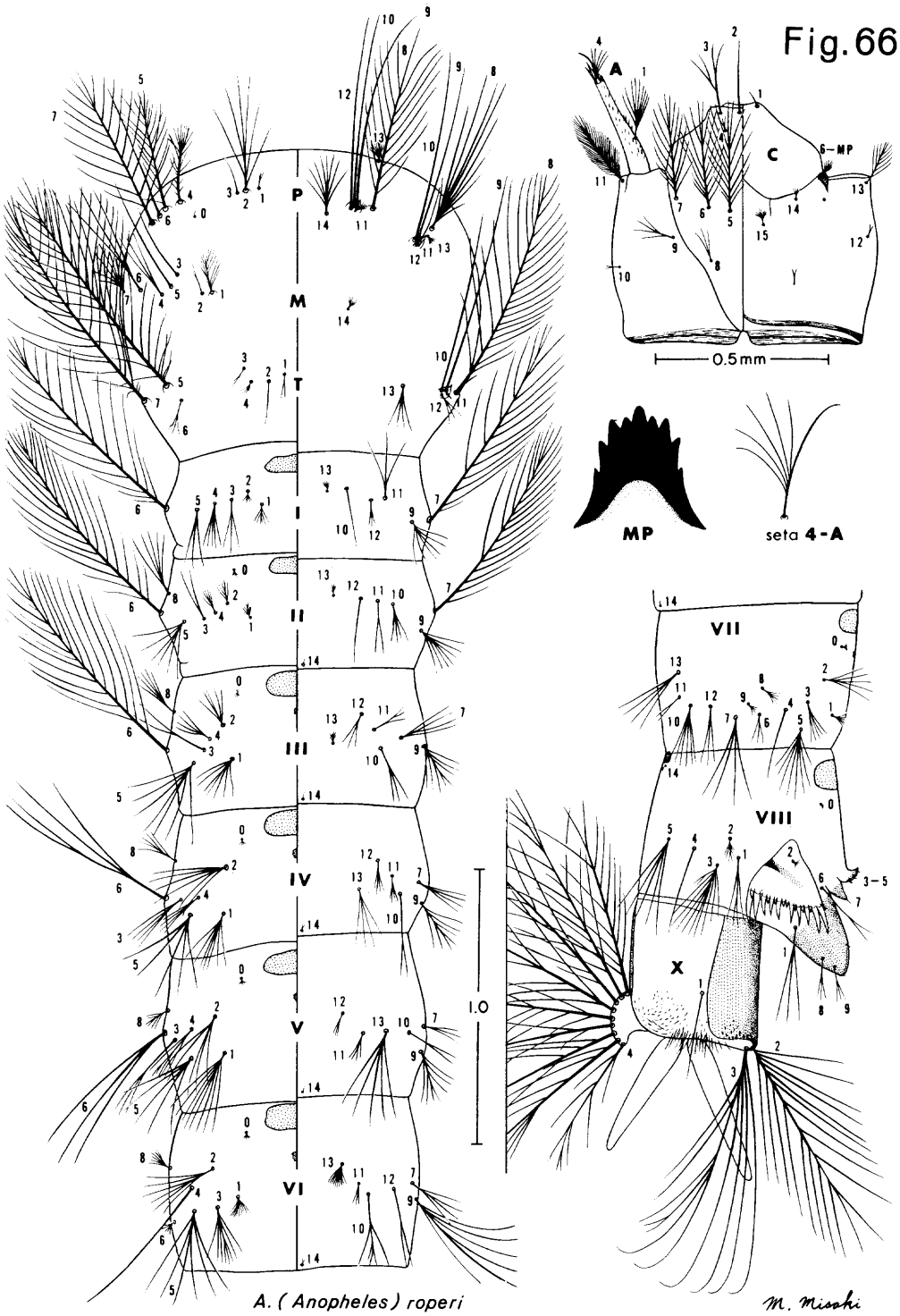
Fig.65



A. (Anopheles) roperi

M. Misaki

Fig.66


P
M
T
I
II
III
IV
V
VI
VII
VIII
X
A
C
6-MP
0.5mm
MP
seta 4-A
1.0
A. (Anopheles) roperi
M. Mitchi

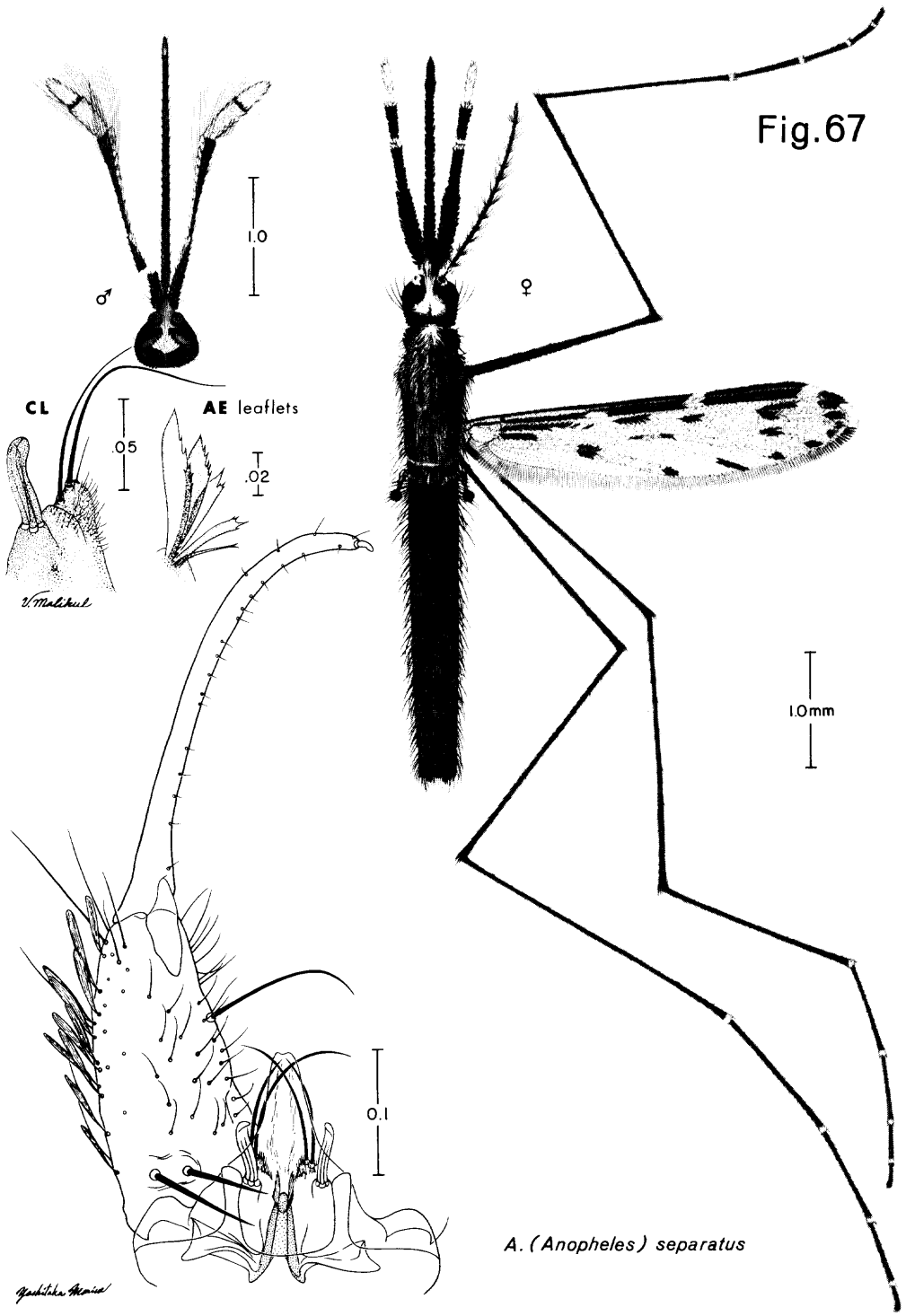
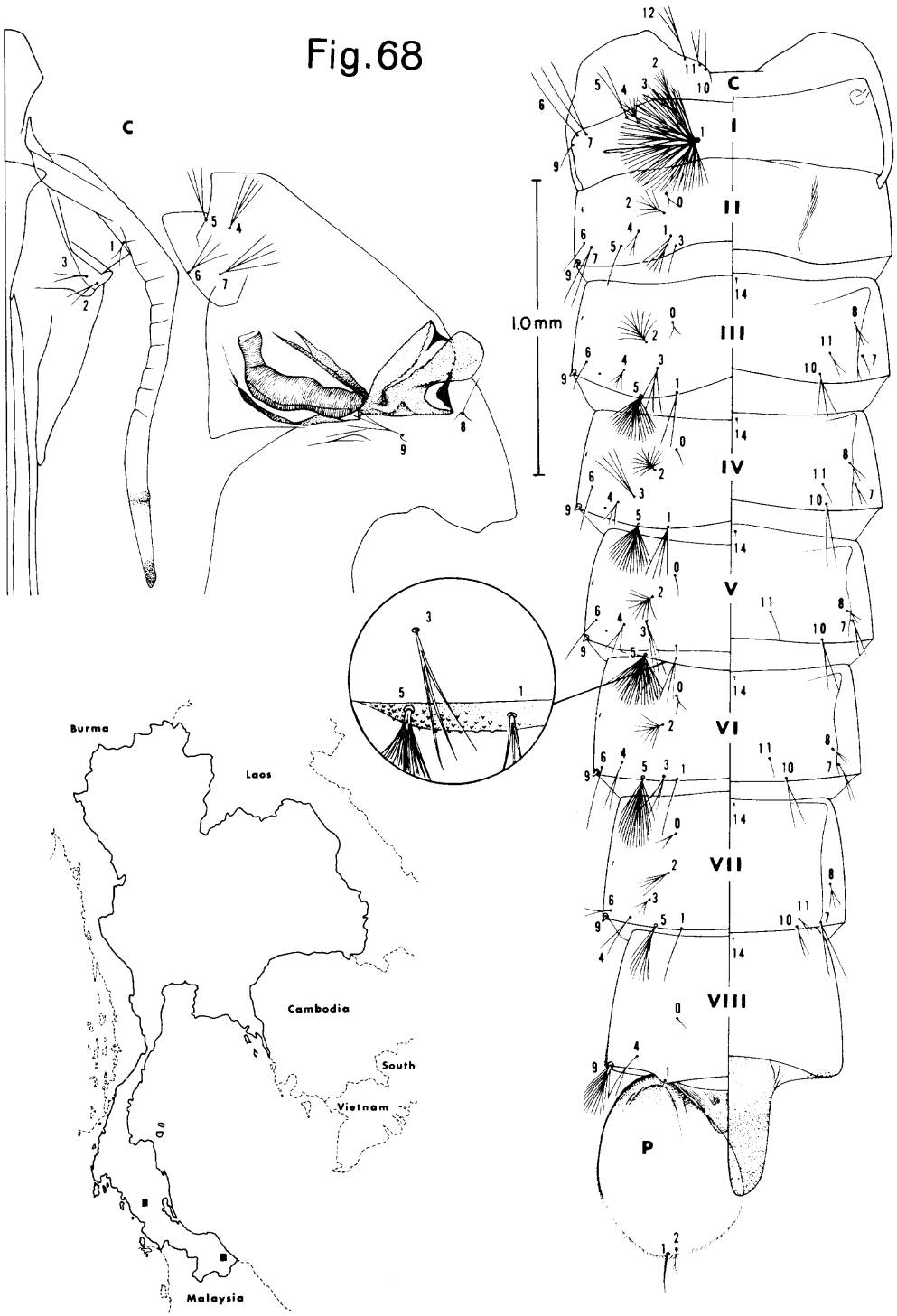

Fig.67
♂
♀
1.0
CL
AE leaflets
.05
.02
1.0mm
0.1
A. (Anopheles) separatus

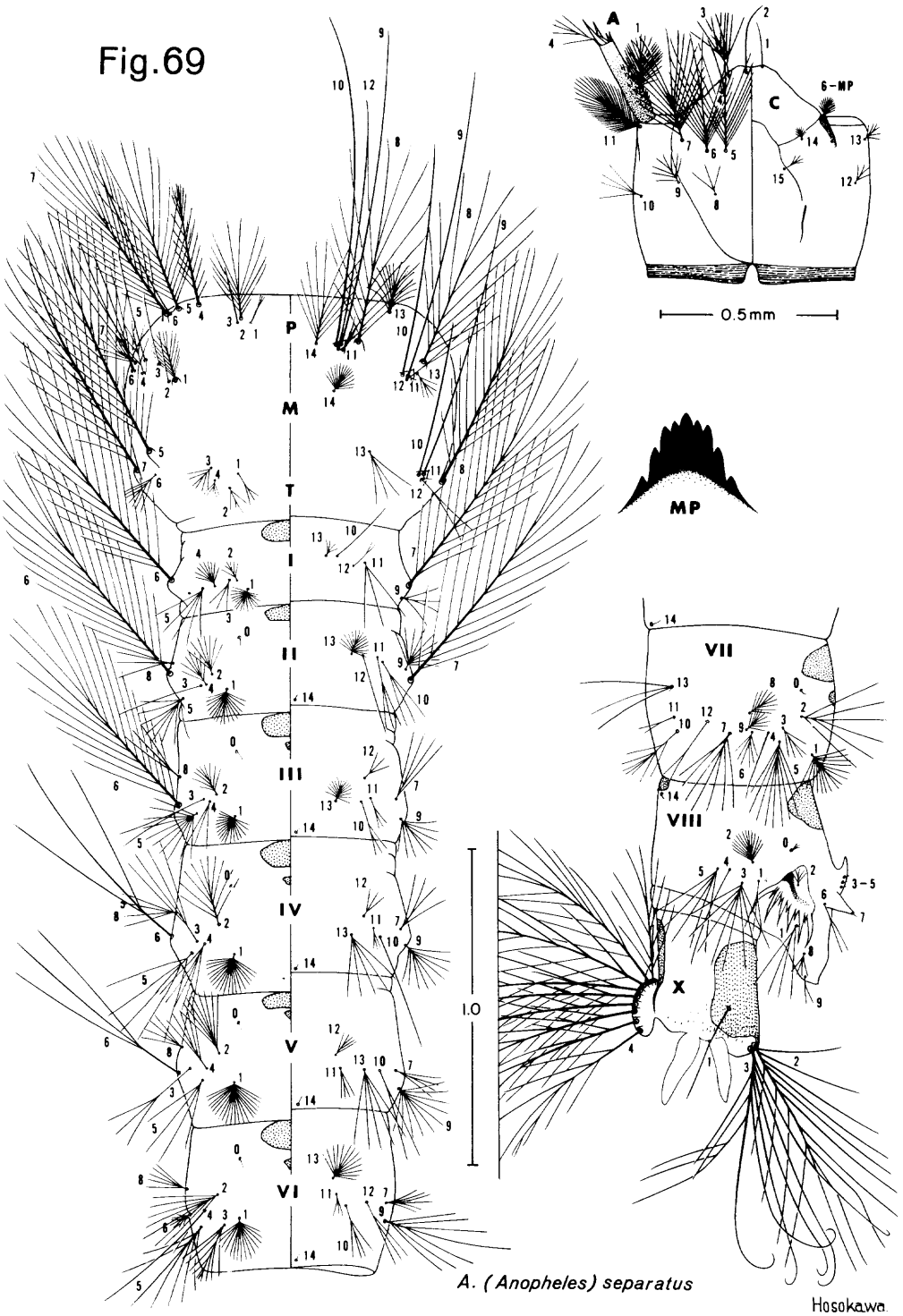
Fig.68



A. (Anopheles) separatus

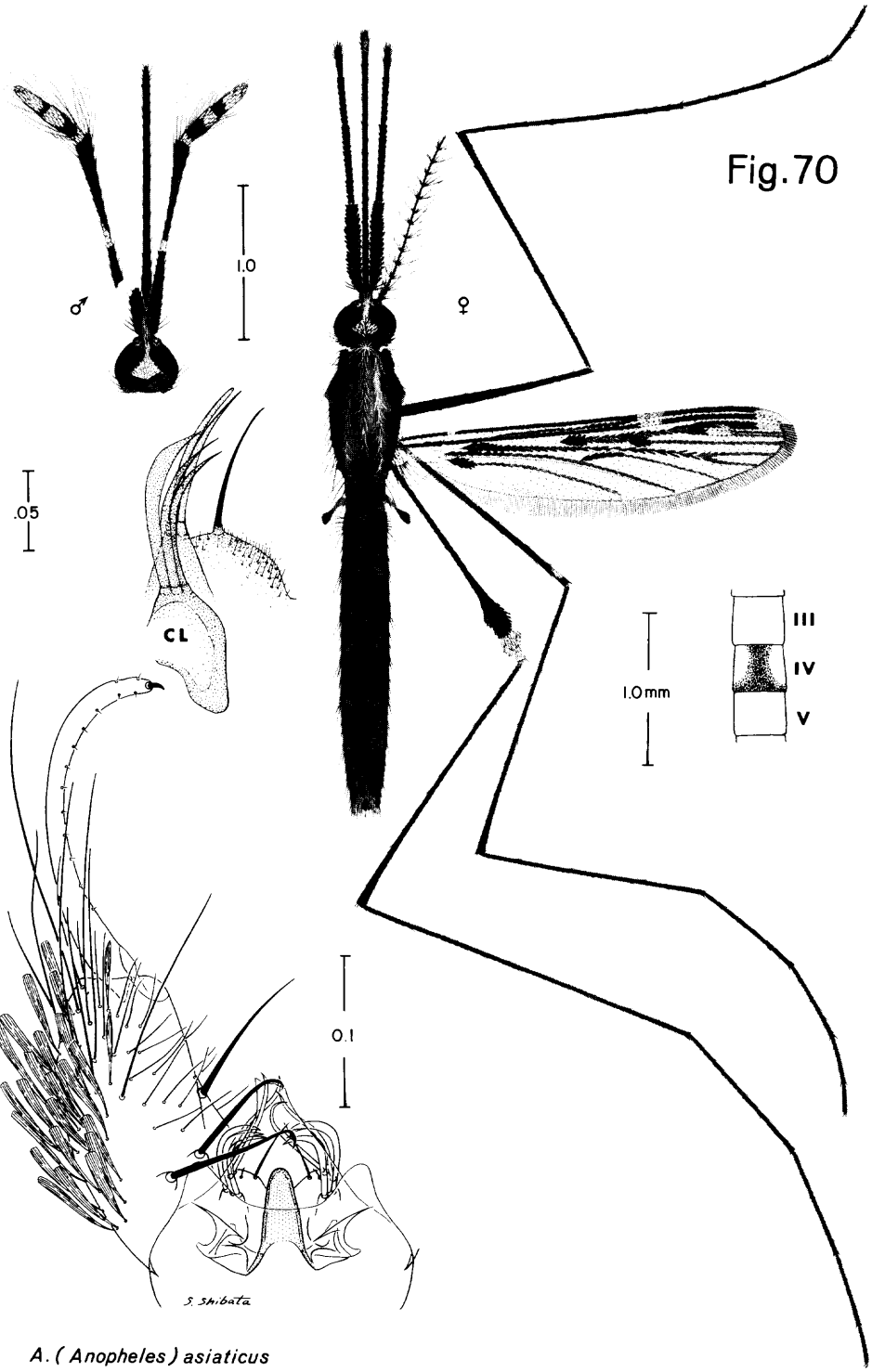
Hosokawa

Fig.69



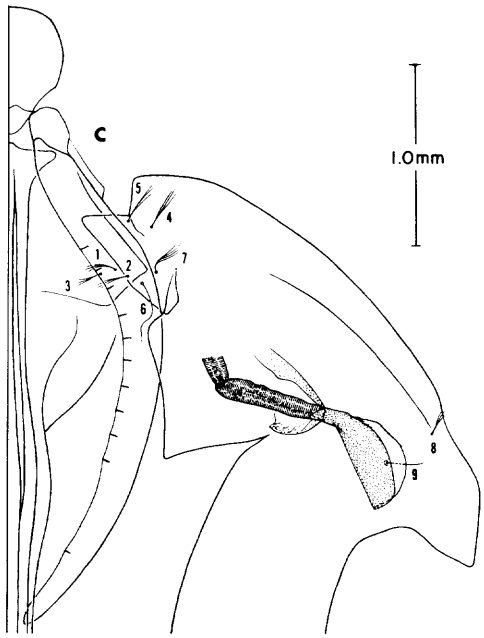
A. (Anopheles) separatus

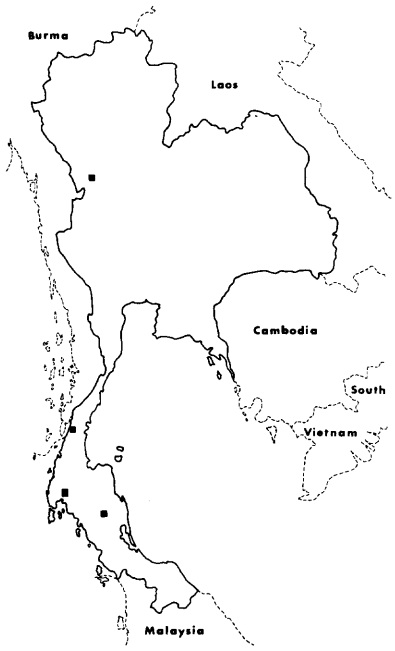
Hosokawa

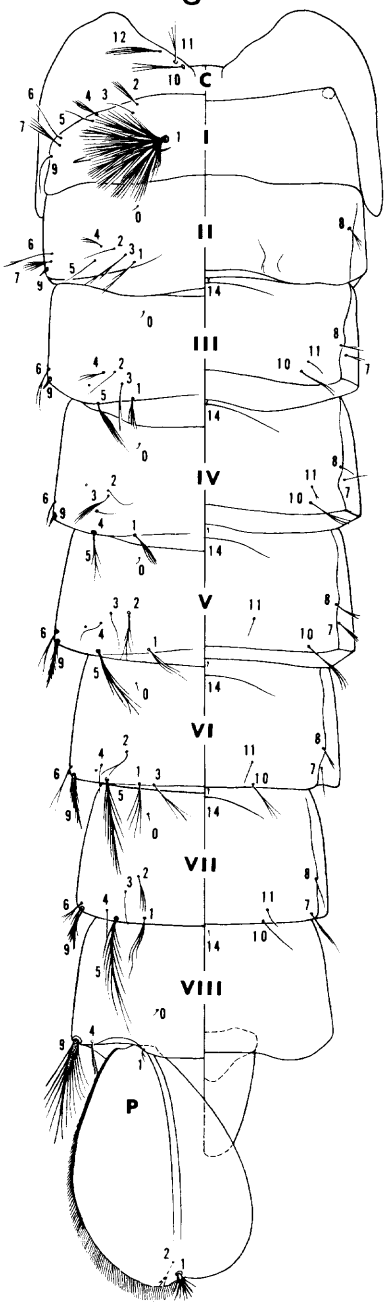


A. (Anopheles) asiaticus

Fig.71



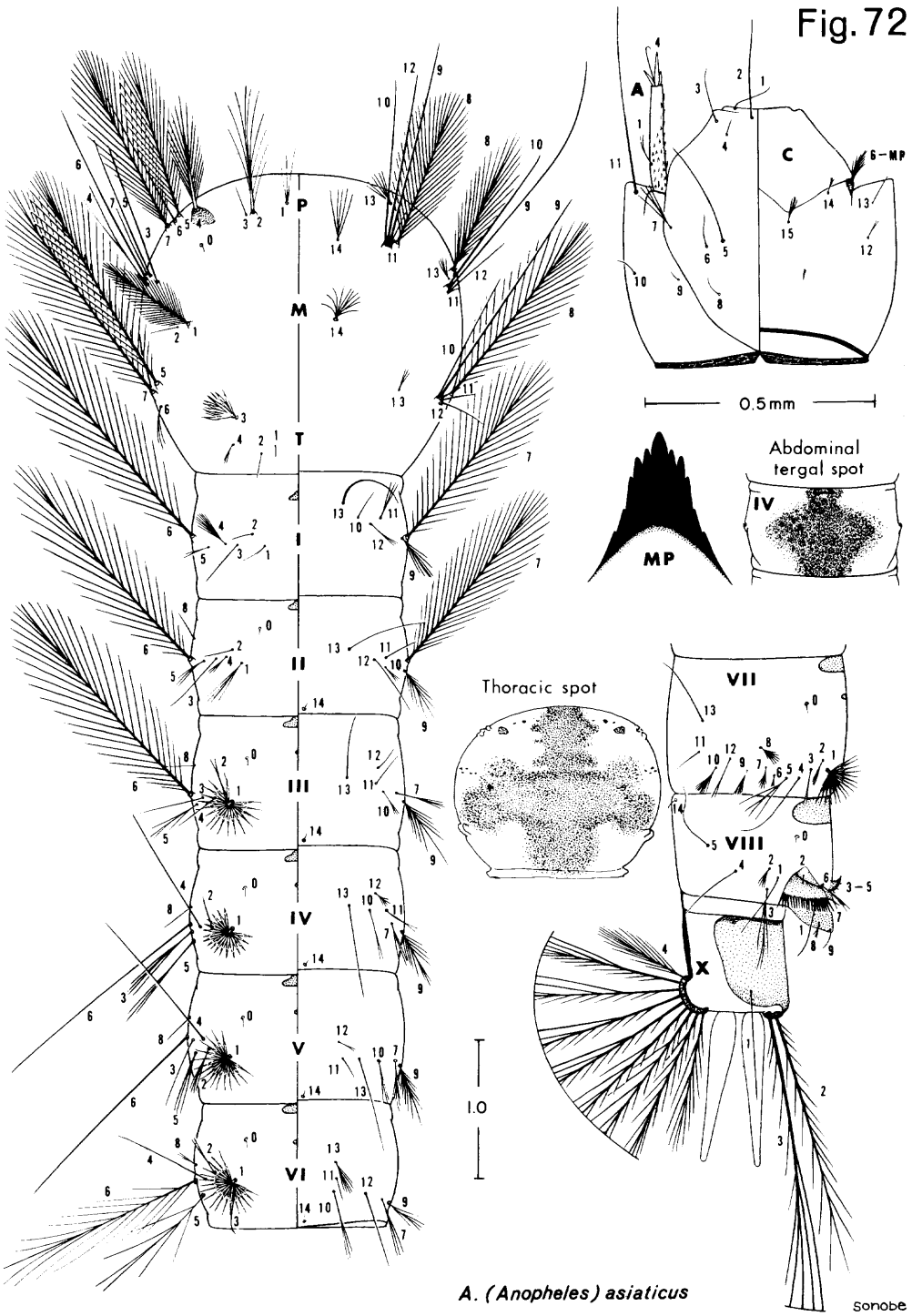




A. (Anopheles) asiaticus

Sonobe

Fig. 72


A
C
6-MP
0.5mm
MP
Abdominal tergal spot
IV
Thoracic spot
VII
VIII
X
3-5
P
M
T
I
II
III
IV
V
VI
1.0
A. (Anopheles) asiaticus
Sonobe

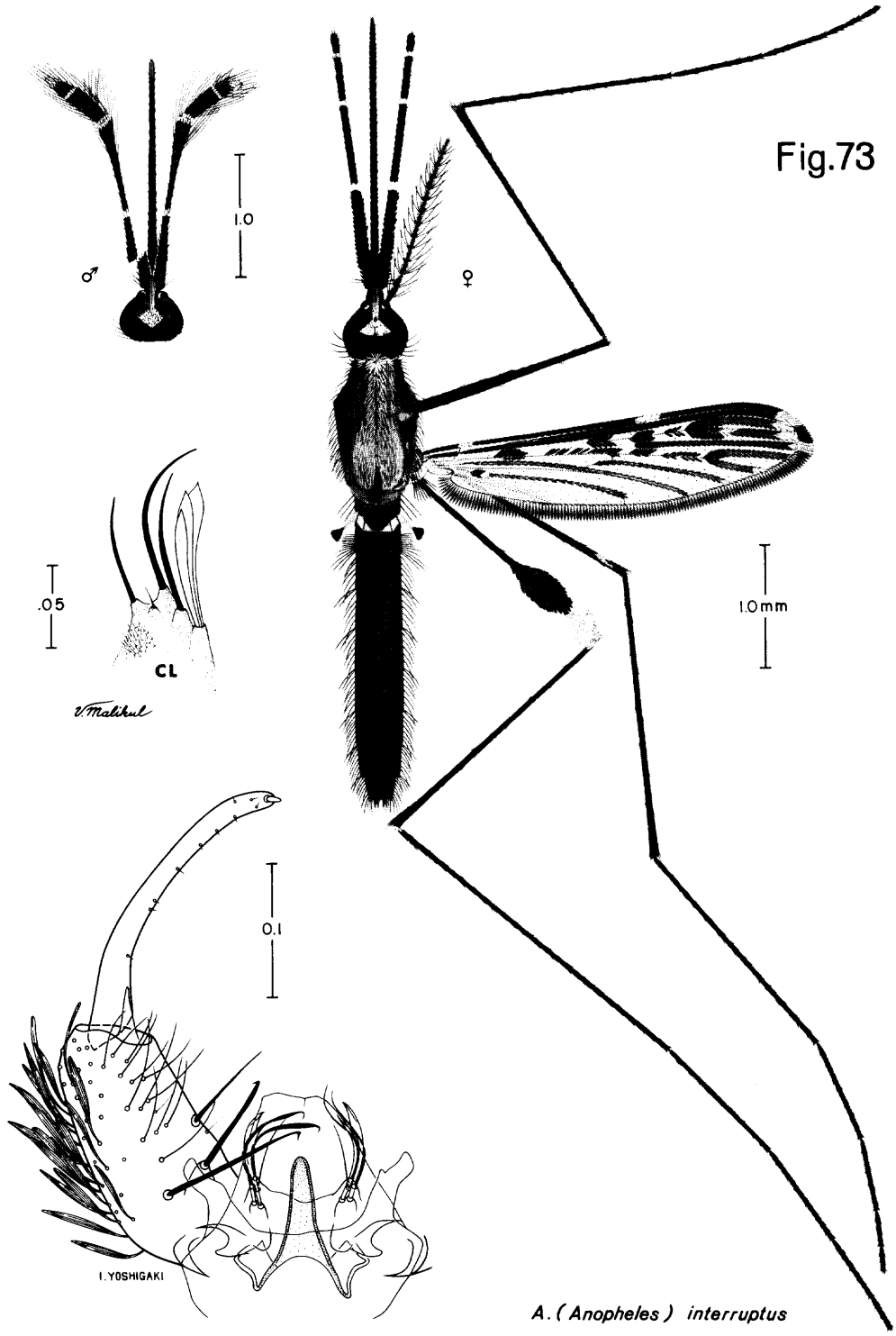
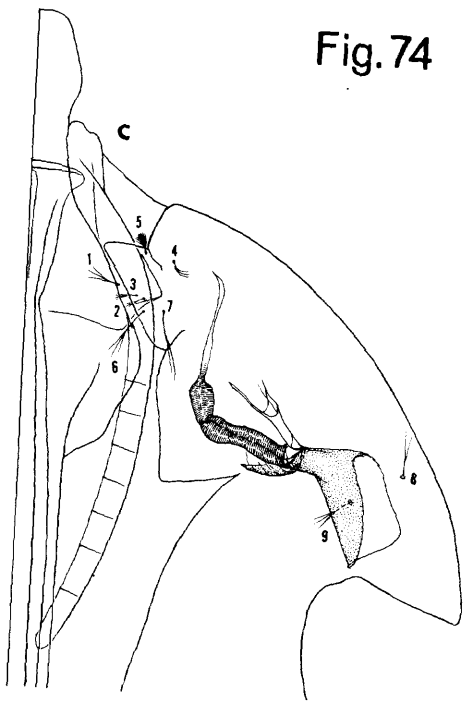
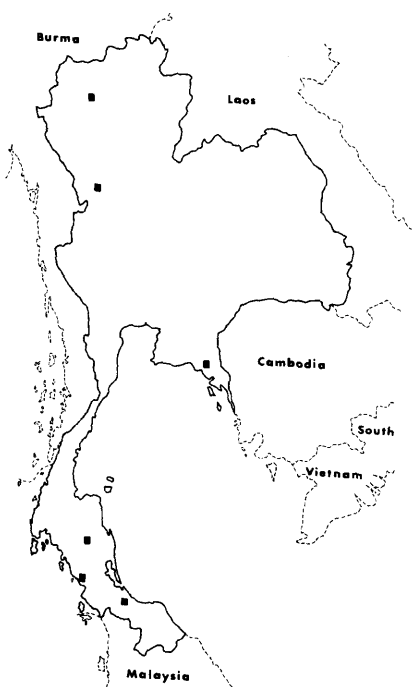
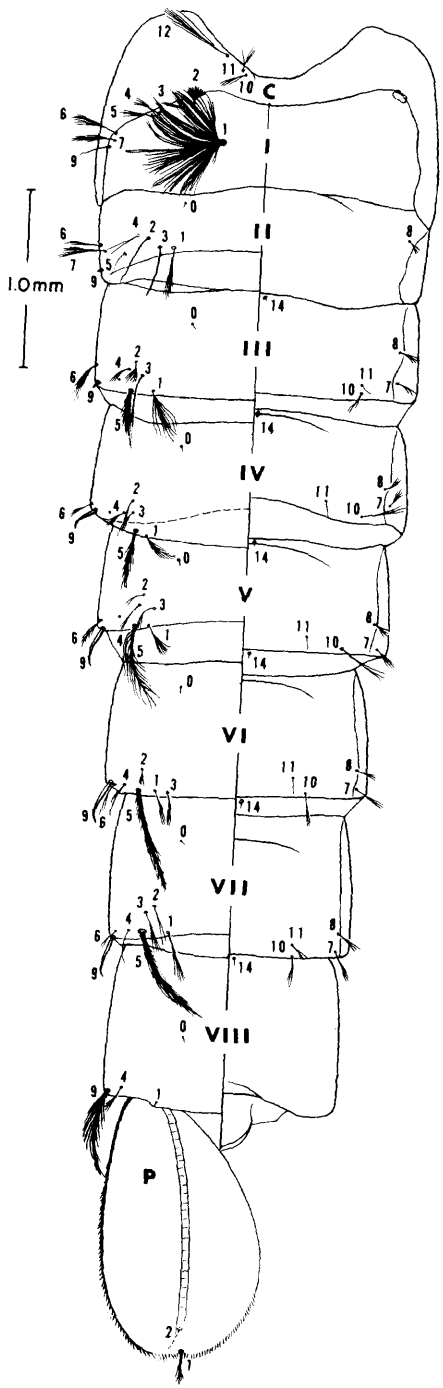

Fig.73
♂
1.0
♀
.05
CL
V. Malikul
1.0mm
0.1
I. YOSHIGAKI
A. (Anopheles) interruptus

Fig. 74

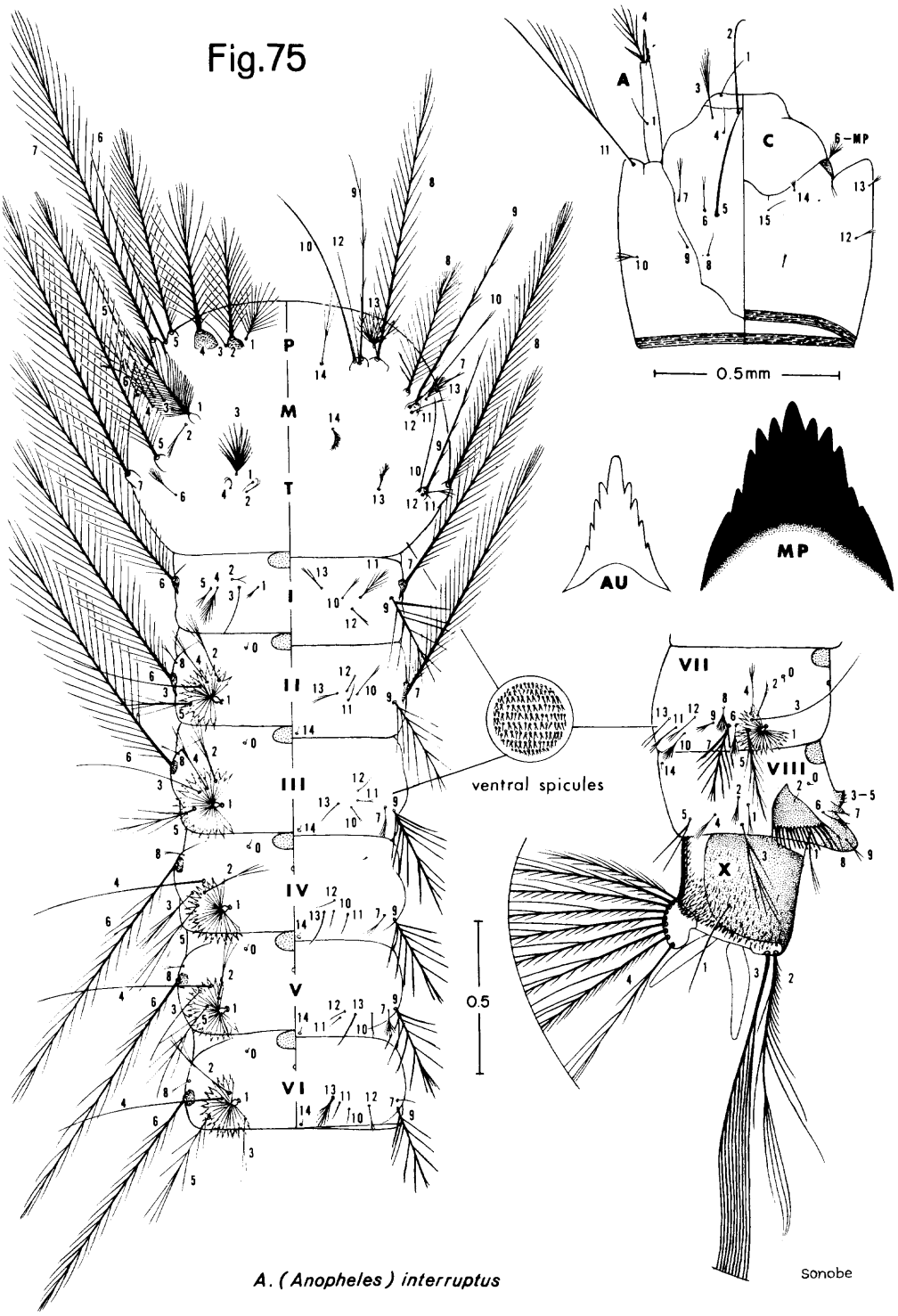


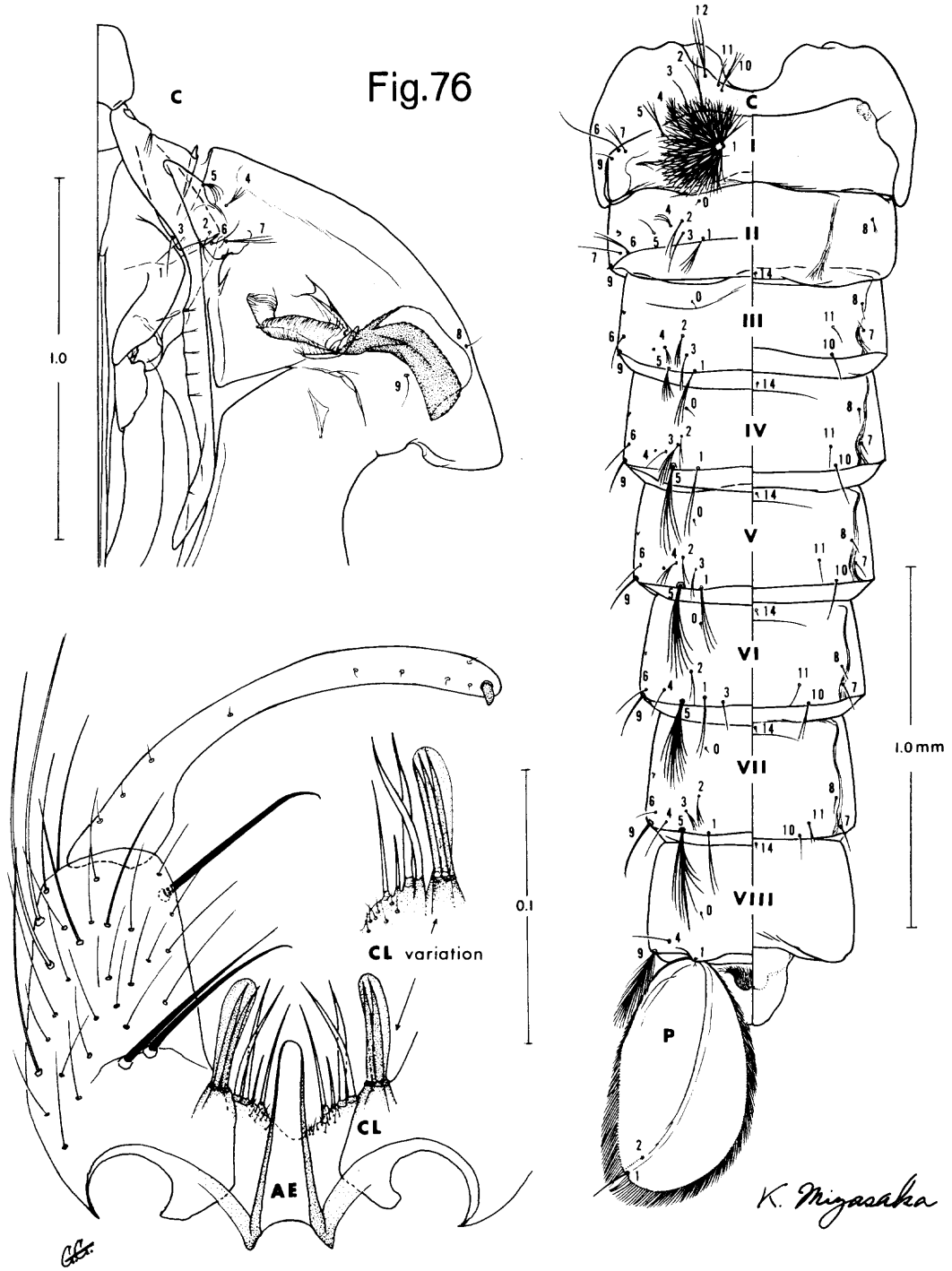




A. (Anopheles) interruptus

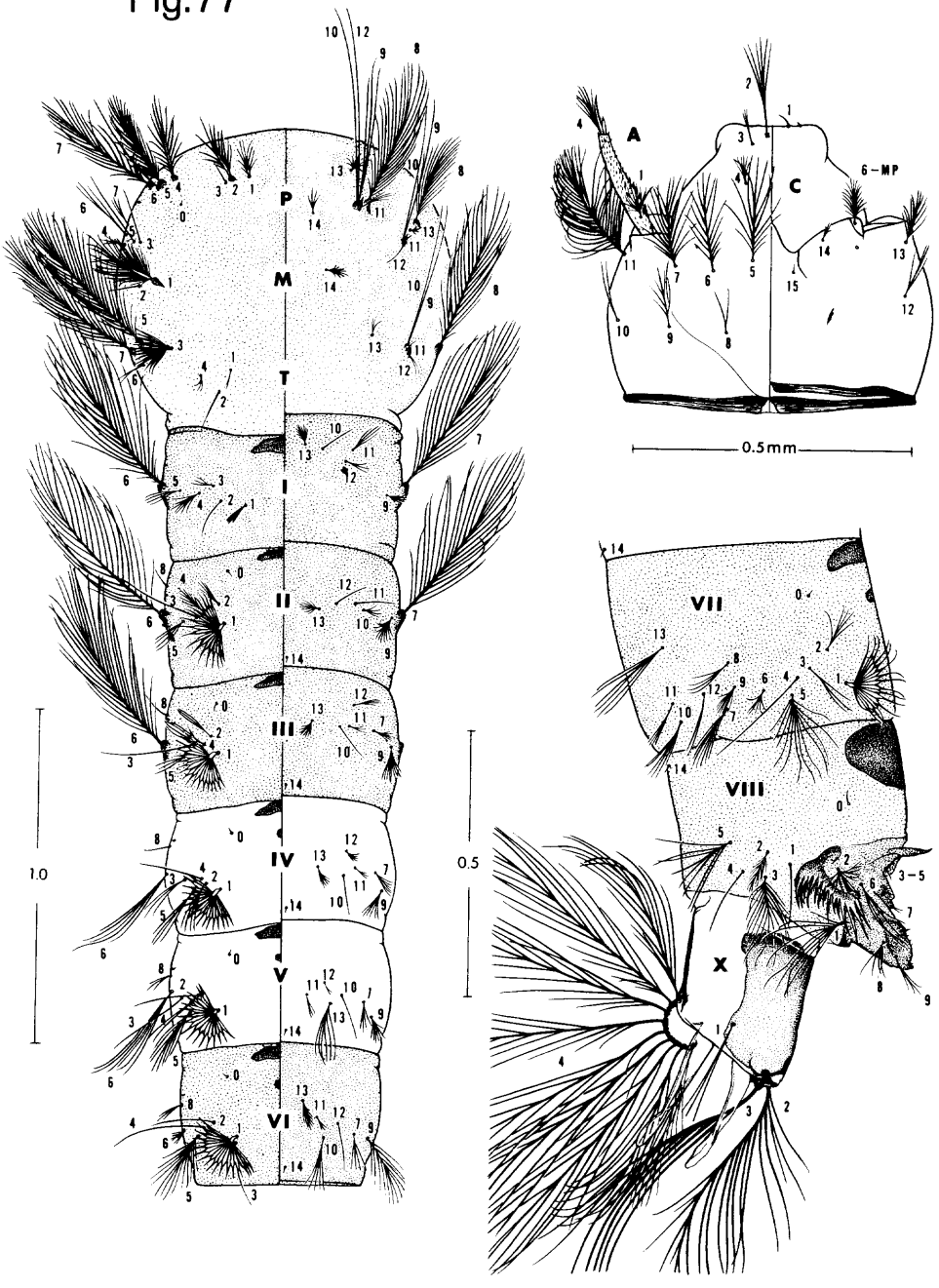
sanobe


Fig.75
A
C
6-MP
0.5mm
AU
MP
P
M
T
I
II
III
IV
V
VI
VII
VIII
X
3-5
ventral spicules
0.5
A. (Anopheles) interruptus
Sonobe



A.(Anopheles) aberrans

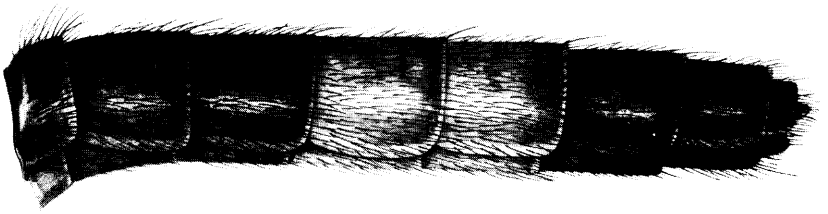
Fig.77



A.(Anopheles) aberrans

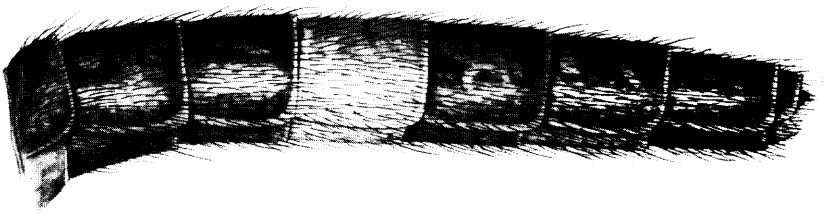
K. Miyasaka

Fig. 78 *A. (Anopheles) aitkenii* GROUP



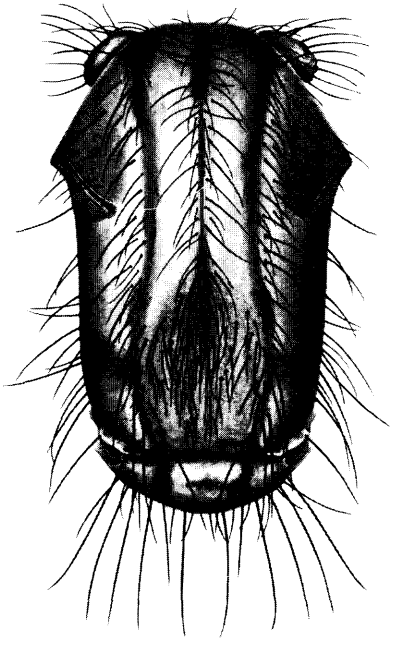
aberrans

1.0



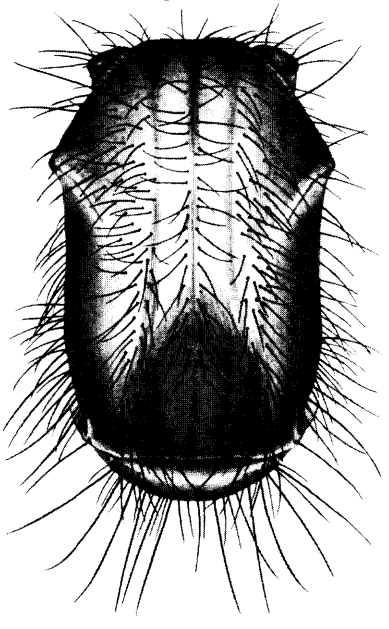
palmatus

insulaeflorum



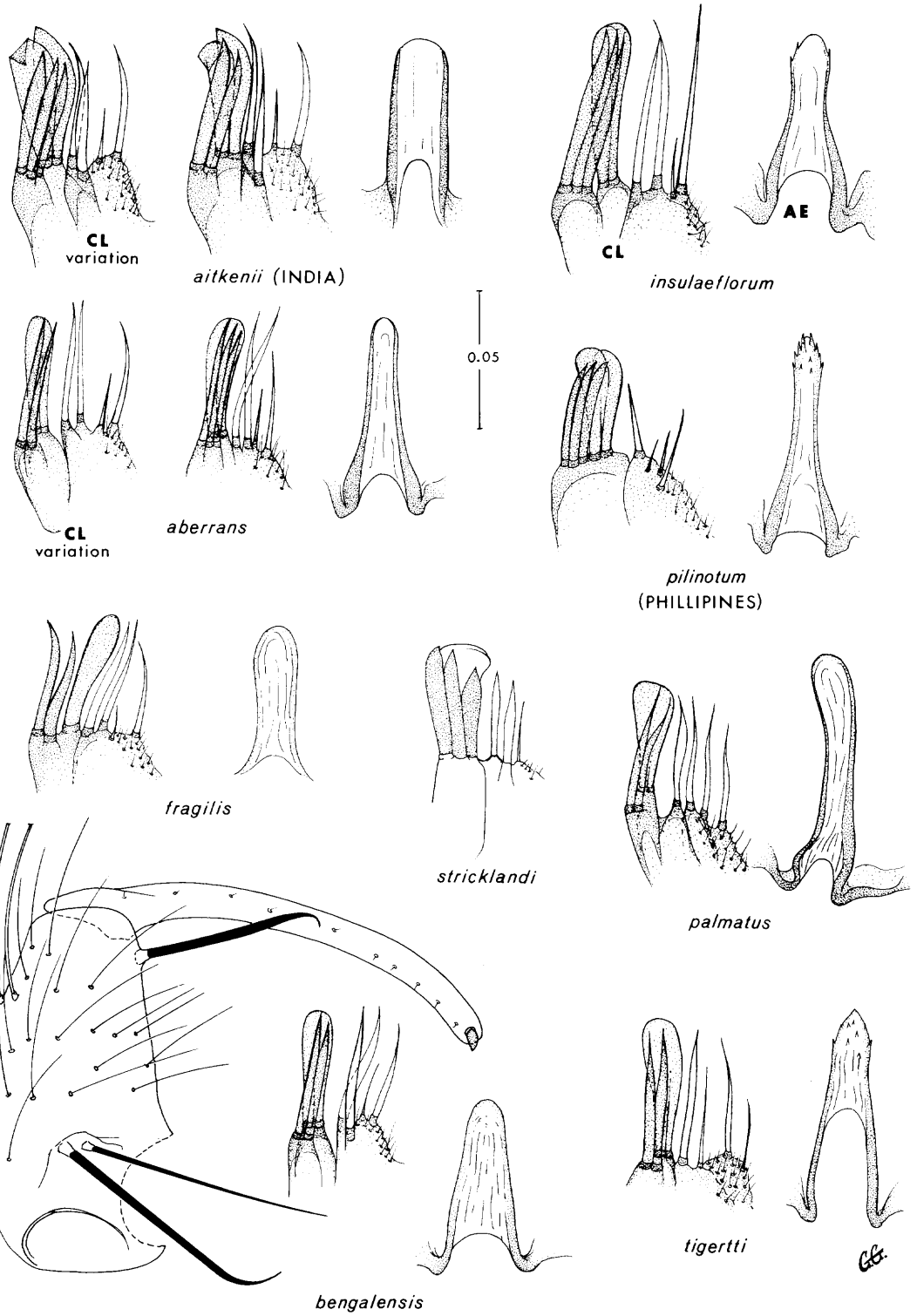
1.0

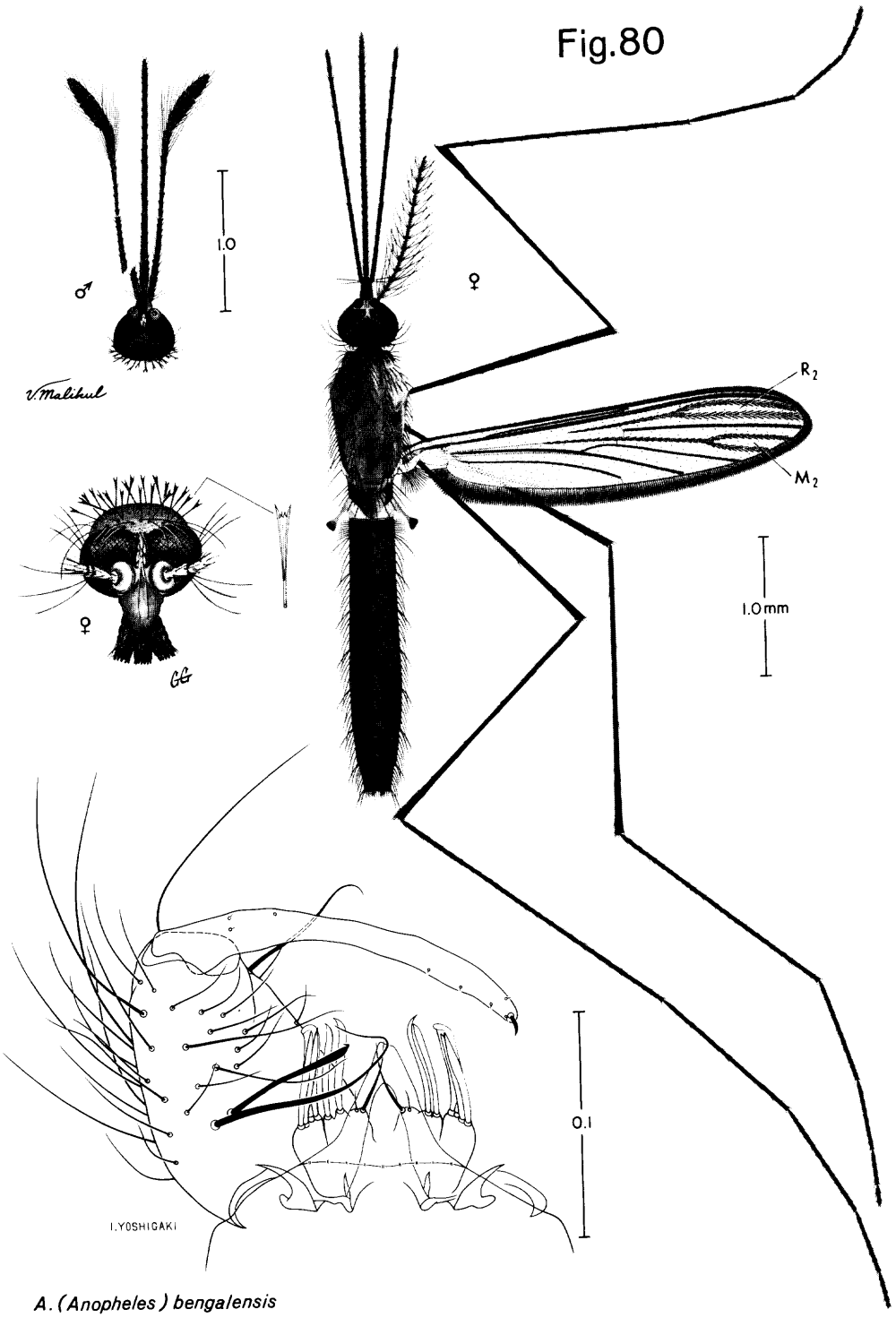
bengalensis



K. Miyasaka

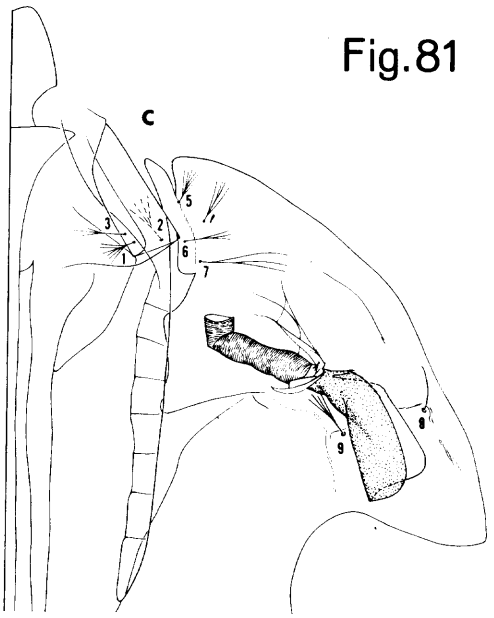
Fig.79 MALE GENITALIA *A.(Anopheles) aitkenii* GROUP

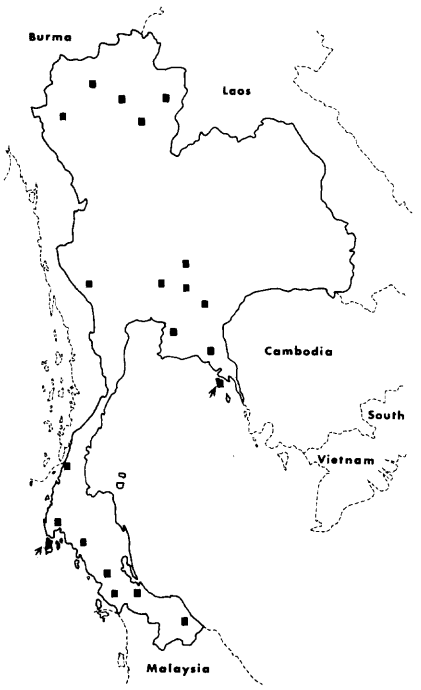




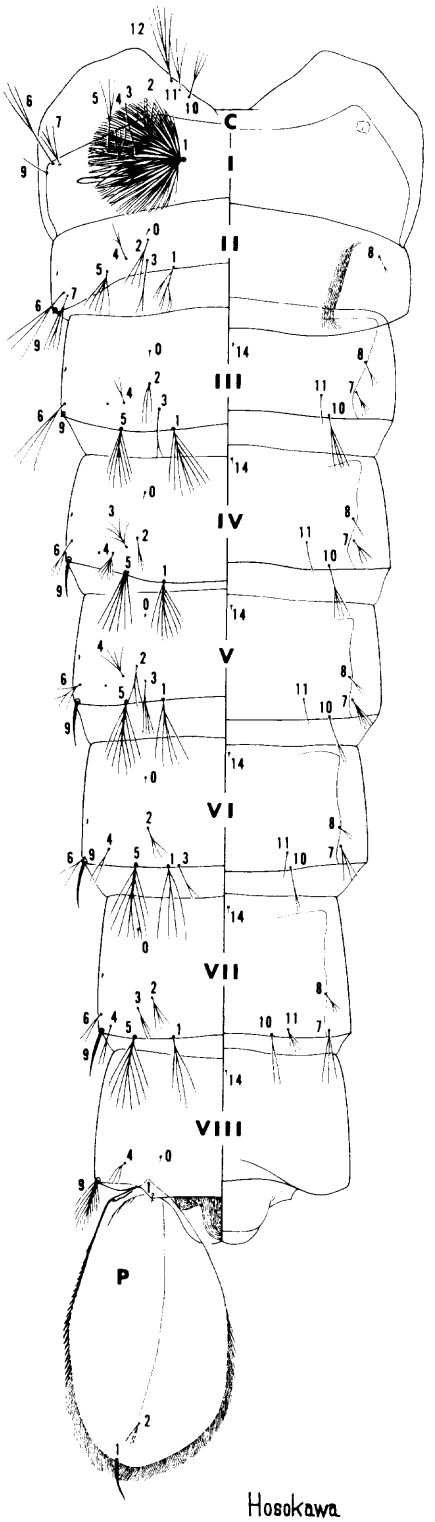
A. (Anopheles) bengalensis

Fig.81

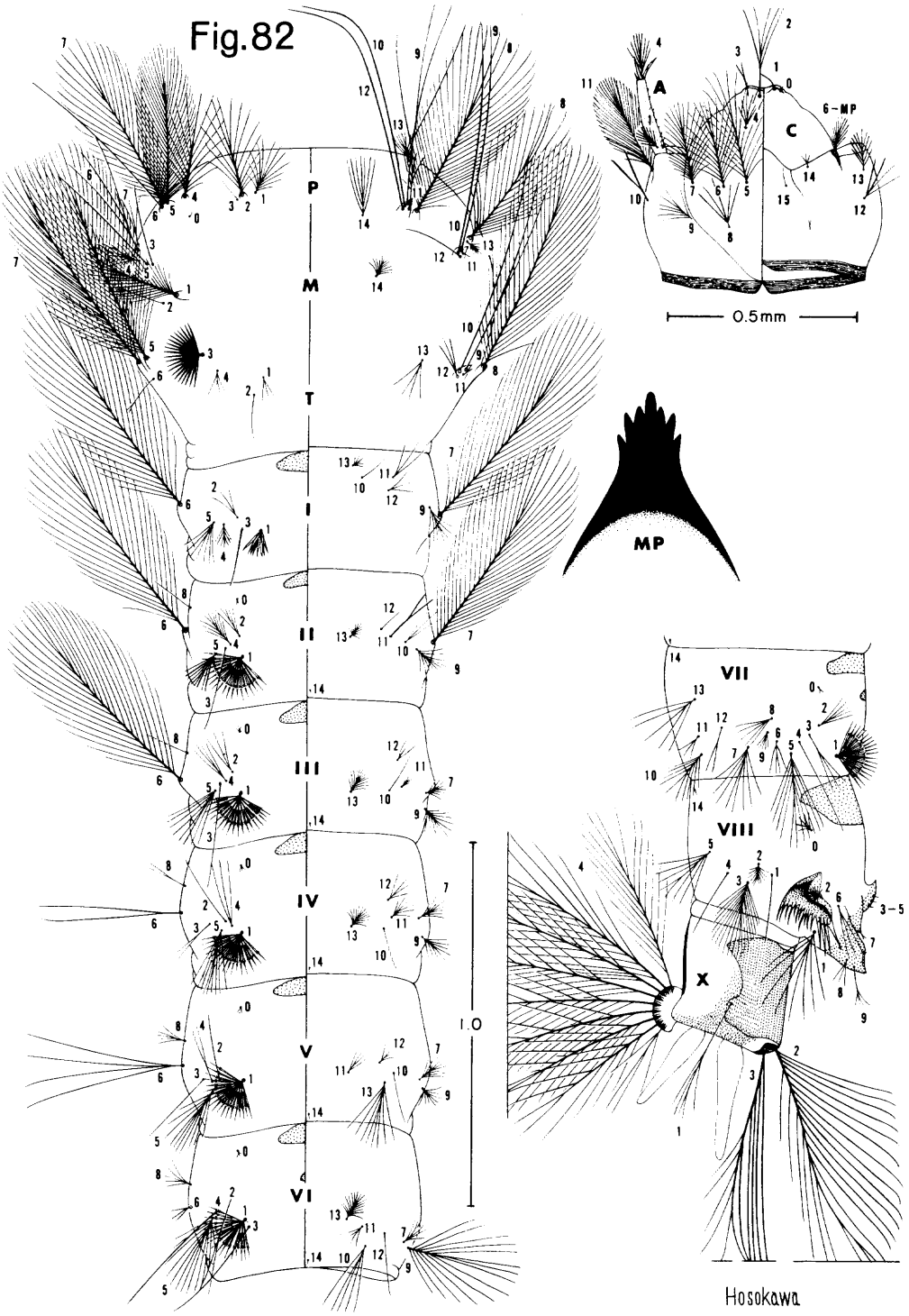




A. (Anopheles) bengalensis

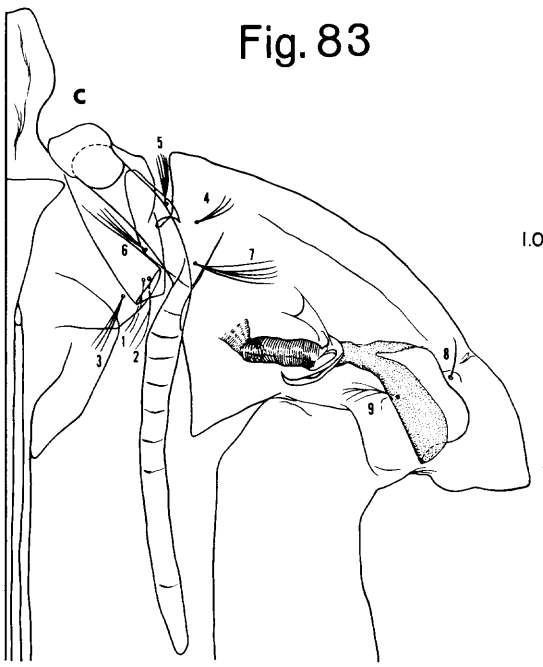


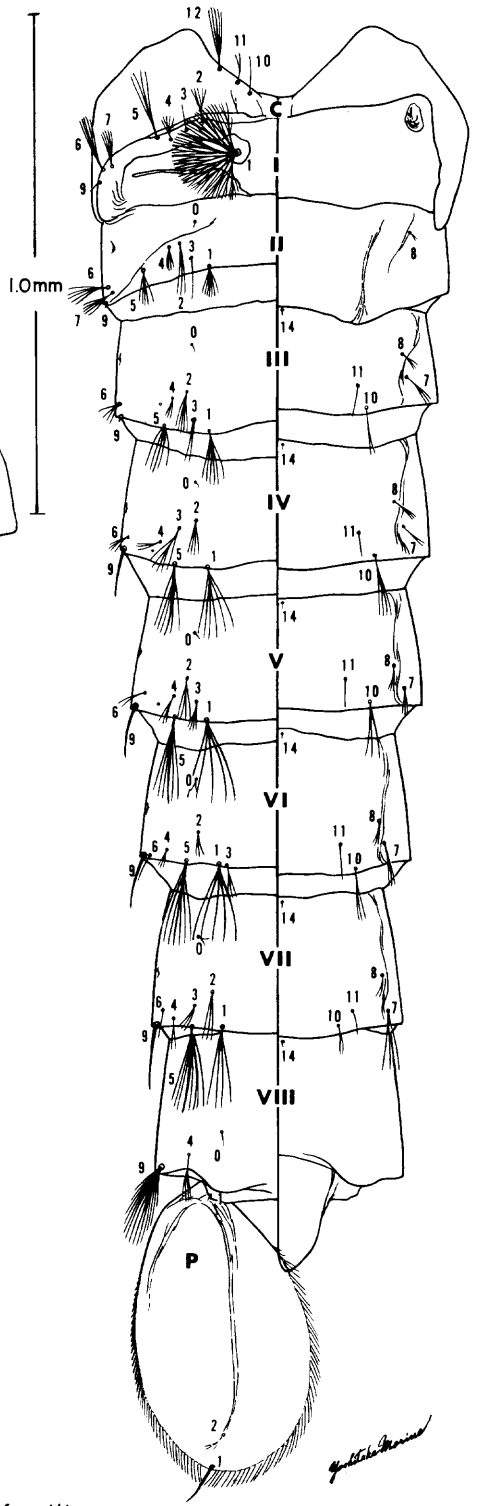
Hosokawa

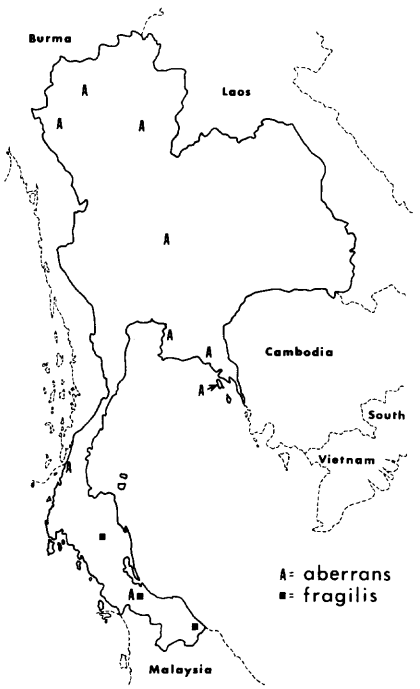


A. (Anopheles) bengalensis

Fig. 83







A.(Anopheles) fragilis

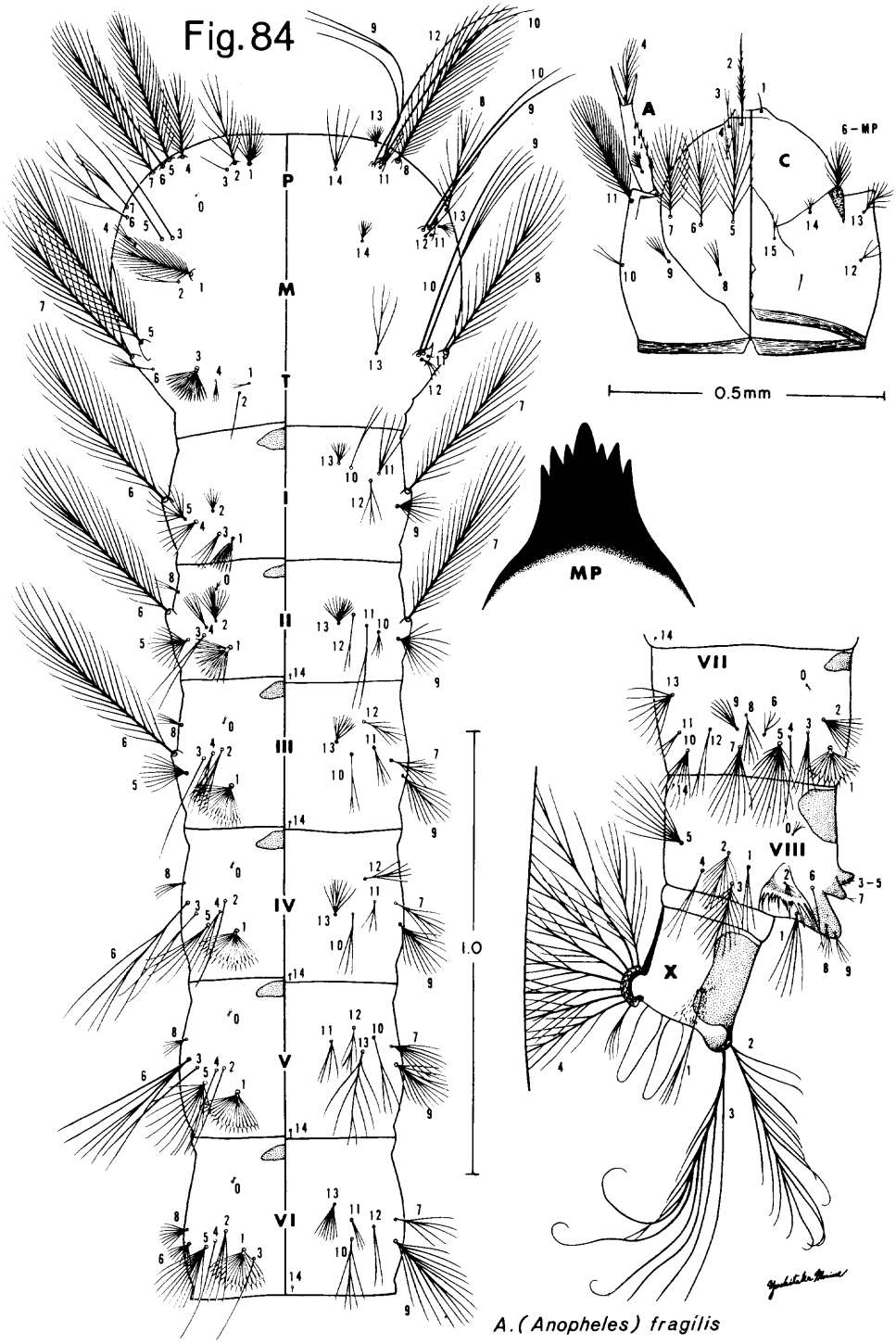
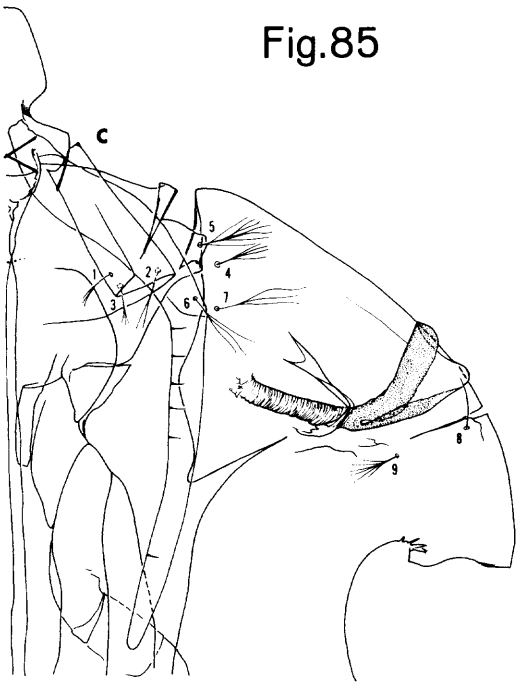
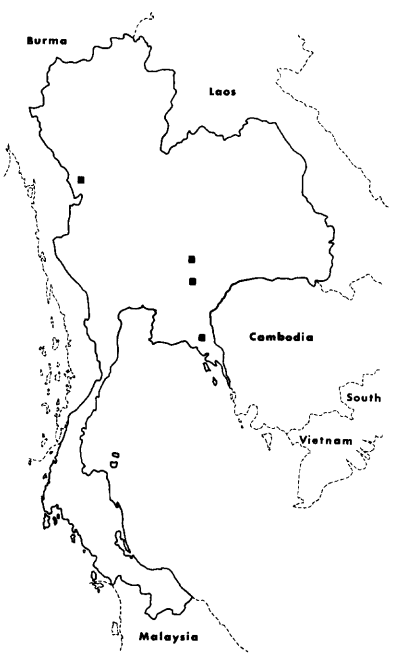
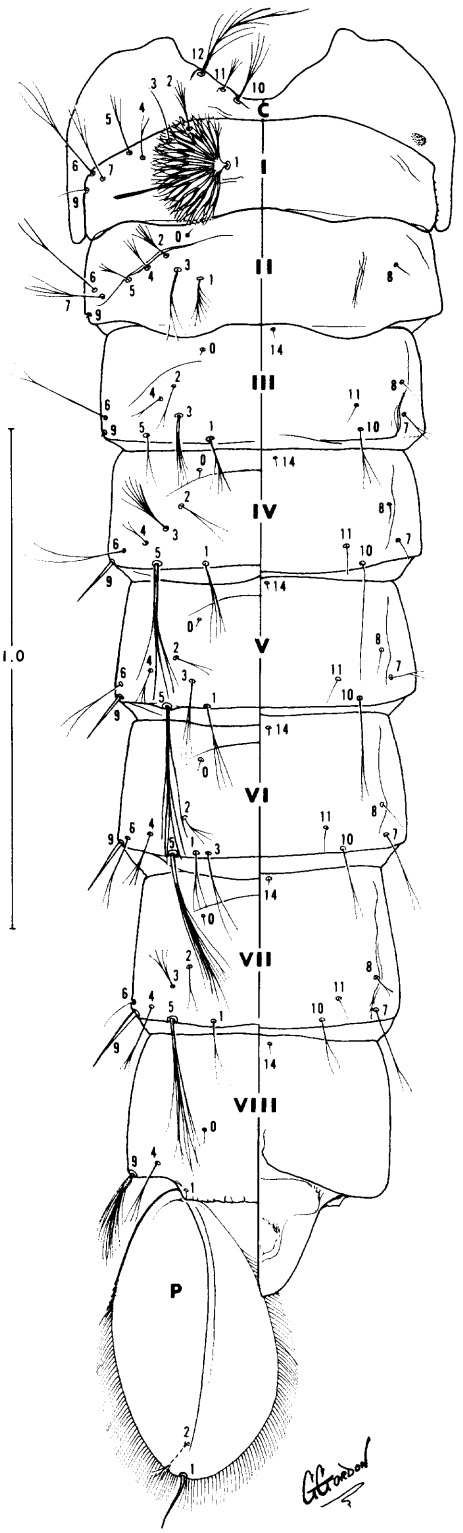

Fig. 84
P
M
T
I
II
III
IV
V
VI
VII
VIII
X
A
C
6-MP
MP
0.5mm
1.0
A. (Anopheles) fragilis

Fig.85







A.(Anopheles) tigertti

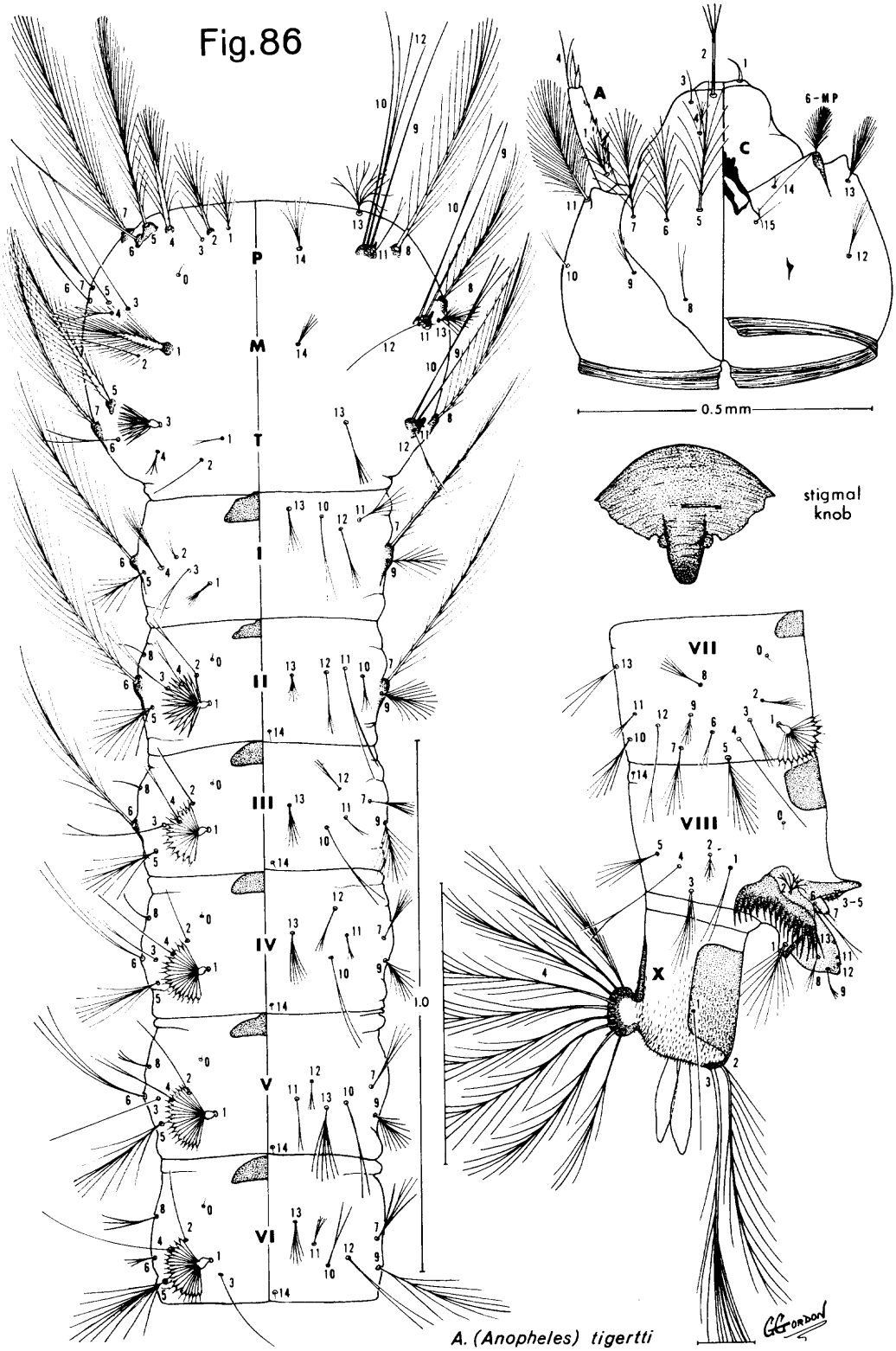
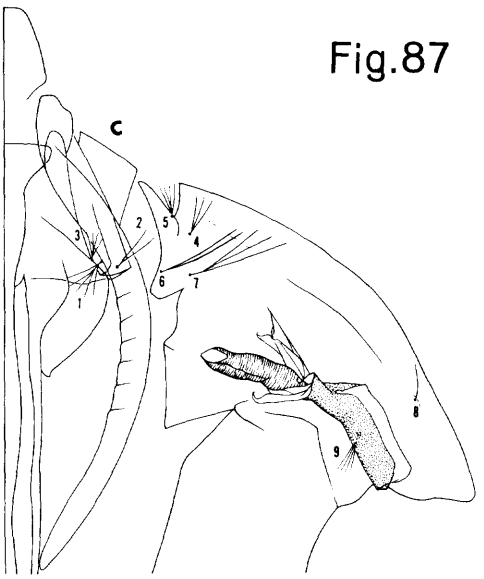
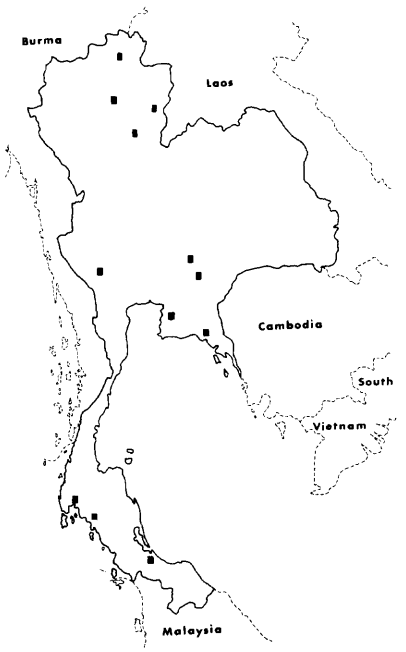
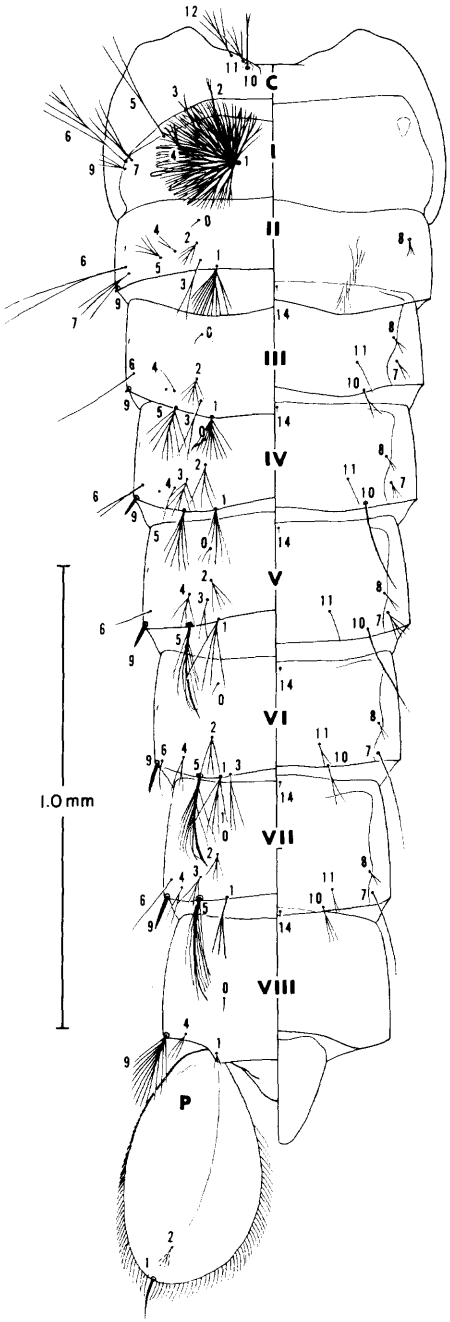

Fig.86
P
M
T
I
II
III
IV
V
VI
VII
VIII
X
A
C
6-MP
0.5mm
stigmal knob
1.0
A. (Anopheles) tigertti

Fig.87







A. (Anopheles) insulaeflorum

Hosokawa

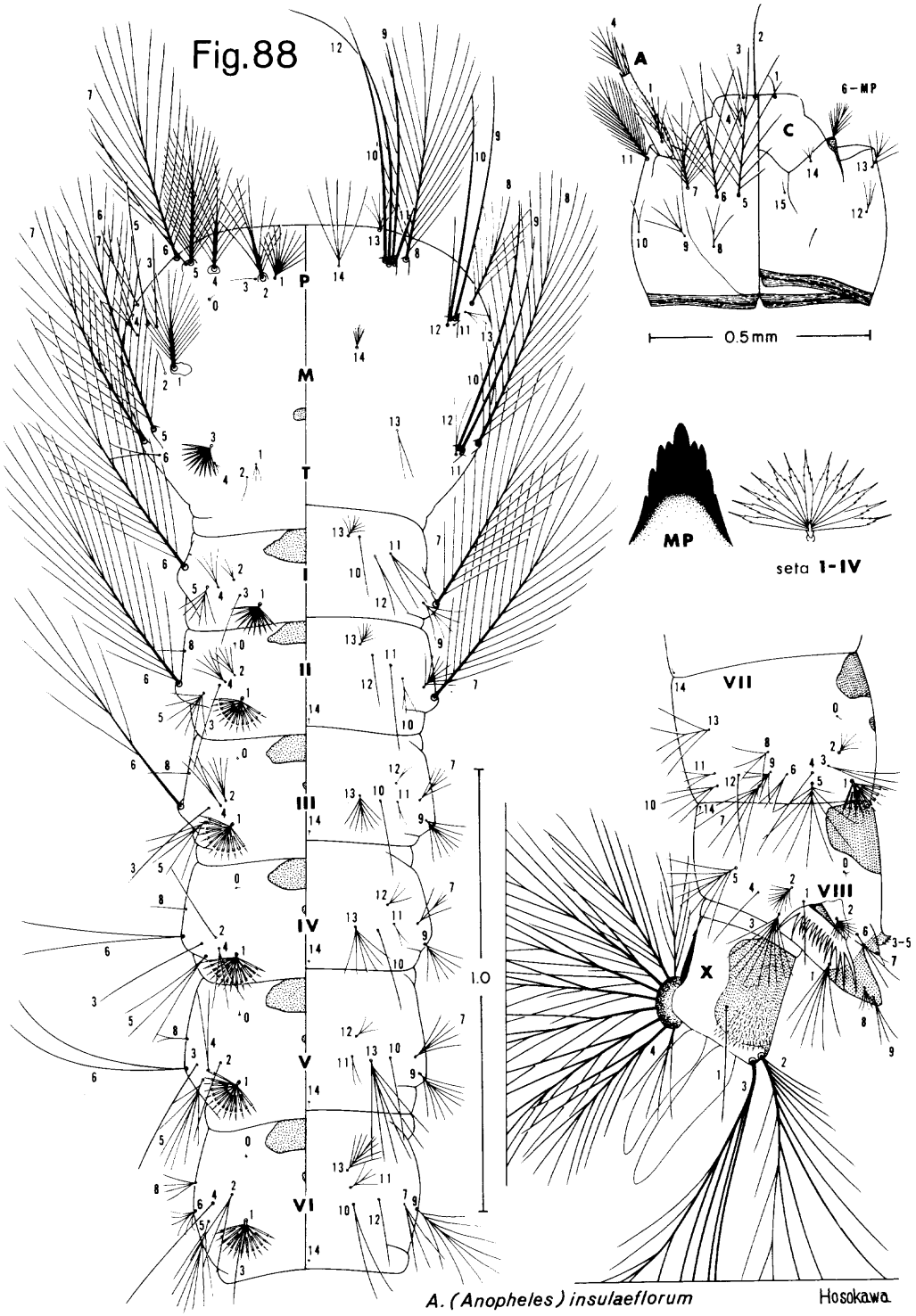
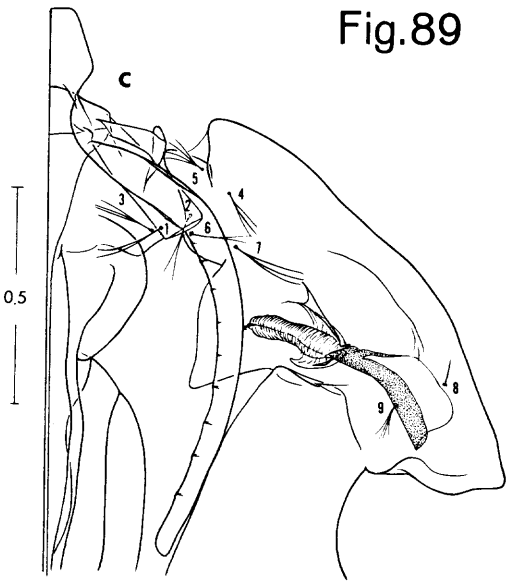
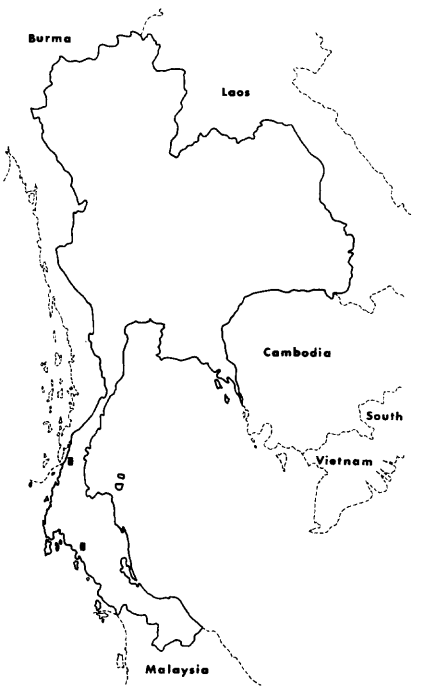
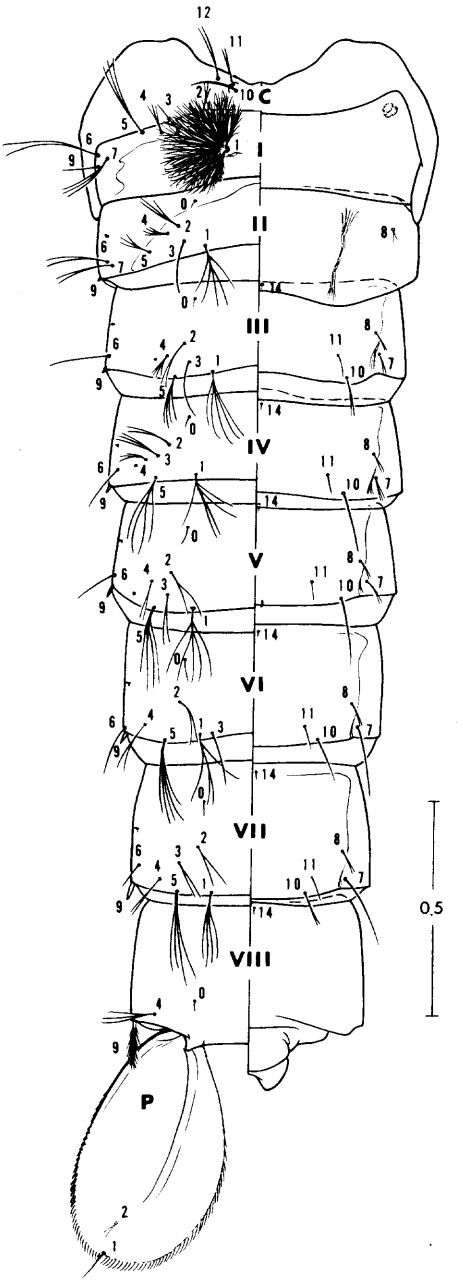

Fig.88
A
C
6-MP
0.5mm
MP
seta I-IV
P
M
T
I
II
III
IV
V
VI
VII
VIII
X
1.0
A. (Anopheles) insulaeflorum
Hosokawa

Fig.89



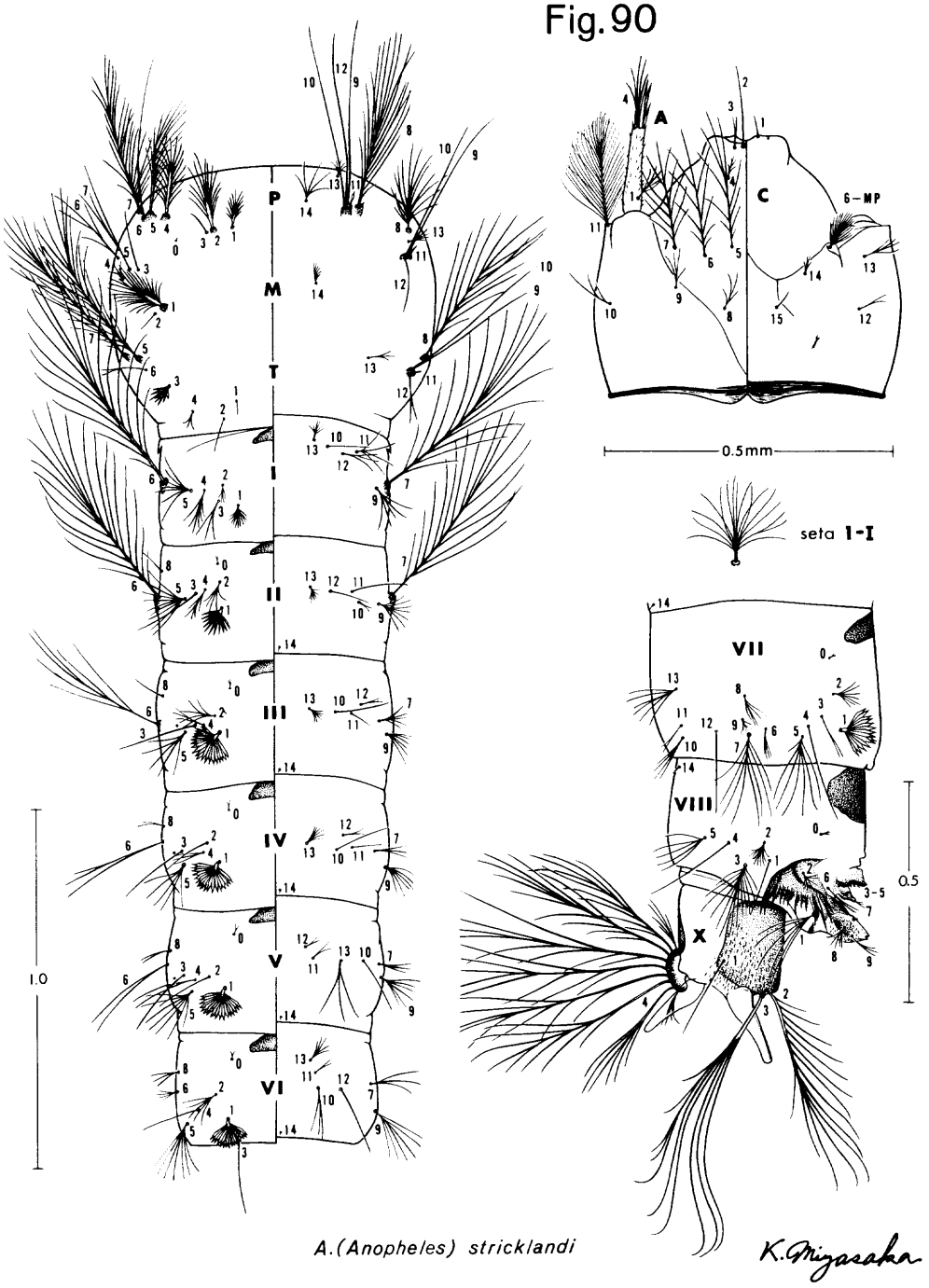




K. Miyazaha

A. (Anopheles) stricklandi

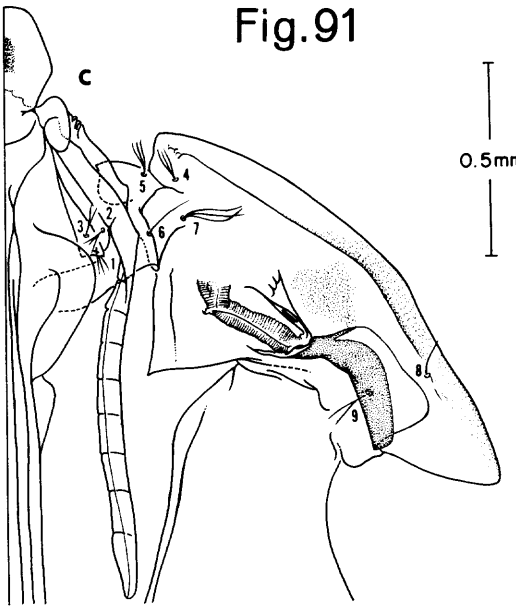
Fig. 90

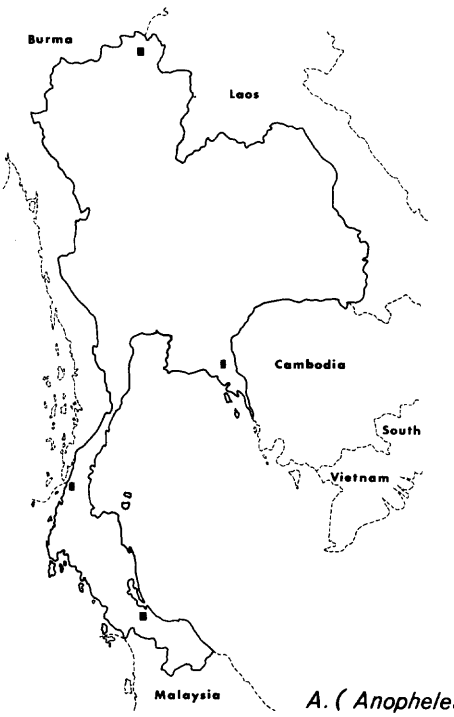


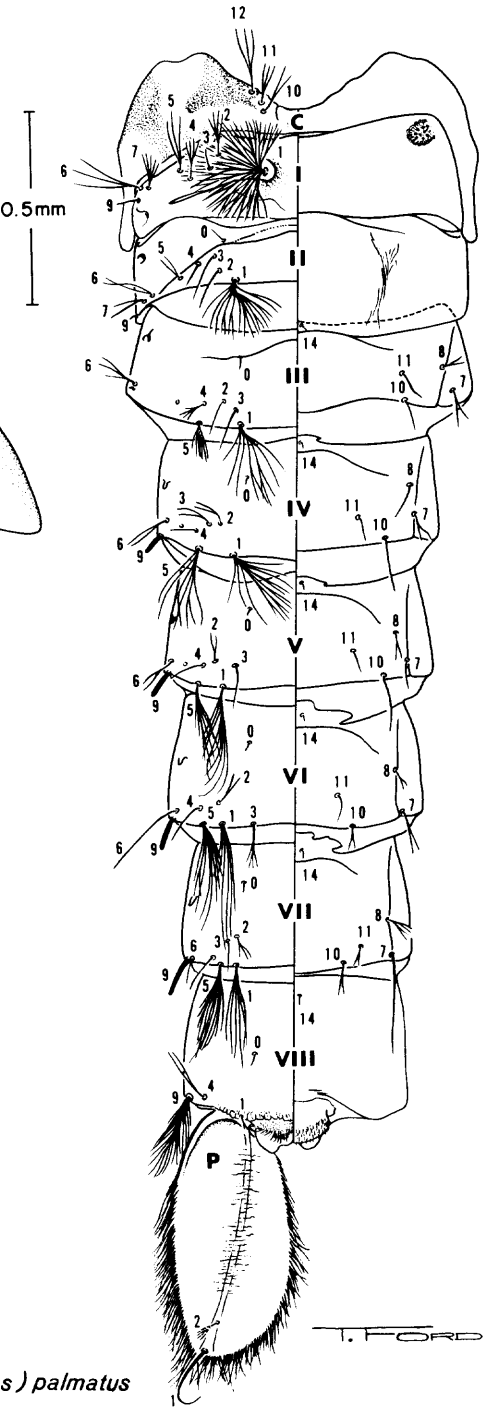
A.(Anopheles) stricklandi

K. Miyasaka

Fig.91

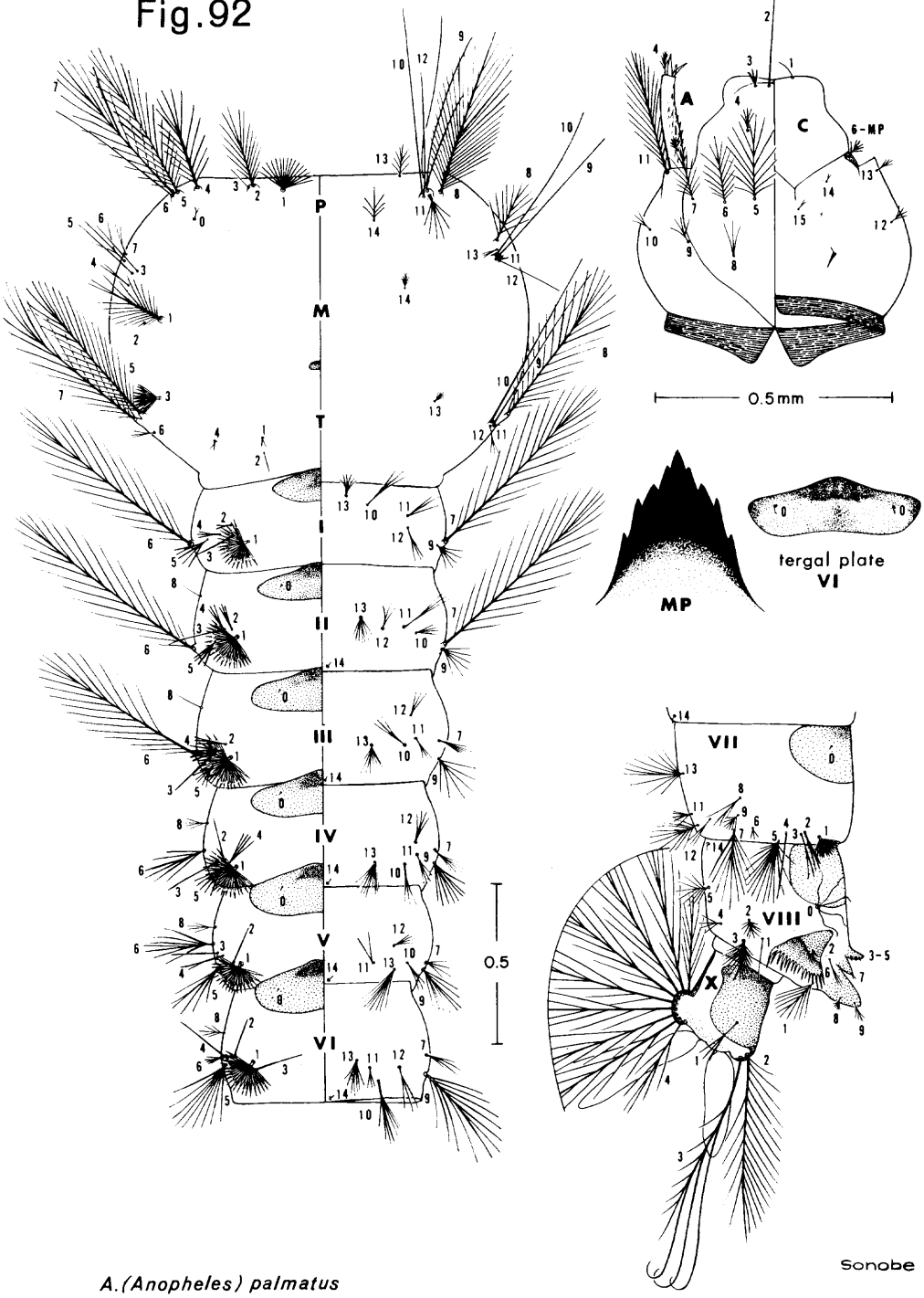






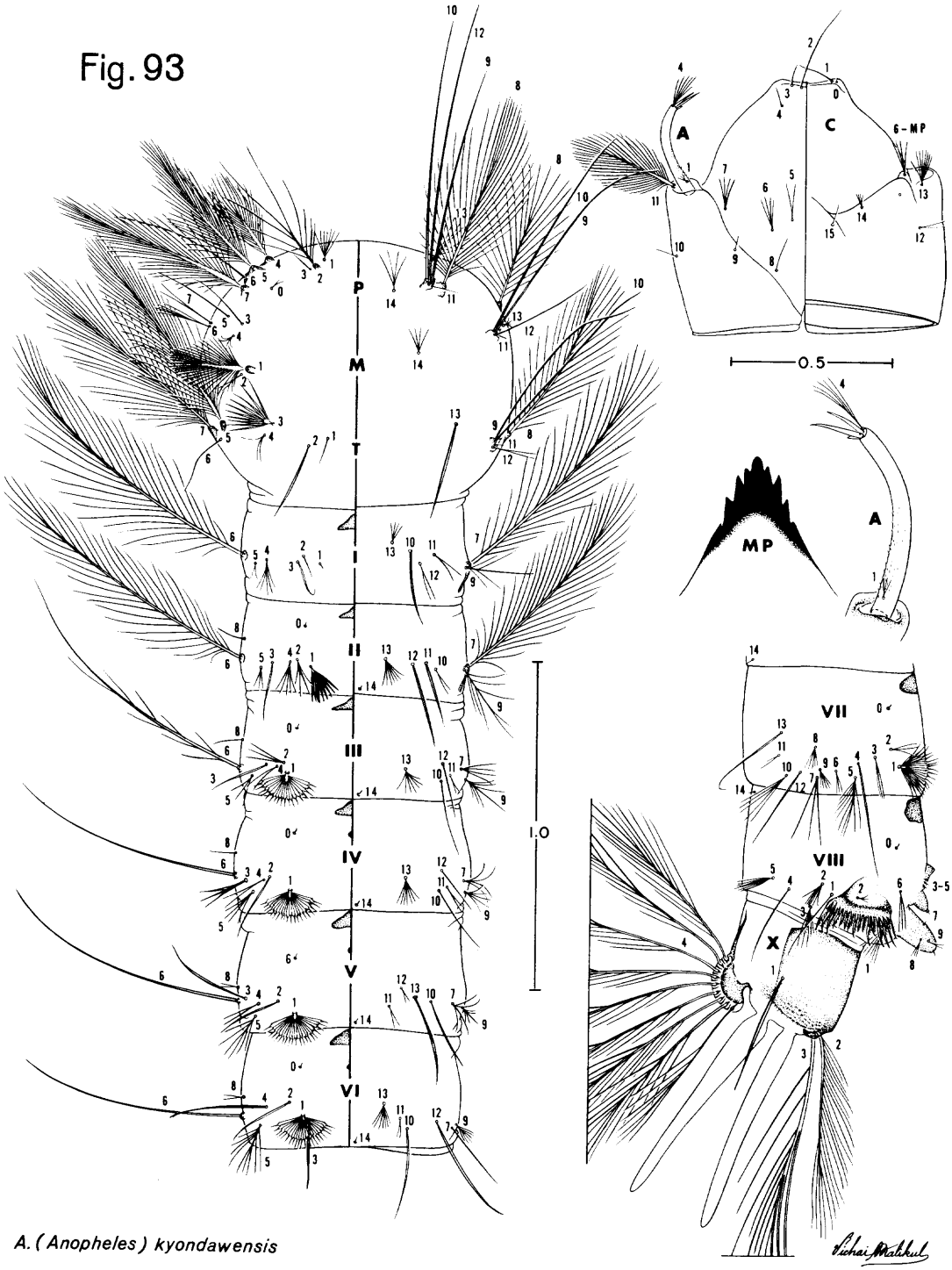
A. (Anopheles) palmatus

Fig.92



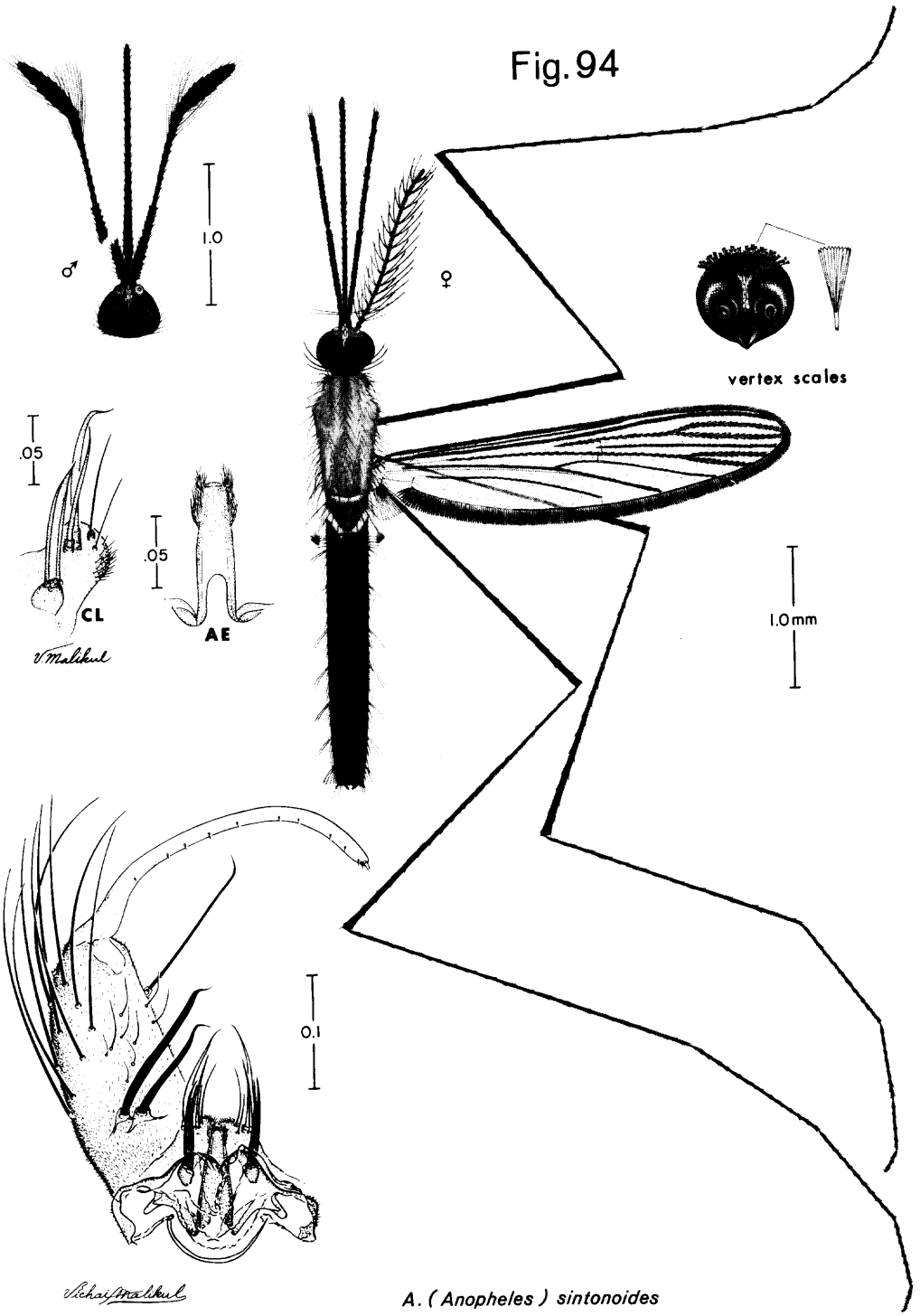
A.(Anopheles) palmatus

Fig. 93



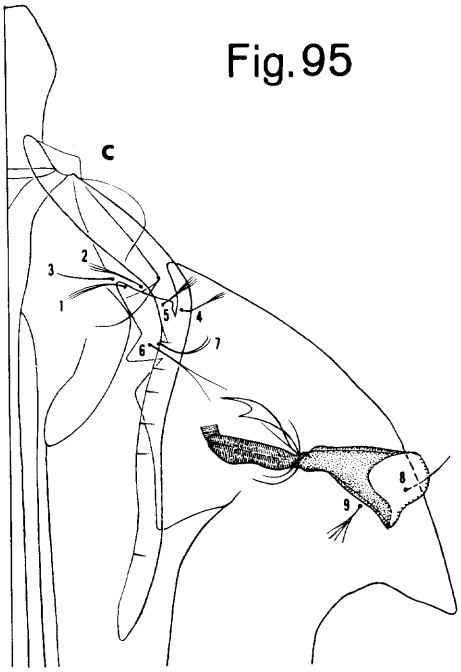
A. (Anopheles) kyondawensis

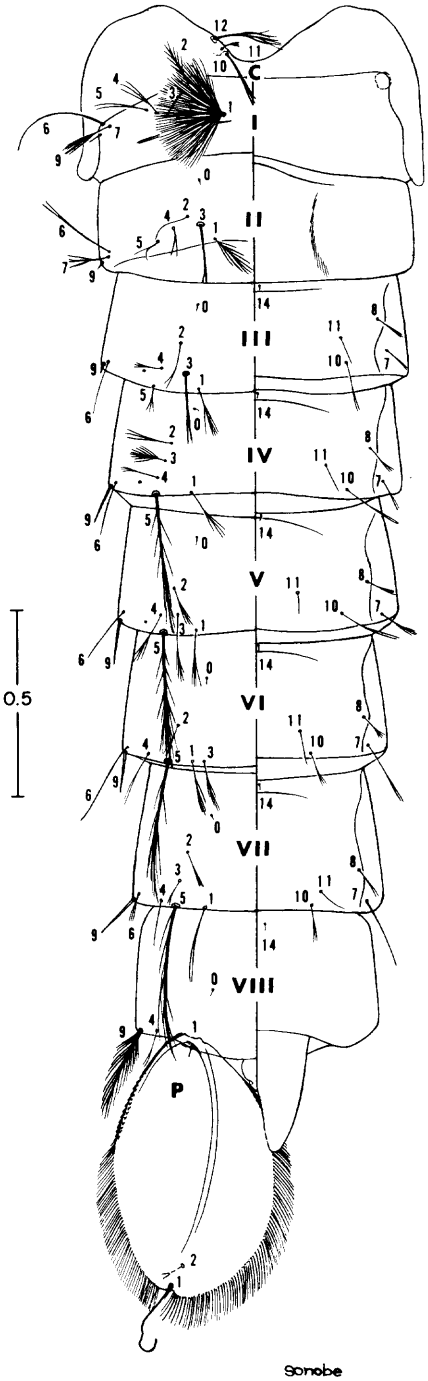
Fig. 94

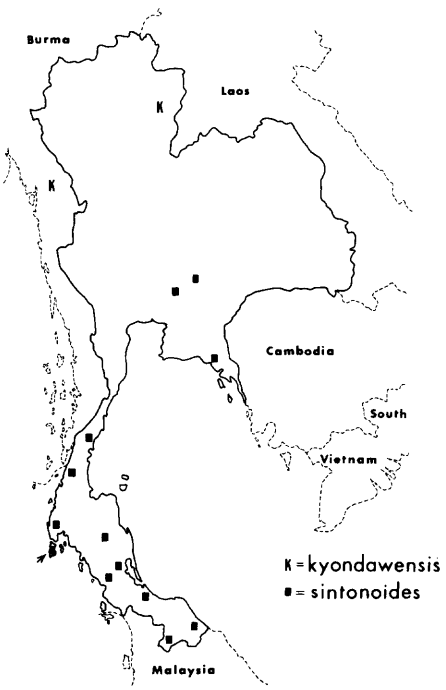


A. (Anopheles) sintonoides

Fig. 95



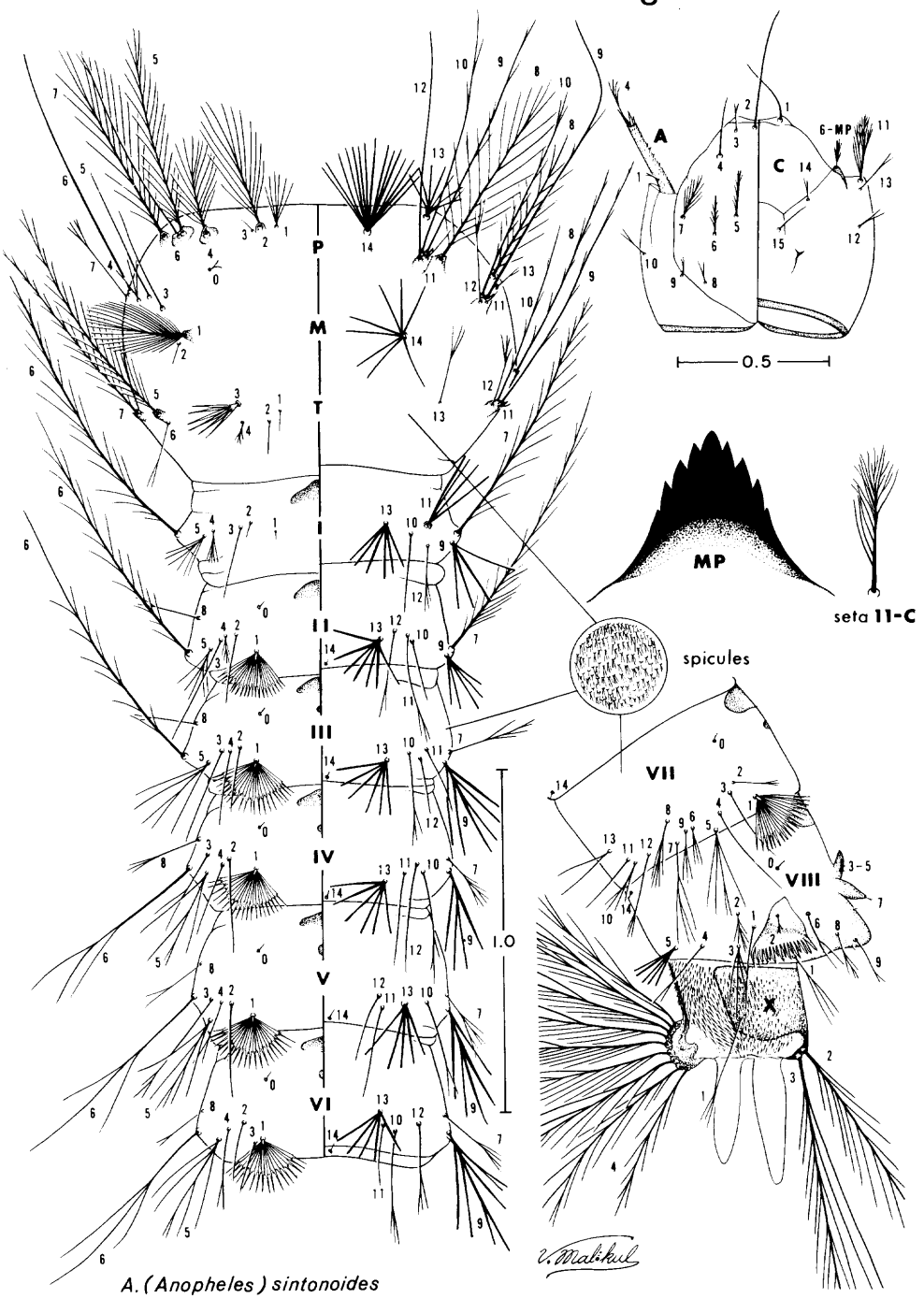




Sonobe

A. (Anopheles) sintonoides

Fig. 96



A. (Anopheles) sintonoides

INDEX

Valid names are set in roman type, synonyms and non-valid combinations are italicized. Italicized pages designate the primary treatment of the taxon. Numbers in parentheses under a given species designate the figure(s) for that species.

aberrans 1, 7, 24, 25, 145, 146, 148-150, *152*, 154-157, 159-162, 166, 175, 176, 191 (76, 77, 78, 79, 83)
acaci 14, 20, 147-149, *150*, 151, 173, 192
aconitus 187
Aedeomyia 138
Aedes 20, 23, 70, 102, 143
Aedimorphus 102
ahomi 79, 80, 192
aitkenii 1, 147-149, *150*-152, 155-157, 160-162, 169 (79)
aitkenii bengalensis 157
aitkenii Group 14, 15, 20, 27-29, 31, 107, 144-146, *147*, 148, 155, 156, 160, 162-164, 169, 172, 173, 175-177, 181, 184
aitkenii palmatus 173
aitkenii var. bengalensis 157
aitkenii var. insulaeflorum 167
aitkenii var. palmata 173
albopictus 70
albotaeniatus 31-33, 192
albotaeniatus Group 27-*31*, 32, 40, 80, 107, 188
albotaeniatus var. montanus 34
algeriensis 144
alongensis 177, *178*, 180, 184, 192
Angusticorn Section 26-28, *132*
Anisodera 133
annandalei, Anopheles *133*, 140, 142, 143, 192
annandalei, Uranotaenia 124
annandalei var. interruptus, Anopheles 140, 142
annularis 186
anophelesica 162
Anopheles (Genus) 1-3, 15, 20, 21, 23-25, 48, 92, 113, 180, 184-186
Anopheles Series 14, 20, 26-29, 31, 135, *144*, 145, 179
Anopheles (Subgenus) 1-4, 6, 7, 14-16, 24, *25*, 26, 28, 33, 135, 148, 175, 184, 186, 192
Anophelinae 21
argyropus 6, 7, 37-44, *50*, 52, 53, 56, 60, 61, 69, 74, 189 (9, 13, 14, 15)
asiaticus 7, 25, 133, 134, *136*, 138-141, 185, 188 (70, 71, 72)
asiaticus Group 15, 27-29, 133-*135*
atratipes 20, 113, 144

baezai 1, 7, 8, 24, 28, 106, 107, 109, 113, *114*-119, 121, 191 (55, 56, 57)
balabacensis 102, 181
balabacensis balabacensis 187
balabacensis introlatus 187
balarensis 31, 32, 192
bancrofti bancrofti, Anopheles 113
bancrofti barbiventris, Anopheles 113, 192
bancrofti Group, Anopheles 20, 40, 80, 113
bancrofti, Wuchereria 75, 88, 93, 96, 114, 122, 124, 128, 132
barberi 148
barbirostris 2, 7, 20, 24, 78-*83*, 85-100, 102, 190 (34, 35, 36)
barbirostris Group 15, 20, 21, 26-33, 40, *78*, 80, 81, 86-88, 90, 92, 93, 96, 99, 102-104, 106, 107, 113, 175, 188
barbirostris Subgroup 32, 33, 79, 99
barbumbrosus 6, 7, 29, 79-83, 86, 87, 89, 90, 94, 98, 99, *102*-105, 190 (49, 50, 51)
barianensis 177
bengalensis, Anopheles, 1, 7, 24, 145, 146, 148-152, 155-*157*, 159-166, 168, 169, 171, 173, 175, 176, 181, 191 (78, 79, 80, 81, 82)
bengalensis, Culex 181
bentleyi 66, 68
bimaculiala 124
Bironella 21
borneensis 148-*151*, 192
brevipalpis 14, 31, 106, 107, 123, 184, 192
brevirostris 106, 107, 192
Bromeliaceae 24

Brugia 33, 40, 50, 53, 57, 61, 65, 70, 75, 88, 89, 93, 96, 118
bulkleyi 7, 133, *134*, 135, 188

campestris 1, 7, 20, 58, 79-83, 86-88, *89*-95, 98, 99, 190 (37, 38, 39)
Cellia 6, 8, 14, 16, 24-28, 144, 145, 181, 184, 186
Chagasia 21
claviger 144
Coelomomyces 162
collessi 106, 108, 120, 123, 192
concolor 144
coustani Group 33, 52
crawfordi 7, 37-40, 42, 43, 45, 48, *54*-58, 60-62, 64, 124, 131, 190 (9, 16, 17, 18)
Culex 36, 102, 167, 181
culicifacies 188
culiciformis 176, 177, *178*-180, 184
culiciformis Group 20, 27-29, 31, 144-146, *176*, 177, 180, 184
Cynocephalus 118
cynomolgi 97, 100, 128, 132
cynomolgi bastianellii 53, 58, 61, 65, 75, 88, 93, 114, 118, 122, 128

D_2 near nigerrimus 75, 77
Dirofilaria 53, 65, 70, 89, 93, 105, 122, 124
donaldi 1, 6, 7, 79-83, 86-88, *94*-99, 101, 190 (40, 41, 42)

Eichornia 65
ejercitoi 31, 32, 192

falciparum 96, 97
fragilis 7, 145, 146, 148-150, 155, 156, 158, 160, 161, *162*-164, 166, 191 (79, 83, 84)
franciscoi 6, 79, 80, 86, 99, 192

gateri 106, 107, 115, 116
Gigantochloa 133
gigas 132, 144, 192
gigas formosus 21, 144
gigas sumatrana 21, 144
goryi 133
grandis 4

habibi 144
hackeri 187
hodgkini 1, 7, 8, 79-83, 87, 94, 95, *97*-102, 104, 190 (43, 44, 45)
hunteri 106, 107, 192
hyrcanus 36, 37, 52
hyrcanus aberration argyropus 50
hyrcanus Group 14-17, 20, 21, 26-31, 33, 34, *36*, 38-40, 48, 50, 52, 57, 61, 65, 79, 80, 89, 106, 107, 128, 131, 175, 188
hyrcanus nigerrimus 50, 58, 68
hyrcanus separatus 128
hyrcanus sinensis 50
hyrcanus subsp. near sinensis 61
hyrcanus var. argyropus 50
hyrcanus var. nigerrimus 66, 70, 71, 73, 75
hyrcanus var. sinensis 45

indefinitus 188
indiana 162
indiensis 38, 58-61, 65, 68, 73
insulaeflorum 1, 7, 25, 145-149, 151, 156, 157, 166, *167*-172, 176, 191 (78, 79, 87, 88)
interruptus 7, 15, 133, 134, *140*, 142, 143, 185, 188 (73, 74, 75)

jamesii 186
javanicus 114
jesoensis 45, 47
jeyporiensis 188
judithae 148

karwari 187
Kerteszia 24
kochi 187
koli 167
kweiyangensis 192
kyondawensis 7, 27, 28, 145, 147, 177, 178, *179*-181 (93, 95)

Laticorn Section 26-*29*
lesteri lesteri 38-40, 50, 56, 63-65, 68, 192
lesteri Malayan form 62, 63
lesteri paraliae 7, 37-45, 48, 56, 57, 60, *61*, 63-65, 78, 189 (9, 22, 23, 24)
lesteri Subgroup 38, 40, 64, 65, 74
letifer 7, 106, 108-110, 113, 114, 117, *118*-127, 191 (58, 59, 60)
letifer Subgroup 106, 108-110, 127
leucosphyrus 138, 181

lindesayi 192
lindesayi Group 32, 33, 144
longirostris 124
Lophoceraomyia 167, 181
Lophomyia 136, 138
Lophopodomyia 24, 135
Lophoscelomyia 136, 138, 139
Lophoscelomyia Series 14, 26-29, *132*-135

maculatus 187
maculipennis 21, 25
maculipennis Group 20, 144
malayi 33, 40, 50, 57, 61, 65, 70, 75, 88, 89, 93, 96, 118
manalangi 79, 80, 86, 99, 192
Mansonia 58, 93
marteri 144
martini 83, 86
minimus 188
minutus 66, 68
montanus 6-8, 16, 20, 27-33, *34*-36, 102, 188 (5, 6, 7)
Muscidus 102
Myzomyia 128, 130
Myzorhynchus 50, 70-73, 83, 105, 110, 112, 128, 136
Myzorhynchus Series 14, 26-*29*, 30, 32, 33, 144

nigerrimus 6, 7, 37-44, 48, 49, 52, 53, 60, 61, *65*-70, 73, 76, 78, 104, 189 (9, 25, 26, 27)
nigerrimus Subgroup 38, 40, 42, 64, 74
nitidus 7, 37-44, 48, 56, *58*-62, 64, 69, 73, 74, 78, 189 (8, 19, 20, 21)
nivipes 187
noniae *133*, 139, 140, 192
novumbrosus 110, 113
Nyssorhynchus 24

obscurus 33
ohamai 31-33, 192
omorii 148, 177

pahangi 93
pallida 1, 150, 157, 159
palmatus 1, 7, 8, 17, 145, 146, 148, 149, 156, 157, 166, *173*, 175, 176, 191 (78, 79, 91, 92)
pampanai 188
Patagiamyia 128
peditaeniatus 7, 34, 37-44, 52, 53, 56, 60, 61, 64, 66, 68, 69, *71*-75, 104, 189 (8, 28, 29, 30)
philippinensis 187
pholeter 167
pilinotum 148-*151*, 156, 168-170, 172, 173, 176, 192 (79)
pinjaurensis 148-*151*, 176
Pistia 78
Plasmodium 53, 58, 61, 65, 75, 88, 92, 93, 96, 97, 100, 114, 118, 122, 128, 132
plumbeus Group 144, 148, 177, 184
plumiger 45, 47
pollicaris 1, 6, 7, 20, 79-82, 87, 98, 99, *100*-102, 113, 190 (46, 47, 48)
pseudobarbirostris 113, 192
pseudopictus 52
pseudopunctipennis Group 144
pseudosinensis 6, 37-39, 68, 74, 192
pujutensis 187
punctipennis Group 144
pursati 6, 7, 31, 37-39, 41-44, 60, 63, 64, *75*, 77, 78, 189 (8, 31, 32, 33)

ramsayi 186
reidi 79, 80
riparis macarthuri 187
roperi 7, 8, 36, 102, 106, 108-110, 112, 113, 118, 120, 121, 123, *124*-128, 191 (64, 65, 66)
rossii 2

samarensis 106, 107, 115, 117, 192
sandoshami 118
saperoi 31-33, 192
scortechinii 133
separatus 7, 30, 105-110, 113, 121, *128*, 130-132, 190 (67, 68, 69)
Setaria 50, 65, 70, 75, 89, 114, 128
similissimus 106, 107, 192
sinensis 6, 7, 10, 37-40, 42-*45*, 47-52, 54, 56-60, 62-66, 68, 69, 71, 73, 74, 76, 77, 190 (2, 8, 10, 11, 12)
sinensis var. peditaeniatus 71
sineroides 192
sintoni 176-*178*, 184
sintonoides 6-8, 20, 27, 28, 107, 145, 147, 177-*181*, 183-185, 191 (94, 95, 96)

species A near umbrosus 118
species B near umbrosus 124
spiculosa 167
splendidus 186
squamifemur 135
stantoni 162, 163
stephensi 187
Stethomyia 1, 24, 150, 157, 159, 162, 163, 167, 173
stigmaticus Group 113, 144, 148
stricklandi 6-8, 145-149, 156, 166, 170, *171*-173, 176, 191 (79, 89, 90)
subpictus 188
sundiacus 187

Tectona 4
tessellatus 187
tigertti 7, 20, 24, 145-149, 152, 155, 156, 160, 162, *164*-167, 169, 175, 181, 191 (79, 85, 86)
tonkinensis 178
traguli 96, 114, 118, 122, 128, 132
Tragulus 114
treacheri 162, 163
typicus var. pseudopicta 50

umbrosus 7, 14, 20, 105-107, 109, *110*, 112-122, 124, 126, 129, 130, 191 (52, 53, 54)
umbrosus Group 15, 16, 20, 23, 25, 27-33, 40, 80, 96, *105*, 107, 108, 112, 113, 122, 123, 131, 175, 188
uniformis 93
Uranotaenia 102, 124, 167, 181

vagus 2, 187
vanus 6, 79, 80, 83, 86, 99, 103, 192
vanus Subgroup 33, 79, 99, 102
variegatus 118
var. djajasanensis 133, 140, 142
var. pallidus 102, 103
var. snijdersi 128, 131
var. williamsoni 66, 68
venhuisi 66, 68
vivax 92, 97

wellingtonianus 135, 192
whartoni 7, 8, 106, 108-110, 113, 114, 119-121, *122*-124, 126, 127, 191 (61, 62, 63)
Wuchereria 75, 88, 93, 96, 114, 122, 124, 128, 132