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THE MYZOMYIA SERIES OF *ANOPHELES (CELLIA)* IN THAILAND, WITH EMPHASIS ON INTRA-INTERSPECIFIC VARIATIONS (DIPTERA: CULICIDAE)

by

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DEDICATED WITH LOVE

to

MY PARENTS

CLAUDE A. and GEORGIA R. HARRISON

for their

faith and patience in allowing me to

pursue my interests.

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MEDICAL ENTOMOLOGY STUDIES - XIII.

THE MYZOMYIA SERIES OF *ANOPHELES (CELLIA)* IN THAILAND, WITH EMPHASIS ON INTRA-INTERSPECIFIC VARIATIONS (DIPTERA: CULICIDAE)[1]

by

Bruce A. Harrison[2]

ABSTRACT

This is a comprehensive revision of the Myzomyia Series of *Anopheles (Cellia)* in Thailand, with a discussion of the other species in the series from the Oriental faunal region. Over 36,000 specimens of 11 species were examined and studied for morphological variations. Included are 23 plates of illustrations of pupae, 4th-stage larvae, male genitalia, and adult female and numerous drawings of the scutum, wing, proboscis and palpus, including variations, for the 6 species in Thailand. Major sections included are: zoogeographic considerations; methods; format; keys to the subgenera and series of the subgenus *Cellia* in Thailand; the Myzomyia Series in the Ethiopian, Palearctic and Oriental faunal regions with keys, and a discussion of the 5 Oriental species not found in Thailand; the Myzomyia Series in Thailand with keys, historical review, medical significance and descriptions of the species; hybridization experiments and appendices. Species descriptions include sections on: synonymy; diagnosis; descriptions of female, male, pupa, 4th-stage larva and egg; type-data; distribution; variations; taxonomic discussion and bionomics. Seven tables on adult variations and adult biting behavior are included in the text and 12 tables on pupal and 4th stage larval setal branching variations are included as appendices.

The type-specimens or type-series for 17 nominal taxa were located and examined. The location of several types is corrected. The pupae of *pampanai* and *varuna* are described and illustrated for the first time. Morphologically deformed variants of *aconitus* and *minimus* adults are described. *Anopheles culicifacies adenensis* and *jeyporiensis* var. *candidiensis* are synonymized. The junior primary homonym *listonii* Liston, is necessarily considered a rejected name. *Pyretophorus jeyporensis* Theobald is considered a junior secondary homonym of *Anopheles jeyporiensis* James. The authorship of the species previously cited as *brahmachari* Christophers by most writers is corrected to McKendrick and Christophers. The name *aconita* var. *merak (cohe-*

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sia) is considered an available name and shown to be a synonym of *flavirostris* instead of *minimus*. Lectotypes are designated for *adenensis, albirostris, christophersi, culicifacies, formosaensis I, jeyporensis* and *listoni*.

Hybridization experiments between *aconitus* and *minimus* show that they are well established species with considerable genetic incompatibility.

INTRODUCTION

Background

The taxonomy and distributions of 10 of the 11 currently known species in the Oriental Myzomyia Series of *Anopheles (Cellia)* have usually been based on the interpretations of King (1932) and Christophers (1933). Only one species has been described since the treatments of the above authors. The 11 species in the series include: *aconitus* Dönitz, *culicifacies* Giles, *filipinae* Manalang, *flavirostris* (Ludlow), *fluviatilis* James, *jeyporiensis* James, *majidi* Young and Majid, *mangyanus* (Banks), *minimus* Theobald, *pampanai* Büttiker and Beales and *varuna* Iyengar. All the species except *culicifacies, jeyporiensis* and *majidi,* form the Minimus Species Group, not to be confused with a true sibling species complex (sensu Mayr 1963). The 8 species in this group have evolved morphological differences in nearly all stages, which is evidence that this is a fairly old assemblage. However, highly variable adult features have previously been used as the primary means for identification and have caused considerable taxonomic controversy. This controversy might have been avoided if workers had followed Strickland (1924) and Manalang (1930), who advocated rearing adults with associated immature exuviae and defining the species by both immature and adult characters.

Reid (1968) attempted to improve our knowledge of the Myzomyia Series, however, the scope of his work was limited because this series was poorly represented in his study area. Subsequently, Scanlon, Reid and Cheong (1968) and Reid (1970) recommended further taxonomic studies on members of this series.

A logical place to conduct such studies was suggested by Reid (1968), who indicated that nearly all of the Oriental species in the series* might be found just north of Malaya, in Thailand (see Zoogeographic Considerations). In fact, by the late 1960's, 9 species and 2 subspecies in the Myzomyia Series had been reported from Thailand in the literature, while another subspecies was recognized in unpublished reports. Two species, *aconitus* and *minimus*, were confirmed vectors of human malarial parasites in Thailand and several of the others were also suspected vectors of human pathogens, primarily because of their known vector capabilities in other countries. Adults were infrequently collected and identified in Thailand that corresponded to species normally encountered in India or the Philippines, however, attempts to collect the immatures of these species were unsuccessful. Medical entomologists working in Thailand became increasingly concerned about difficulties encountered in identifying adults of this series (Scanlon, Peyton and Gould 1968, Scanlon, Reid and Cheong 1968). Characters used to differentiate adults were known to be

*The category "Series" is used throughout this study, but is not intended to denote any official status as defined by the International Code of Zoological Nomenclature (ICZN = Stoll et al. 1964).

variable, possibly even overlapping; however, the frequency and types of variations occurring on Thai specimens had not been established. Some of the species recorded from Thailand were suspected to be misidentifications (Peyton and Scanlon 1966, Scanlon, Peyton and Gould 1968), but a major revisionary work was deemed necessary to determine the species in the Myzomyia Series actually occurring in Thailand.

The present study was initiated in 1967 with hopes of resolving the above confusion. The initial 33 months of field work was conducted in Southeast Asia, primarily Thailand, under the aegis of the Walter Reed Army Institute of Research (WRAIR), Washington, D. C. and the U. S. Army Medical Component-Southeast Asia Treaty Organization (SEATO), Bangkok, Thailand. Several years of laboratory studies were conducted with support from: WRAIR, Washington, D. C.; the Southeast Asia Mosquito Project (SEAMP) and the Medical Entomology Project (MEP), Smithsonian Institution, Washington, D. C.; and the Department of Entomology, North Carolina State University, Raleigh, North Carolina.

Initial plans called for a taxonomic revision of the entire Oriental Myzomyia Series. However, after several years it became apparent that adequate numbers of reared feral specimens from 2 critical areas, India and Indonesia, would not be available for study. Accordingly, the study was restricted to Thailand, although some results are of much broader scope.

The primary objectives of the present study were to: (1) determine those species occurring in Thailand; (2) establish the range of morphological variations for each species in Thailand and find reliable characters for use in keys; (3) describe completely the 4th larval, pupal and adult stages; (4) determine the distributions of those species in Thailand; and (5) colonize the available species and attempt crosses between them to determine if hybridization in nature could be responsible for highly variable (even overlapping) adult characters. A secondary objective was to gain additional information on the behavior and biology of those species in Thailand.

Zoogeographic Considerations

Harrison and Scanlon (1975) briefly discussed the zoogeography of Thailand. Since then, provincial changes have occurred in Thailand and additional publications have appeared, making further discussion necessary.

The country is now divided into 72 Changwats (= provinces) (Fig. 1). Recently, Chiang Rai Province was divided into Chiang Rai and Phayao provinces and Ubol Ratchathani Province was divided creating Ubol Ratchathani and Yasothorn provinces. In addition, Thon Buri and Phra Nakhon provinces were combined into Krungthep Maha Nakhon Province. The list of Province names employed (Fig. 1), as in Harrison and Scanlon (1975), conforms to the Official Standard Names Gazeteer No. 97 of the U. S. Board of Geographic Names, Washington, D. C.

Thailand is approximately 514,000 km^2 in size and occupies a unique zoogeographic position in Southeast Asia. Beside having its own endemic fauna, Thailand serves as a crossroads for floral and faunal dispersal from at least 3 different subregions of the Orient [Indian, Chinese and Sundaic (= Malaysia-Indonesia)]. Because of this location, its extension from 6° to 21° N latitude, its distribution of mountains (Pendleton and Kingsbury 1962, Harrison and Scanlon 1975) and several regional weather patterns (see below), Thailand has a wide variety of habitats with a tremendous variety of plant and animal life.

Accordingly, Thailand has about 13% (400/3,000) of the world's described mosquito species, of which approximately 58 are *Anopheles*. This abundance of species means that a given nocturnal adult collection will often include 8-12 species, and under special conditions may include up to 20 species of anophelines.

Although there are 2 basic monsoon seasons in most of Southeast Asia (Bingham 1968, MacKinnon and MacKinnon 1974), 3 seasons as defined by Ayurakit-Kosol and Griffith (1962) more accurately depict the climate in the northern half of Thailand. The monthly parameters for these seasons are variable from year to year causing the different dates seen in the literature. Generally these seasons are: (1) cool-dry season (late November to early February); (2) hot-dry season (late February to late May); and (3) rainy season (June to early November). The rainy season has been further divided into 2 parts by Pendleton and Kingsbury (1962). These last authors offer the most comprehensive discussion of climatic factors in Thailand.

Descriptions of the forest cover of Thailand by Pendleton and Kingsbury (1962) and by MacKinnon and MacKinnon (1974) are outdated. Current estimates are that nearly all of Thailand's forests will be cut or destroyed in the next 15-20 years. Such drastic changes will alter the distribution and population densities of animals, including mosquitoes.

Thailand is usually divided into 6 regions based on orography, precipitation and floral patterns (Kloss 1915): North, Northeast (Korat Plateau), Central Valley, Western Mountains, Southeast, and South (Peninsular). Pendleton and Kingsbury (1962) listed only 5 major regions, combining the North and Western Mountains into a "Continental Highlands" region. Bunnag (1977) advocated 6 biogeographic regions, but combined the Western Mountains with Central Valley and split the South (Peninsular region) into South and Far South. Most recently, Lekagul and McNeely (1977) have de-emphasized (although still recognizing the 6 regions listed initially above) the regionalization of Thailand and have emphasized the role of orography and rainfall patterns in determining the basal floral patterns, which in turn serve as the primary key to faunal (mammal) distributions in Thailand. These last authors also discuss the geological history of the Sunda Shelf (including Thailand), the classification of the forest types and the current disruption and destruction of the forests in Thailand.

Most Thai anophelines can be categorized on the basis of forest type, which lends support for possibly 5 or 6 biogeographic regions in the country: (1) North and Western Mountains; (2) Central Valley; (3) Korat Plateau; (4) South (Peninsula from Isthmus of Kra south to Malaysia); and (5) Southeast (primarily Chanthaburi and Trat provinces). The northern region and the western mountains (hill and dry evergreen forest areas) down to at least Kanchanaburi Province, contain anopheline species which are usually considered Indian elements. The South apparently represents a gradient area in which a number of typical Malayan anophelines extend into Thailand. Several of these anophelines have their northernmost extension in the most southern Thai provinces (possibly dependent on evergreen rainforest found primarily in the far South), while several *Anopheles (Anopheles)* species extend up the west side of the peninsula, probably into southern Burma (Harrison and Scanlon 1975). Conversely, several *Anopheles (Cellia)* species, including *minimus*, extend southward to approximately the Thai-Malaysia border (Reid 1968). The Southeast contains evergreen rainforest, semi-evergreen and dry evergreen forests like the forests on the peninsula. The Southeast also contains several typical Malayan anophelines (Harrison and Scanlon 1975), which suggests these evergreen for-

ests were probably connected during the Pleistocene. The Korat Plateau and Central Valley regions have nearly identical anopheline faunas; however, at least one species, *pampanai*, found on the Korat Plateau is apparently very rare or absent in the Central Valley.

The Thai members of the Myzomyia Series fit into these biogeographic regions as follow: (1) *aconitus* occurs in all the regions; (2) *culicifacies* occurs only in the North and the Western Mountains; (3) *jeyporiensis* has essentially the same distribution as *culicifacies;* (4) *minimus* probably still occurs in foothill-mountainous areas of all the regions, but with the alteration of this environment (pesticides, deforestation, silting, pollution) it is absent or very sparsely distributed in sections of the Central Valley, Korat Plateau and the South; (5) *pampanai* is currently known only from the North, Korat Plateau and one collection from the Southeast adjacent to the Cambodian border and (6) *varuna* has been confirmed from only 2 sites in the North.

Methods

The methods employed during this study were different from those used in most taxonomic studies based primarily on morphology. From the beginning, the variability of species in this series was recognized, but parameters of those variations were unknown. With a more classical or numerical taxonomic study, museum specimens of adults with or without associated immature skins, larval specimens and possibly adults reared from colony specimens, would have been analyzed for intra-interspecific variations. In this study, parameters of intraspecific variation were determined primarily on the basis of studying adult progeny (with associated immature skins) from feral females. With the wild mother pinned and her characters analyzed, the stability or variability of characters within the brood were easily assessed by comparing the progeny, and the progeny with the mother. After sufficient broods of progeny had been analyzed for frequencies of certain variations, these frequencies were then compared with frequencies of the same variations occurring on feral adults or adults (with immature skins) reared from wild larvae. In the absence of reared progeny broods of the Myzomyia Series in museums or other repositories, it was necessary for the investigator to make extensive collections of this series in Thailand and other parts of Southeast Asia. Following an analysis of intraspecific variations, interspecific variations with or without overlap were analyzed and then, depending on the ability to colonize or maintain adequate adults by the forced mating technique (Ow Yang et al. 1963), hybridization studies were attempted. Due to the low density and limited distribution of several species and the long time involved in rearing progeny broods to adults, the study of progeny and subsequent hybridization experiments were possible only with *aconitus* and *minimus*.

Collections were designed to capture the greatest number of feral adults or immatures of Myzomyia species. Consequently, less productive methods (e.g. man-biting inside houses for *minimus*) were discontinued and unproductive collection sites were avoided. All specimens were identified initially by published keys (Christophers 1933, Peyton and Scanlon 1966, Reid 1968, Rattanarithikul and Harrison 1973) with the aid of a microscope. Adult females were examined for external morphological color and meristic variations, particularly on the proboscis, palpi, thorax, wings and legs. Characters that had been judged most reliable in published keys and descriptions were considered "classical," while characters not fitting the keys or the classical

descriptions were called "variations."

All specimens were assigned a collection number and immatures were individually isolated and reared to adult with the 4th larval and pupal exuviae preserved and mounted on a slide. Adult feral females were usually offered a blood meal and placed in isolation in oviposition vials containing a small amount of water. After oviposition each female was pinned and assigned an identification number. Only F_1 progeny from feral females were examined for intra-interspecific variations, progeny were not obtained from females reared from field-collected immatures. Progeny from a given female were isolated upon becoming 4th instar and reared to adults, with the 4th-stage larval and pupal exuviae preserved and mounted on a slide. Each adult (and its immature skins) from a progeny brood had an individual coded identification number which could be associated by prefacing numbers with the other siblings in the brood, its mother and the general collection in which the mother was captured.

The distributions for the 6 species occurring in Thailand are based primarily on adults confirmed by associated immature skins. Species with a large number of specimens are recorded by provinces (= Changwats) while more precise locality records are listed for rare species. Distribution listings outside of Thailand are based on specimens examined and published records. Certain published distribution records are questioned or considered misidentifications.

All feral females displaying variations were isolated for oviposition while those conforming to the classic description of the respective species were not always isolated. The biased selection of females with variations was designed to accrue the widest range in variations in progeny. In actuality, progeny from "classical" mothers proved to be as variable as those from "variable" mothers.

In Thailand, a laboratory in Phra Phutthabat, Sara Buri Province, about 130 km north of Bangkok, was used as the center for most of the collections and rearings. The rearing of progeny broods was greatly expedited by having a permanent base-laboratory. The lengthy time and space required to individually rear isolated broods essentially eliminated this technique from field trips of less than 30-35 days. Although 507 collections were made in Thailand during an 800-day period, from 7° 30" N to 19° 20" N latitude and 98° 20" E to 103° 20" E longitude, 75.3% (382/507) were made within a 150 km radius from Phra Phutthabat. Over 97 locations were visited for collections, however, 9 sites in the 150 km radius of the base laboratory furnished most of the specimens. Of the 507 total collections, 396 were adult collections (mostly human-or bovine-biting outside, resting or CO_2) and 111 were immature collections.

Two collecting trips were made outside of Thailand. The first trip, to Luzon and Mindoro islands in the Philippines, was designed to collect and rear adults (with associated immature skins) of the 3 species of the series that occur in the Philippines (*filipinae*, *flavirostris* and *mangyanus*). At the time of this trip, 2 of these 3 species had been identified (adults only) in Thailand, and confirmed specimens with immature skins from the Philippines were needed to verify their existence in Thailand. The Philippine trip yielded 52 larval and 11 adult collections, 1,304 adults of the 3 species (1,042 with associated immature skins) and hundreds of whole larvae.

The 2nd trip was to the New Territories, Hong Kong, and was designed to collect reared adults with immature skins of *jeyporiensis* and topotypic specimens of *minimus*. The holotype of *minimus* has been lost for many years and

specimens from the vicinity of the original description were needed for comparison with those from Thailand. The Hong Kong trip produced 37 larval and 8 adult collections, 943 adults of the 2 species (852 with associated immature skins) and over 600 whole larvae.

A most important aspect of this study was the examination of type-species and type-series. Of the 30 nominal taxa involved in the taxonomy of the Oriental Myzomyia Series, one was a *nomen novum* (without types) and 10 were confirmed to have either no type-specimens or the specimens are currently lost. I located and examined the type-specimens or type-series for 17 of the remaining 19 nominal taxa. These examinations were conducted during visits to the British Museum (Natural History) (BMNH), London, the Pasteur Institute, Paris (PIP) and the National Museum of Natural History (USNM), Washington. Of the existing type-specimens, only those for *aconitus* and *brahmachari* McKendrick and Christophers were not examined.

The usage of "series" in this work follows that of previous workers and is not considered a primary subdivision of a genus (Stoll et al. 1964, article 42d), but an infrasubgeneric category. An historical review of this usage and some associated problems are presented in the "Taxonomic Discussion" under the Subgenus *Cellia*.

An extensive review of the literature was made during this study, however, a comprehensive review was impossible considering all of the periodicals throughout Asia that have referred to various members of the series as vectors of diseases. Every effort was made to cite all references important for an understanding of the biosystematics of the Oriental members of this series. Abbreviations for references conform to "Serial sources for the BIOSIS data base," Vol. 1978, Bio-Sciences Information Service, Philadelphia, Pennsylvania.

The morphological terminology used here is that used by Harrison and Scanlon (1975), with some modification.

In the present study scale lines intentionally were not added to certain drawings, so that size (highly variable) would not be considered important.

The numbered wing spot terminology code of Harrison and Scanlon (1975) has been replaced in the present work by abbreviations of the spot names (e.g., Reid 1968).

The Oriental members of the Myzomyia Series all possess sparsely scattered pale scutal scales that are usually small and difficult to see (except those on *jeyporiensis* and *majidi*). Aside from these last 2 species, when these scales are viewed under the dissection microscope, they usually appear like small pale setae. At higher magnification under a compound microscope they appear as a variety of scales, mostly falcate, fusiform, piliform and intermediate types (Harbach and Knight 1978b). Due to the intra-interspecific variations of these scale types, their more or less random distribution, and based on their usual appearance, I have decided to call them "seta-like" scales to avoid confusion.

Chaetotaxy tables (Appendix) for pupal and larval setal branching have been added to provide an understanding of the innate variation that exists in the series. The counts entered in the tables came from field-collected 4th-stage larvae, or pupae reared from field-collected 4th-stage larvae. Counts were not made from colony specimens or progeny immatures from feral females, due to possible branching changes that might be induced by colony inbreeding, or by the laboratory environment and/or techniques.

The wing, leg, pleuron, scutum, palpus and proboscis illustrations on Figs. 2-6 (except the wing veins and hypothetical wing) were drawn from single

specimens. The remaining illustrations (Figs. 7-24) are composite drawings based on more than one specimen.

The cibarial armature of species in the Oriental Myzomyia Series is fairly uniform. Myzomyia members typically have 2 rows of cibarial teeth, one of cones the other of rods. The cones lack roots and have a single row of short spines on the crest of the pediment. Christophers (1933) presents a description of this structure in all of the Oriental Myzomyia species except *filipinae, flavirostris, mangyanus* and *pampanai*. Gater (1935) and Reid (1968) present excellent reviews of the morphology of this structure. Only very minor differences in the cibarium were detected between Myzomyia species (Christophers 1933), and these characters can be analyzed only after dissection, mounting and careful study. Accordingly, I decided a careful analysis of the cibarial characters during this study was not justified.

The male genitalia characters of species in the subgenus *Cellia* are rarely of specific value, and this holds true for species in the Oriental Myzomyia Series. Genitalia preparations were examined, but specific characters were not found, although a difference was detected between the proctigers of *aconitus* and *minimus*. However, genitalia are so uniform in *Cellia* that characters to separate the various series or species groups are still unknown. Adult males of the Oriental Myzomyia Series are best identified on the basis of associated immature skins.

Primary emphasis was placed on the study of pupae. The position in life of this stage next to the adult, and its brevity, make it extremely valuable for confirming adult identities. In recent years, Reid (1950a, 1953, 1962, 1965, 1968), Belkin (1962), Harrison and Scanlon (1975) and Floore et al. (1976) have demonstrated the taxonomic value of *Anopheles* pupae. In comparison with larvae, the pupal stage possesses fewer setae that are easier to locate, its skin is sturdier, and it is easier to rear, preserve and mount. Except by Baisas (1936) and Reid (1968), pupae of the Oriental Myzomyia Series have not been considered taxonomically important and were usually ignored in taxonomic publications. Baisas (1936) was unable to find characters to separate the 3 Philippine species, *filipinae, flavirostris* and *mangyanus*, and Reid's (1968) characters for separating Malaysian *aconitus* and *minimus* are not always valid for Thai specimens. During this study, excellent characters were found for separating the pupae of the 6 species in Thailand, and characters were found for separating the pupae of 10 of 11 species in the Orient. Only *fluviatilis* and *minimus* pupae remain inseparable, primarily due to the lack of *fluviatilis* specimens for study. Most pupae of the Philippine species, *filipinae, flavirostris* and *mangyanus*, can be separated, but some overlap occurs and additional characters are needed.

Reid (1968) discussed "minute short spicules" on the inner wall of the trumpet meatus. These appear as "stellate spicules" on the 6 Myzomyia species in Thailand (Fig. 14).

The pupa setal and morphological designations herein conform to those used in Harrison and Scanlon (1975) except: (1) "CT" is used to signify the cephalothorax instead of "C"; (2) "MP" is used to signify the metanotal plate instead of "C"; (3) "mesal angle" (Fig. 14) is that point on the paddle mesal margin that first touches the vertical axis of a hypothetical or actual right angle at the same time the paddle apex is touching the horizontal axis. A left facing 90° angle is used with the left paddle and a right facing 90° angle with the right paddle. The vertical axis of the right angle must be parallel to a straight line drawn between the 2 most distant points on the paddle (base and apex, not including fringe and setae).

Larval characters have been known and used for years to separate the Oriental species in the Myzomyia Series. Most of the known larval characters have been considered fairly stable. Primary efforts during this study were to determine the amount of variation occurring in known larval characters and to find new characters for separating larvae of these species. Most larval characters were found to be variable, however, combinations of characters were found which would identify essentially 100% of the larvae from Thailand.

The larva setal and morphological designations used here conform to those in Harrison and Scanlon (1975) except: (1) 20-C is used to designate the hypostomal sclerite seta previously designated 6-MP (Knight and Harbach 1977); (2) the posterior lateral sclerotized lobes of the spiracular apparatus, where 8 and 9-S are inserted, are considered the "posterolateral spiracular lobes" and the median sclerotized plate previously labeled "ventrolateral valve" by Harrison and Scanlon (1975) is called "median plate" after Harbach and Knight (1978a); and (3) the length of seta I-X is used in a ratio by dividing it by the length of the saddle along its dorsum (midline). The term "simple" seta is used sensu Harbach and Knight (1978b).

No attempt was made to analyze egg characters, however, eggs were retained for later study. Egg characters have been described for some, but not for all 11 species. The eggs of several species are already known to exhibit considerable variations, and in view of the influence of environmental and genetic factors on egg variation (White 1977), the eggs of the other species are probably variable. Thus, very little reliance should be accorded the eggs (as presently known) of Myzomyia species for species identification.

Format

The format for this work basically follows that presented in Harrison and Scanlon (1975). However, changes and additions are summarized below. A historical review section has been included to summarize all of the publications that apply to the series in Thailand. Instead of discussing medical importance under each species, a separate section entitled "Medical Significance" covers the 6 Thailand species. The medical significance of the other 5 Oriental species is briefly presented under each species in the Taxonomic Discussion for the Myzomyia Series. Illustrations (Figs. 2, 3, 6) have been included to show a number of common adult variations, and chaetotaxy tables have been added to give pupal and larval setal branching variations.

Under the individual species treatments the synonymy includes all of the known nominal taxa. In addition, a number of taxonomic changes involving the status of the nominal taxa have been included in the synonymy and type-data sections. These changes supersede the taxonomic interpretations listed in the catalog of the mosquitoes of the world (Knight and Stone 1977) and its supplement (Knight 1978a). The synonymy sections were also expanded to include not only important taxonomic entries, but also the first publications to describe and/or illustrate the respective life stages, and important biological and medically important references. Within the parentheses following each synonymy 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.

A section on variations has been included under each species. This section

covers adult, pupal and larval variations that are of intra-interspecific importance. For some species, data are presented (tabular), on frequencies of selected variable characters. In these tables (1, 3, 4, 5, 7), the 1st column shows the frequency *(f)* of that character and the 2nd cites the number (No.) of specimens with that character in the sample. Specimens exhibiting morphological abnormalities (genetic or non-genetic) are also listed with references to similar or identical abnormalities found in other species.

In the taxonomic discussion sections, primary diagnostic characters are listed and compared with the same characters on the other species. Secondary characters are discussed and listed that may be of value in identifying unusual or difficult specimens.

The bionomics sections cover the major aspects of adult and larval behavior as currently understood, and offer numerous important references. Other subjects covered in this section are: (1) information on the susceptibility of the species to pesticides; (2) a list of currently known parasites and pathogens for the species; and (3) special topics of importance for the understanding of the species and its role in the epidemiology of disease transmission.

A section on hybridization experiments (p. 119) covers the techniques and results from 122 crosses between *aconitus* and *minimus*.

TAXONOMY

A good taxonomic base is most important for work on research conducted on a group of insects, particularly a medically important group such as the Myzomyia Series of *Anopheles (Cellia)* in Thailand. Once a good base has been established, however, the search for new and better characters must continue, otherwise the base will not retain the quality necessary to support ever-changing research goals and techniques. Because good adult and larval taxonomic characters were found in India and the Philippines for most of this series during the 1930's, further taxonomic efforts on these species nearly stopped. However, those studies were not based on Thai specimens, and did not fully recognize the importance of population genetics in taxonomy. During recent years the need for additional morphological characters to distinguish species in Thailand became very obvious. The following taxonomic efforts stem from that need.

KEYS TO THE SUBGENERA OF *ANOPHELES* IN THAILAND

ADULTS

Costa divided by pale spots into 4 or more dark marks involving both veins C and R-R_1; male basimere with cluster of 4-6 parabasal spines, no internal spine. . . . . *Cellia*

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 innermost parabasal shorter and stouter than the outer. . . . . *Anopheles*

PUPAE

Seta 1-P long, strongly curved or coiled, usually hooked at tip (except Neomyzomyia Series with: stout spiny teeth on basal 0.50-0.80 of lateral

paddle margin; paddle fringe filaments short; fringe filaments sparse, not well developed on mesal paddle margin); male pupae with rounded point or knob on apex of each genital lobe. . . . . *Cellia*

Seta 1-P short, straight and simple or branched (except *lindesayi* Giles, *palmatus* (Rodenwaldt) and *sintonoides* Ho, with: spiny teeth absent or limited to small area on basal 0.33 of lateral paddle margin; paddle fringe filaments very long; fringe filaments dense and very well developed on mesal paddle margin, nearly extending to base); male pupae with apices of genital lobes blunt. . . . . *Anopheles*

LARVAE

Seta 1-A simple; setae 2-C inserted at least as far apart as the distance between 2-C and 3-C on one side. . . . . *Cellia*

Seta 1-A branched (except on several species with setae 5-7-C reduced); setae 2-C inserted close together, closer (rarely equal) than the distance between 2-C and 3-C on one side. . . . . *Anopheles*

Subgenus *Cellia* Theobald

Cellia Theobald 1902a: 181-3. Orthotype: *Anopheles pharoensis* Theobald (for detailed synonymy see Knight and Stone 1977).

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

ADULT. Wing with colors in defined spots, not randomly mixed pale and dark scales; R, M forks and crossvein intercepts pale-scaled.

FEMALE. Cibarium with teeth, often separated into rods and cones.

PUPA. With angusticorn type trumpets; seta 1 on abdominal segments V-VII as strongly developed as seta 5.

LARVA. Antennal seta simple, usually inserted on outer aspect of antennal shaft; metathorax with at least one long branched pleural thoracic seta (9 or 10-T) (except Neomyzomyia Series).

DISTRIBUTION. Species in the subgenus *Cellia* are currently confined to the Eastern Hemisphere, with representatives in the Australian, Ethiopian, Oriental, Palearctic and South Pacific faunal regions. During the 1930's one member of this subgenus in the Gambiae species complex [probably species "B" = *arabiensis* Patton (White 1974, 1975)] became temporarily established in Brazil. It was eradicated from the Western Hemisphere only after considerable monetary and human expenditure (Soper and Wilson 1943).

Cellia is the largest subgenus in the genus *Anopheles*, containing approximately 173 species (White 1977). The anopheline fauna of the Ethiopian region is predominately *Cellia*, i.e., 112 of 122 recorded species (White 1975). In the other Eastern Hemisphere zoogeographical regions, *Cellia* is less prominent and the subgenus *Anopheles* is often the numerically superior category, e.g., 33 species of subgenus *Anopheles* and 25 *Cellia* in Thailand.

TAXONOMIC DISCUSSION. A number of authors, e.g., Christophers (1924a), Sinton and Covell (1927), Puri (1931) and Edwards (1932), have proposed and/or discussed systems for indicating affinities in the subgenera *Anopheles* and *Cellia*. Edwards (1932) used the terms "group" and "series" in descending order for additional categories between subgenus and species in

the subgenus *Anopheles*, and "group" for such categories in *Cellia*. These categories are very useful tools for taxonomists, and thus were accepted in monographs by Christophers (1933), Evans (1938), de Meillon (1947), Bonne-Wepster and Swellengrebel (1953) and Belkin (1962). In 1961, Reid and Knight revised the infrasubgeneric categories of the subgenus *Anopheles*, modifying the original "groups" of Edwards (1932) and substituting the term "section" for "group" to eliminate possible confusion with "species group." The original subgenus *Anopheles* "series" of Edwards remained the same except that Arribalzagia and Christya were reduced from group to series level. Independently, Reid (1968) and Gillies and de Meillon (1968), changed the Edwards term "group" in *Cellia* to "series." However, Gillies and de Meillon went a step further and introduced a category called "section" below the series level, apparently unaware that Reid and Knight (1961) had used this term for a category above the series level. Fortunately, this disparity with "section" has not altered the basic series (= group) scheme used by Edwards (1932). Based on this scheme there are currently 6 series recognized in the subgenus *Cellia:* Cellia, Myzomyia, Neocellia, Neomyzomyia, Paramyzomyia and Pyretophorus. On the basis of cibarial armature, larval pleural thoracic setae, adult chaetotaxy and adult color pattern, Neomyzomyia would appear to represent a more generalized ancestral assemblage, with Myzomyia intermediate and Pryetophorus and Neocellia the most derived series.

KEYS TO THE SERIES OF THE SUBGENUS *CELLIA* IN THAILAND

ADULTS

1. Propleuron without setae; hindtarsomere 5 entirely pale-scaled (except *stephensi* Liston, which is rare and confined to extreme northern Thailand). . . . . Neocellia
   Propleuron with 1-4 setae; hindtarsomere 5 at least partially dark-scaled. 2

2(1). Palpus with 4 or more pale bands; anterior pronotum with scales. Neomyzomyia
   Palpus with 3 pale bands; anterior pronotum without scales. 3

3(2). Legs entirely dark-scaled or with narrow apical bands or dorsal patches on some tarsomeres; male and female abdominal segments VII, VIII and female cerci without scales, male basimere with scales. Myzomyia (p. 24)
   Legs with basal and apical pale bands on some foretarsomeres; abdominal segments VII, VIII, female cerci and male basimere with at least few scales. . . . . Pyretophorus

PUPAE

1. Seta 1-P short and straight or slightly curved, not hooked at tip; 9-V-VII usually less than 0.35 length of their respective segments. Neomyzomyia
   Seta 1-P long, curved, sinuate or kinked and hooked at tip; 9-V-VII usually 0.35 or more length of their respective segments. 2

2(1). Seta 9-I simple, rarely branched, long, usually 2.0 or more length of segment. . . . . Pyretophorus
Seta 9-I simple or branched, shorter to slightly longer than segment. 3

3(2). Seta 9-IV usually 0.67 or more length of 9-V, with same tapering sharp pointed shape as 9-V; 1-II with 8 or more branches. Myzomyia* (p. 24)
Seta 9-IV 0.15-0.67 length of 9-V, appearance usually different from 9-V, broader with less acute rounded apex; 1-II with 2-10 branches, usually less than 8. . . . . Neocellia*

LARVAE

1. Long thoracic pleural setae, 9, 10 and 12 on prothorax and 9 and 10 on meso- and metathorax simple. . . . . Neomyzomyia
Metathorax with at least seta 9 branched and one or more of long pleural setae may be branched on the pro- and mesothorax. 2

2(1). Metathorax with only one pleural seta (9) branched; abdominal segments IV-VII with anterior tergal plates very large and enclosing posterior tergal plates, or smaller with separate posterior tergal plate and pair of small submedian posterior plates. . . . . Myzomyia (p. 24)
Metathorax with both long pleural setae (9, 10) branched; abdominal segments IV-VII with small to moderate sized anterior tergal plates; posterior tergal plates if present, always separate from anterior tergal plates, without pair of submedian posterior plates. 3

3(2). Prothorax with one long branched pleural seta (9), and one short branched pleural seta (11) (except *stephensi*); mesothorax with one long branched pleural seta (9); setae 2,3-C with minute barbs or distinct lateral branches (except *stephensi*); setae 1,2-P with well sclerotized bases. . . . . Neocellia
Pro- and mesothorax with long simple pleural setae or with one pleural seta on each segment with 2,3 distal branches; setae 2,3-C simple; setae 1,2-P with very weakly sclerotized bases. . . . Pyretophorus

Myzomyia Series

Christophers 1924a: 44 (as group Myzomyia); Gillies and de Meillon 1968: 2 (as Series Myzomyia); Reid 1968: 53 (as Myzomyia series).

Ethiopian and Palearctic Faunal Regions

Approximately 50 Ethiopian species are recognized in this series (Gillies and de Meillon 1968) and 2 Palearctic species, *dthali* Patton and *sergentii*

**jeyporiensis*, a member of Myzomyia, will key out with Neocellia in this couplet, but is easily separated from pupae of Thai Neocellia in having a dark, short fringe on the distomesal half of the paddle from the tip to the mesal angle.

(Theobald), extend eastward across northern Africa to Pakistan. An additional 11 species are recognized here from the Oriental region. Since the majority of species are found only in the Ethiopian region and outside the scope of this paper, the series will not be defined on a world-wide basis.

Gillies and de Meillon (1968) divided the Ethiopian species of this series into one unassigned and 4 poorly defined sections: Funestus, Marshallii-Hancocki, Wellcomei and Demeilloni. Although some generalized characters were presented for these, no keys to the above sections were offered. The Funestus Section is by far the most important section in the Ethiopian segment of the Myzomyia Series. This section contains *funestus* Giles, which is a very important vector of human malaria, filarial and arboviral pathogens in Africa. Furthermore, the Funestus Species Complex is most closely related to the Oriental Minimus Group. These 2 species assemblages are so closely related that they are probably considered distinct only because of their geographical separation and the fact that no one has studied them jointly. There is, however, an unconfirmed record (Colbourne and Smith 1964) of one member of the Minimus Group, *fluviatilis*, from the Hadramawt region of Yemen (Aden), which places it very near the edge of the known distributions in Ethiopia, of *funestus*, *leesoni* Evans and *rivulorum* Leeson, members of the Funestus Complex. This record needs confirmation based on associated immature skins, because adults in the Funestus Complex and Minimus Group are not always separable. More recently, Maffi (1971) reported on 6 larvae of *fluviatilis* collected between Ta'izz and Mocha, Yemen, not far from the Red Sea coast. This identification is considered tentative by Maffi, until further specimens can be collected and adults reared with associated immature skins. I have examined the specimens upon which Knight (1953) recorded *fluviatilis* from Yemen, and they are not *fluviatilis*. Mattingly and Knight (1956) suggested these specimens might be *demeilloni* Evans.

Oriental Faunal Region

When used in conjunction with the above key characters, the following additional characters may be useful in identifying the Oriental species in this series.

ADULT (General). Palpus with pale bands, without spots; forefemur slender or only slightly swollen; abdominal segments covered with setae, without scales (except male basimere) or scale tufts. *Male*. Palpal joint 2,3 bare or with dark scales, without pale band.

PUPA. Trumpet with short meatus; paddle lateral margin with small serrations, spines or filaments, without large spine-like spicules.

LARVA. Seta 3-C either simple or with short lateral barbs or oranches, without large bushy apex; 8-C rarely simple *(culicifacies)*, usually with 3 or more branches; dorsum of thorax often with one to 3 pairs of small median or submedian sclerotized plates; median plate on spiracular apparatus usually with lateral arms.

KEYS TO THE ORIENTAL SPECIES IN THE *MYZOMYIA* SERIES

FEMALES (and males where indicated).

1. Center of scutum covered with fairly broad white scales back onto scutellum; hindtarsomeres with broad pale bands, or some foretarsomeres with pale bands nearly 2.0 the width of tarsomere diameter (females and males). 2

Center of scutum appearing nearly bare except for setae, or with slender seta-like pale scales back to scutellum; legs entirely dark, or some tarsomeres with apical pale bands or dorsal patches not wider than tarsomere diameter. 3

2(1). Hindtarsomeres with broad pale bands, tarsomere 5 entirely pale; scutum with supraalar row of pale scales just above wing root. *majidi* (p. 22)
Hindtarsomeres with narrow pale bands, tarsomere 5 black; scutum with only setae in supraalar row over wing root. . . *jeyporiensis* (p. 65)

3(1). Base of vein R next to remigium with patch of gray or black scales (females and males). 4
Base of R with only white or yellow-white scales* 5

4(3). Female preapical dark palpal band much longer than apical pale band (females and males hereafter): remigium usually entirely dark-scaled; foretarsomeres dark scaled; vein R_{4+5} usually dark except at base. . . . . *culicifacies* (p. 52)
Female preapical dark palpal band approximately equal or shorter than length of apical pale band (females and males hereafter): remigium with dark scales only at apex; foretarsomeres 1-3 (often 4) with narrow apical pale bands or dorsal patches; vein R_{4+5} with dark spots near base and apex, middle pale. . . . . *pampanai* (p. 99)

5(3). Preapical dark palpal band longer than apical pale band, and 3.0-5.0 longer than small preapical pale band. . . . . *fluviatilis* (p. 20)
Preapical dark palpal band variable, from slightly longer than nearly equal apical and preapical pale bands to much smaller than pale bands, or even absent with apical 0.33-0.40 of palpus pale. 6

6(5). Hind margin of wing with pale fringe spot at vein 1A. 7
Hind margin of wing without pale fringe spot at vein 1A. 8

7(6). Proboscis with distal 0.33-0.60 pale-scaled on dorsum and venter (widespread). . . . . *aconitus* (p. 33)
Proboscis entirely dark-scaled (confined to Philippines). *filipinae* (p. 18)

8(6). Costa with humeral and presector pale spots (confined to Philippines). *mangyanus* (p. 23)
Costa usually with presector pale spot or without pale scales basal to sector pale spot. 9

9(8). Foretarsomeres 1-4 with very small dorsoapical pale patches or pale bands (mainland Southeast Asia and Indian subregions). *minimus* (p. 78)
Foretarsomeres entirely dark-scaled. 10

*Males of the remaining species are best identified on the basis of associated immature skins. The characters used here to identify females of the remaining species are considered 90-98% reliable.

10(9). Costa without pale spot or scales basal to sector pale spot; vein Cu_1 often with one long dark spot distal to m-cu crossvein (widespread in Indian subregion and the western mainland part of the Southeast Asian subregion). . . . . *varuna* (p. 107)
Costa with or without pale scales basal to sector pale spot; vein Cu_1 usually with 2 dark spots distal to m-cu crossvein (confined to Philippines and Indonesia). . . . . *flavirostris* (p. 19)

PUPAE

1. Seta 7-VI, VII shorter than to slightly longer than 9-VI, VII, approximately 0.35-0.70 length of segments VI, VII lateral margins. . . 2
Seta 7-VI, VII much longer than 9-VI, VII, approximately equal to or longer than segments VI, VII lateral margins.
Minimus Species Group (p. 18) 4

2(1). Paddle fringe not extending mesad of seta 1-P. . . *culicifacies* (p. 52)
Paddle fringe extending mesad of seta 1-P, to or nearly to mesal angle of paddle. 3

3(2). Paddle refractile margin extending 0.84-0.97 of distance from base to seta 1-P; seta 5-III with 3-6 branches; 5-VI with not more than 3 branches. . . . . *jeyporiensis* (p. 65)
Paddle refractile margin extending to seta 1-P; seta 5-III with 9-11 branches; 5-VI with 5 or more branches. . . . . *majidi* (p. 22)

4(1). Seta 0-III-VII long, with 1-7 branches, usually branched on III-V; 0-IV-VII more laterad, directly cephalad of 4, 5-IV-VII. *minimus* (p. 78)
fluviatilis (p. 20)
Seta 0-III-VII short, simple or infrequently bifid; 0-IV-VII more mesad, directly cephalad of 2-IV-VII. 5

5(4). Paddle fringe extending as long filaments mesad of seta 1-P to mesal angle of paddle. 6
Paddle fringe stopping at seta 1-P, or extending as short scattered filaments up to 0.75 of distance to mesal angle. 8

6(5). Paddle lateral margin with short spines extending 0.7 or more of distance from base to seta 1-P; paddle refractile margin extending 0.89-0.96 of distance from base to seta 1-P (confined to India, Sri Lanka and mainland Southeast Asia). . . . . *varuna* (p. 107)
Paddle with short spines ending 0.5-0.6 of distance from base to seta 1-P, changing to long filaments abruptly; paddle refractile margin short, extending 0.50-0.69 of distance from base to seta 1-P (confined to Philippines and Indonesia). 7

7(6). Seta 9-III approximately 0.33-0.50 length of 9-IV; 9-IV nearly equal length of 9-V; sum of branches of the 2 pairs of seta 2 on VI, VII, 12 or less, usually 8-10. . . . . *mangyanus* (p. 23)
Seta 9-III less than 0.33 length of 9-IV; 9-IV approximately 0.66-0.75 length of 9-V; sum of branches of the 2 pairs of seta 2 on VI, VII, more than 12, usually 15 or more. . . . . *flavirostris* (p. 19)

8(5). Paddle lateral fringe changing from short spines to long filaments

abruptly at about 0.5-0.6 of distance from base to seta 1-P; paddle fringe not extending mesad of seta 1-P; seta 1-III with 13-27 branches. . . . . *pampanai* (p. 99)
Paddle lateral fringe gradually changing from short spines to long spines to long filaments at about 0.60-0.75 of distance from base to seta 1-P; paddle fringe extending mesad of seta 1-P, as short scattered filaments, not to mesal angle; seta 1-III with 7-17 branches. 9

9(8). Paddle refractile margin extending 0.74-0.90 of distance from base to seta 1-P (widespread in India, Sri Lanka, mainland Southeast Asia and Indonesia). . . . . *aconitus* (p. 33)
Paddle refractile margin extending 0.60-0.79 of distance from base to seta 1-P (confined to Philippines). . . . . *filipinae* (p. 18)

LARVAE

1. Anterior tergal plates on segments III-VII very large, more than 0.5 width of segment, enclosing small median posterior tergal plate . . 2
Anterior tergal plates on III-VII smaller, less than 0.5 width of segment, not enclosing small median posterior plate. 8

2(1). Seta 2-C with one to many lateral barbs*. 3
Seta 2-C simple*. 5

3(2). Seta 4-C simple. . . . . *varuna* (p. 107)
Seta 4-C forked or with branches. 4

4(3). Seta 3-C with 1-9 short lateral barbs, rarely simple; seta 3-T leaflets with blunt apices (Southeast Asia except Philippines). *aconitus* (p. 33)
Seta 3-C simple or forked, without lateral barbs; seta 3-T leaflets with fine filaments (confined to Philippines). . . . . *filipinae* (p. 18)

5(2). Seta 0-IV-VI arising on anterior tergal plate, internal to lateral margin. 6
Seta 0-IV-VI arising on segment membrane posterolateral to anterior tergal plate, or just on or at edge of plate. 7

6(5). Seta 3-T leaflets with long fine filaments; seta 2-VII simple or bifid on distal half (confined to Philippines). . . . . *mangyanus* (p. 23)
Seta 3-T leaflets with blunt apices or very short filaments; seta 2-VII with 2-4 branches (confined to mainland Southeast Asia). . *pampanai* (p. 99)

7(5). Seta 0-IV-VII small, simple or bifid (confined to Philippines and parts of Indonesia). . . . . *flavirostris* (p. 19)
Seta 0-IV-VII large, particularly on IV, with 2-6 branches, rarely simple (widespread across mainland Southeast Asia and parts of India). . . . . *minimus* (p. 78) *fluviatilis* (p. 20)

*Occasional *varuna* have both setae 2-C simple, these can be identified by having: seta 0-II-VII on the anterior tergal plates, 3-T leaflets with long slender filaments and anterior tergal plate on II fused with small posterior tergal plate.

8(1). Setae 2, 3-C with numerous lateral barbs; apex of median plate on spiracular apparatus with lateral arms; 4-C with 2-5 branches. *jeyporiensis* (p. 65)

Setae 2, 3-C simple; apex of median plate on spiracular apparatus without lateral arms; 4-C simple. 9

9(8). Seta 6-V, VI with 3-4 branches, 13-IV, V with 3-5 branches; seta 8-C simple. . . . . *culicifacies* (p. 52)

Seta 6-V, VI with 5-8 branches; 13-IV, V with 8-19 branches; seta 8-C usually with 2-6 branches, rarely simple. . . . . *majidi* (p. 22)

Distribution

The combined distribution for the Oriental members of this series extends from *culicifacies* in the Eritrean region of Ethiopia, through Southwest Asia, India, across southern China and the Indochina-Malay Peninsula below 30° N latitude, to *minimus* in the Ryukyu Island chain, and south down through the Philippines to *aconitus* at the eastern end of Indonesia. Actually, this large area can be subdivided into 3 subregions based on groupings within the series. Two species, *culicifacies* and *fluviatilis* occur from the vicinity of the Red Sea across semi-arid Southwest Asia to at least India in the case of *fluviatilis* and on into Burma, Thailand and Vietnam for *culicifacies*. Three species, *filipinae*, *flavirostris* and *mangyanus* are confined to the Philippines, with *flavirostris* also extending down into Indonesia. Records of *filipinae* in Nepal (Pradhan and Brydon 1960) and *mangyanus* in Nepal (Brydon et al. 1961) were based entirely on adult characters and are not considered reliable here. The remaining 6 species, *aconitus*, *jeyporiensis*, *majidi*, *minimus*, *pampanai* and *varuna* are distributed primarily in the India-Indochina peninsular regions, with *majidi*, *pampanai* and *varuna* having the most limited distributions.

Taxonomic Discussion

I currently recognize 11 species in the Oriental portion of this series, they are: *aconitus*, *culicifacies*, *filipinae*, *flavirostris*, *fluviatilis*, *jeyporiensis*, *majidi*, *mangyanus*, *minimus*, *pampanai* and *varuna*. Of these, 8 species are members of the Minimus Species Group (Reid 1968), they are: *aconitus*, *filipinae*, *flavirostris*, *fluviatilis*, *mangyanus*, *minimus*, *pampanai* and *varuna*. Due to overlapping characters, adults of some of these species are often extremely difficult or impossible to identify. The male genitalia characters are also very similar in this series and usually of little value for identifying species. Consequently, the primary diagnostic characters are found on the larval and pupal stages in most cases. Reared adults with associated immature skins should be used as the basis for determining which species occur in a given area. The 3 unassigned species, *culicifacies*, *jeyporiensis* and *majidi*, are easily identified in the adult, pupal and larval stages.

Five of the species in this series, *filipinae*, *flavirostris*, *fluviatilis*, *majidi* and *mangyanus*, are not found in Thailand. Since they are not thoroughly treated later, each deserves a short discussion.

Anopheles filipinae was described as a variety of *aconitus* by Manalang (1930) from Luzon Island, Philippines. This taxon was elevated to species status by Christophers and Puri (1931). Although the adults usually have vein 1A with 3 black spots and a pale fringe spot like *aconitus*, the basal 0.33 of the costa normally has humeral and presector pale spots and the proboscis is dark-scaled. The pupa is very similar to that of *aconitus* and needs additional study. The larva is also very much like that of *aconitus*, but differs

from *aconitus* in having seta 3-C simple or forked on the distal half and seta 3-T leaflets with fine filamentous tips, like those on *varuna* and *mangyanus*. Knight and Stone (1977) list the type as non-existent, however, Basio (1971) lists the type(s?) as in Division of Malaria, Department of Health, Manila, Philippines. In 1969, Mr. Kol Mongkolpanya (SEATO Medical Research Laboratory) and I collected Minimus Group species on Luzon and Mindoro islands, Philippines. That trip yielded 406 reared adults of *filipinae* with associated immature skins and numerous whole larvae from Mindoro Island. These specimens are currently in the USNM. The primary sources for *filipinae* immatures on Mindoro were cool spring or seepage water habitats (semi-permanent to permanent) with considerable vegetation of all types and usually partial shade. A preliminary examination of the above Mindoro specimens and others in the USNM, revealed that *filipinae* adults are as variable as adults of other members of the Minimus Species Group. Although diagnostic larval characters are known, this stage and particularly the pupal stage need further study. This species is apparently most similar to *aconitus*, *pampanai* and *mangyanus*, in descending order, and has the fewest similarities with *fluviatilis*. Major publications dealing with *filipinae* are King (1932), Russell and Baisas (1934, 1936), Cagampang-Ramos and Darsie (1970) and Baisas (1974). According to Baisas (1974), *filipinae* has been incriminated (by dissection) as a vector of human malarial parasites, but its role is apparently very limited.

I consider *filipinae* as confined to the Philippines, and the records of *filipinae* from Nepal (Pradhan and Brydon 1960) and Thailand (Thurman 1959) as misidentifications. The Nepal record was based on one specimen and the location of the specimen(s?) on which the Thailand record was based is unknown. Based on my study of *filipinae* and the variations found on *aconitus* and *minimus* in Thailand, I believe that these records were based on variant specimens of one or both of the last 2 named species.

Anopheles flavirostris was described from Luzon Island, Philippines by Ludlow (1914). King (1932) assigned it to subspecies status under *minimus*. Since then it has been considered a subspecies of *minimus* in almost every major publication. However, as noted by Knight and Stone (1977), Baisas (1957) guardedly suggested specific status for *flavirostris* and more recently (Baisas 1974: 163) reemphasized that change. I am in total agreement with specific status for *flavirostris*. During this study over 1,000 specimens of *flavirostris* (500 plus with associated immature skins) were examined, including the lectotype in the USNM. These examinations revealed highly reliable differences (80-100%) between *flavirostris* and *minimus* in the adult female, pupal and larval stages. Females of *flavirostris* usually possess a pale ventral scale patch on the proboscis, while *minimus* normally have a dark proboscis. Frequencies for this character were: *flavirostris* with pale patch, 0.964 (109/113 - King 1932); and *minimus* with dark proboscis, Hong Kong feral females - 0.987 (443/449), Thailand feral females - 0.939 (2,127/2,264), and Thailand progeny females - 0.943 (805/854). A very stable pupal difference is the development, branching and position of seta 0 on abdominal terga III-VII (see pupal key above). Two other pupal differences are: seta 9-III-darkly pigmented on *flavirostris*, very pale on *minimus*; and paddle refractile margin - 0.54-0.68 of distance from base to seta 1-P on *flavirostris*, while that of *minimus* is 0.63-0.85, usually more than 0.68. A very stable larval difference involves the development and branching of seta 0 on abdominal terga IV-VII (see larval key above). Another larval difference, with less reliability (80-85%), is the development of the anterior tergal plate (ATP) on abdominal tergum II: *flavirostris* usually has the posterior margin of ATP-II

concave and not enclosing the posterior tergal plate (PTP), while *minimus* usually has the posterior margin of ATP-II convex and enclosing the PTP-II. Beside morphological differences, I also consider the 2 species geographically isolated, with *minimus* not extending further south than northern Malaysia (Perlis) and all previous records of *minimus* (none based on reared specimens with associated immature skins) in Indonesia applying to *flavirostris*. This decision has been made on a tentative basis since some adults I have seen from Sumatra resemble *minimus*. However, I suspect they are dark proboscis variations of *flavirostris* as King (1932) noted in the Philippines. The records of Mangkoewinoto (1919) and Swellengrebel and Swellengrebel-de Graff (1920) for *aconita* var. *merak(cohesia)* and *minimus* var. *aconita* (larval variety) respectively, definitely apply to *flavirostris* (based on their descriptions) and place this species in western Java and Sumatra. Records of *varuna* in Indonesia (Van Hell 1933) can be attributed to *flavirostris*. Manalang (1930) first pointed out that *flavirostris* without a presector pale spot on the costa resembled *varuna*. Specimens of *flavirostris* without the costal Psp and/or pale scales on the proboscis have the appearance of *minimus*. I have examined more than a dozen adults collected on Java and Sumatra from the Bonne-Wepster collection that were labeled *minimus*. They all resembled variations of *flavirostris* or *minimus*. The only resolution to the question of *minimus* on Java and Sumatra will come through a study of reared adults with associated immature skins. Currently, only 3 species in this series are recorded from Java and Sumatra, i.e., *aconitus*, *flavirostris* and *minimus*. The The larvae of *flavirostris* are distinct and easily separated from the other 2 species by the characters outlined in King (1932), Russell and Baisas (1934), Cagampang-Ramos and Darsie (1970), Baisas (1974) and the attached key. Pupal stages of these 3 species are easily separated by the characters in the attached key. Baisas (1936) studied the pupae of the 3 Philippine species, *filipinae*, *flavirostris* and *mangyanus*, however, the characters for *flavirostris* presented in that paper were not found satisfactory during this study. More reliable characters for separating the pupae of the 3 Philippine members of Myzomyia are presented in the attached key, however, the pupae of these 3 species need additional study.

Anopheles flavirostris is the most common member of the Myzomyia Series in the Philippines and is also one of the more widespread species of the series as it also occurs in Sabah and much of Indonesia. A map showing an approximation of the distribution for *flavirostris* was published in Brown and Pal (1971). The distribution of the species should probably be extended to include all of Sumatra. Immature stages are typically found in slow flowing streams of clear fresh water with grassy margins. This species is particularly prevalent in streams opened up to sunlight during land settlement or lumbering operations. *Anopheles flavirostris* has been incriminated by dissection as a vector of human malarial parasites in numerous studies in the Philippines, and has also been the main target of malaria eradication efforts for years. It has also been incriminated as a vector of *Wuchereria bancrofti* (Cobbold) on Luzon and Palawan (Rozeboom and Cabrera 1964, 1965). The species is definitely exophilic and developed resistance to dieldrin in 1959, but remains susceptible to DDT (Brown and Pal 1971).

Anopheles fluviatilis was described from India by James (1902). This name is a junior synonym of *listonii* Liston 1901 from India, by which the species was recognized until the early 1930's. Christophers (1924a) pointed out that *listonii* was a junior primary homonym of *listoni* Giles, and that *fluviatilis* was the proper name, but this usage did not gain general favor until

the appearance of Edwards (1932) and Christophers (1933). The type of *fluviatilis* is unknown, but 2 female syntypes of *listonii* Liston are in the BMNH. Both females have the same labels: (1st label) - "L" (in long hand); (2nd label) - "Deccan, Capt. Liston"; and (3rd label) - my *fluviatilis* ID label. According to Stoll et al. (1964 - ICZN), *listonii* must be considered a rejected name. Based on my examination of the syntypes of *listonii* and the description of *fluviatilis*, I am convinced they are the same species. Knight and Stone (1977) list 2 junior synonyms of *fluviatilis*, they are *leptomeres* Theobald 1903 and *arabica* Christophers and Chand 1915. The holotype of *leptomeres* is in the BMNH in fair to good condition. Based on my examination of this type, this nominal taxon is obviously a synonym of *fluviatilis*. Edwards (1932) maintained *arabica* in its original status (as var. of *funestus*), but Mattingly and Knight (1956) synonymized *arabica* under *fluviatilis*. Two specimens labeled "paratype" of *arabica* (♂ & ♀) are in the BMNH and are in good condition. Since Christophers (1924a) discussed 2 "types" in BMNH, they should be considered syntypes. I examined these in 1972 and suspect they are not equal to *fluviatilis*. However, since further study of this problem is necessary, *arabica* is best left a synonym of *fluviatilis*.

The published distribution of *fluviatilis* is very wide, extending from Yemen to Taiwan (Knight and Stone 1977). However, after studying progeny broods of *minimus* from Thailand I am convinced that most records of *fluviatilis* east of northeastern India probably were based on *minimus* variations. A few (7♂, 5♀) specimens of *fluviatilis* have been reported from Hong Kong (Edwards 1935; Jackson 1936a, 1951), which were reared from immatures collected from a stream during the winter season (Jackson 1936a). I examined those specimens in 1972 in the BMNH and the males cannot be differentiated from *minimus* males, while the females are identical to several variant *minimus* that I collected and reared with associated skins during October 1969, in the New Territories, Hong Kong. Besides specimens with *fluviatilis*-like palpi, I also collected specimens intermediate between *minimus* and *fluviatilis* as well as *varuna*-like variants of *minimus*. Specimens were also examined from Taiwan that were previously identified as *fluviatilis* and they also appear to be *minimus* variants. Palpal variations were very common on Thailand *minimus* and female progeny from one feral female exhibited a range of variations like the top 4 palpi shown for *minimus* on Fig. 6. In view of the range of palpal variations found on reared topotypic *minimus* in Hong Kong, reared and progeny *minimus* from Thailand and the very low frequency of specimens with *fluviatilis*-like palpi east of India. I am confining the range of *fluviatilis* to the Middle East and the Indian subregion. I consider specimens with *fluviatilis*-like palpi from Thailand and more eastern countries as hypermelanic variants of *minimus*. It is interesting to note that Sweet et al. (1942) had reservations about *fluviatilis* in Yunnan; Robertson (1941) did not report *fluviatilis* from northern Burma and Macan (1948) considered 2 specimens with *fluviatilis*-type palpi from western Burma as *minimus* variants. More recently, Khin-Maung-Kyi (1971) mapped the limited distribution of "*fluviatilis*" in Burma. Of major interest is the fact that Burmese specimens were collected primarily between October-December, the post-monsoon cool season. This information supports my contention that most *fluviatilis* of various authors in Burma are probably hypermelanic *minimus* variants, most commonly found during the cool season. Actually, the distribution of *fluviatilis* in India mapped by Christophers and Puri (1931) is like the distribution I propose here. I believe *fluviatilis* occurs in Nepal, West Bengal, probably Bangladesh, but rarely, if at all, in northeastern Assam and in Burma. I do not think it occurs east of these areas,

thus I am not recognizing the records of this species from Thailand as summarized by Scanlon, Peyton and Gould (1968). Christophers (1933) listed *fluviatilis* as occurring in Sri Lanka (as Ceylon) and most writers have presumed the *listoni* of Carter (1925) referred to *fluviatilis*. However, Carter's *listoni* actually applies to *varuna* (see under *varuna*), and there are no confirmed records of *fluviatilis* or *minimus* from Sri Lanka (D'Abrera 1944, Carter 1950). In Nepal, *minimus* does not occur much above 671 m, while *fluviatilis* occurs up to nearly 1,829 m (Brydon et al. 1961, Pant et al. 1962). This ecological difference in an area of sympatry is additional evidence for the specific distinction of *minimus* from *fluviatilis*. These 2 species are very closely related and are differentiated only on the basis of the palpal banding patterns and distribution. To date, I have been unable to find larval or pupal differences to separate those 2 species (see *minimus* variations section). The criteria listed by Christophers (1933) are not considered reliable. However, only 3 or 4 feral adults of *fluviatilis* with skins were available for study. Dr. B. N. Chowdaiah, Bangalore University, India, kindly supplied many adults and skins of *fluviatilis* from a colony at that institution. But, since this is an old inbred colony I am reluctant to use data from these to represent *fluviatilis*.

Sharma (1961) has an extensive review of the Indian literature regarding the biology, behavior and vector capabilities of *fluviatilis*. The immature stages are apparently found in essentially the same type water habitats as *minimus*. This species is a well documented vector of human malaria parasites in India. Thurman (1959) pointed out 2 earlier published reports erroneously implicating *fluviatilis* as a vector of malaria parasites in Thailand. These references plus that of Simmons et al. (1944) probably based their vector statements on Anigstein's (1932) study in Thailand. Anigstein's records of *listoni, culicifacies* and *minimus* apparently involve some identification mix-ups and should not be relied on (see further discussion on this subject in *culicifacies* Distribution section). This species is susceptible to DDT in much of India, but resistance to DDT has developed in several areas (Brown and Pal 1971). Current population levels of *fluviatilis* in many areas of India are very low (Prakash and Husainy 1974a, Rahman et al. 1975).

Anopheles majidi is a poorly known species of no known medical importance, that was described from southwestern India by Young and Majid (1928). Knight and Stone (1977) list the type-location as "MSI" which is now housed in the National Institute of Communicable Diseases, Delhi, India. In 1972, I found 3 males and 3 females labeled paratype in the BMNH. All 6 specimens were in fair to good condition and had the following label "S. India, Coorg, Mercara, Dr. I. M. Puri, BM 1929.450." Whether or not these actually represent part of the original type-series is not known.

Anopheles majidi is not a member of the Minimus Group, and apparently is not closely related to the other Oriental members of the series. Adults are very distinct in having broad pale bands on the hindtarsomeres and a row or line of pale scales just over the wing root. I found several long dark flattened setae or scales on the anterior portion of the anterior pronotum on the above paratypes. Myzomyia species are characterized in part by not having scales on the anterior pronotum, a character often seen on Neocellia species in Asia. Several adult characters of *majidi* suggest a relationship to Neocellia, but the immature stages and the adult also have definite Myzomyia characters. The pupal stage resembles that of *jeyporiensis* and is very poorly known (see key). The larva has anterior tergal plates like those of *jeyporiensis*, but simple setae 2, 3-C and the median plate on the spiracular apparatus without arms. *Anopheles majidi* probably represents an annectent species between the

Myzomyia and Neocellia Series in the Oriental region. It is apparently a forest species that once had a wide distribution in India. Immatures are found in grassy slow running streams, open ditches in tea gardens and fallow rice terraces (Christophers 1933). This species has been recorded from India (Karnataka, West Bengal), Nepal (Brydon et al. 1961) and Burma (Khin-Maung-Kyi 1971). Recently, it was collected in Madhya Pradesh, India (Prakash and Husainy 1974a, b). The records from Burma consisted of only 2 collection sites and Khin-Maung-Kyi considered the species as scarce. Thurman (1959) reported *majidi* from Thailand, and Scanlon, Peyton and Gould (1968) were able to pinpoint the collection site as Fang District, Chiang Mai Province in June 1952. However, no specimens confirming the record have been found in the USNM or collected since 1952. Reid (1968) noted that females of *karwari* (James) with the distal segment of the palpus broken off look very much like *majidi*. Currently there is little justification for recognizing the Thailand record of *majidi*. Therefore, I am dropping this species from the list of Thailand anophelines.

Anopheles mangyanus was described from Mindoro Island, Philippines by Banks (1906) and described again as *febrifera* by Banks (1914) from Luzon Island. The type-specimens for these 2 nominal taxa are apparently non-extant (Knight and Stone 1977). Until the early 1930's *mangyanus* was generally considered a synonym of *flavirostris*. King (1932) revised the status of the Philippine members of the Myzomyia Series and recognized *mangyanus* as a valid species, with *febrifera* as its synonym. Adults of this species look very similar to *flavirostris*, but do not have pale scales on the proboscis and nearly always have humeral and presector pale spots on the base of the costa. The pupa is very similar to that of *flavirostris* (see key), and needs additional study. The larva is also very similar to that of *flavirostris*, but has seta 0 arising on the anterior abdominal tergal plates and has very long filamentous tips on the seta 3-T leaflets. The immatures are typically found along the edge of partially to heavily shaded forest streams with cool clear water. During personal collections on Mindoro Island in 1969, *mangyanus* larvae were not found in open sunlight. In streams containing both *flavirostris* and *mangyanus*, the former was usually most abundant in areas with only partial shade or open sunlight, while the latter was most common in sectors of the stream inside the forest under heavy shade. I consider *mangyanus* a true forest species, probably more directly associated with and dependent on the forest than any other member of the Minimus Species Group. *Anopheles mangyanus* feeds readily on man and has been incriminated by dissection as a vector of human malarial parasites (Urbino 1947). Actually, *mangyanus* may have played a much more active role in the transmission of malaria parasites in the Philippines than it is usually credited (King 1932). Baisas (1957) pointed out that *mangyanus* is usually a vector in more primitive areas, while *flavirostris* was the most important vector. In 1969, Mr. Mongkolpanya and I made human bait collections in the Macatoc area, previously described as a very malarious area by Urbino (1947). Our collections found *flavirostris* very abundant and *mangyanus* rare. According to area public health personnel, malaria cases were rarely (1969) found in this locality. However, 10-12 km away in a heavily forested area where members of a group of the Mangyan tribe lived, malaria transmission was still very active. A human bait collection in the latter area was unproductive due to strong winds, but collections in forest streams approximately halfway to the Mangyan settlement yielded almost pure *mangyanus*. During the collections on Mindoro and Luzon in 1969, 118 adults (107 reared with associated skins) and numerous larvae of *mangyanus*

were collected. These specimens are deposited in the USNM. Two adult *mangyanus* were reared from pupae and larvae collected in a stream at approximately 823 m elevation just south of Balete (Dalton) Pass in Nueva Ecija Province, Luzon. This apparently equals the highest elevation record known for this species (Baisas et al. 1950).

I am limiting the distribution of *mangyanus* to the Philippines. Brydon et al. (1961) recorded this species from Nepal, but I consider this a misidentification, probably of a *minimus* variation (see *minimus* Taxonomic Discussion section) rather than a specimen of *pampanai* (which is not known from Nepal) as proposed by Reid (1968). Some major publications and keys treating *mangyanus* are King (1932), Russell and Baisas (1934, 1936), Baisas (1936, 1974) and Cagampang-Ramos and Darsie (1970).

MYZOMYIA SERIES IN THAILAND

Historical Review

Scanlon, Peyton and Gould (1968) presented a good review of publications treating Thailand anophelines and more recently, a generalized review of this subject was included in the introduction of Harrison and Scanlon (1975).

The first references to members of the Myzomyia Series in Thailand were in Barnes (1923a, b), who recorded *aconitus* from Bangkok and Chiang Mai, *culicifacies* from Chiang Mai, *fluviatilis* (as *funestus* Giles, = *listoni* Liston) from Bangkok and Chiang Mai and *minimus* from Bangkok. Barnes (1923b) also contained a key to the adults of the first 3 species. Barraud and Christophers (1931) essentially repeated Barnes' records and added information from specimens collected by J. A. Sinton on a rail trip between Bangkok and Chiang Mai. Of particular importance in this last publication was a lengthy discussion on adult variations found on *aconitus* collected in Bangkok (see *aconitus* Variations section). Anigstein (1932) made an extensive malaria and mosquito survey in Thailand for the League of Nations. He surveyed 4 areas during a 3 1/2 month period (Bangkok area, 5 northern provinces, one malarious area in central Thailand and 3 southern provinces), and made major contributions by outlining the topography, hydrography, climate, forests, irrigation systems, economics, people and public health of the 4 areas. Anigstein only found a few *aconitus* larvae in the Bangkok area and he noted that *listoni* as reported in Bangkok by Barnes (1923a) would be "unusual" due to the larval habitats of that species. He also tried to justify the *minimus* record (Barnes 1923a) from Bangkok by noting similar breeding of *minimus* in the plains of Bengal. However, his "*minimus*" from the Plains of Bengal, probably referred to *varuna* instead of *minimus*. In the northern provinces of Chiang Mai, Chiang Rai, Lampang, Nan and Phrae, he reported various combinations of *aconitus*, *culicifacies*, *listoni* and *minimus*. In the central Thai malarious area of Thab Kwang (Sara Buri) he reported only *listoni* and *culicifacies* larvae, while in the southern provinces of Singora (= Songkhla), Phatthalung and Nakhon Si Thammarat he reported combinations of *aconitus*, *culicifacies*, *listoni* and *minimus*. I am convinced that Anigstein's records of *aconitus*, and particularly *culicifacies*, *listoni* and *minimus* in Thailand are not reliable (see *culicifacies* Distribution section). Christophers (1933) recorded the above 4 species from "Siam" and was the first person to use the correct name, *fluviatilis*, for the species previously called *funestus* and *listoni* in Thailand. Payung-Vejjasastra (1935) recorded *aconitus* from the southern province of Yala and incriminated *minimus*, by dissection, as the vector of human malaria parasites in Tung Song District, Nakhon Si Thammarat. Causey (1937) collection *aconitus*, *culicifacies* and *minimus* from several areas of Thailand, but primarily reported on

the mosquitoes in Bangkok. He found *aconitus* had a very low density in the Bangkok area and collected a single specimen (out of 3,817) of *minimus* in a light trap. This specimen would appear to confirm Barnes' (1923a) record of *minimus* (also one specimen) from Bangkok, however, the absence of *minimus* larvae in the collections and the variations known for *aconitus* in central Thailand, lead me to suspect both records were misidentifications.

Until the 1950's most references on Thai anophelines relied heavily on Anigstein (1932) and this led to several erroneous references to *fluviatilis* as a major vector in Thailand (see *fluviatilis* section, also Thurman 1959). Shortly after World War II, de Fluiter (1948) and Wilson and Reid (1949) published accounts of malaria problems and probable vector species in prisoner-of-war camps in Kanchanaburi Province. Both papers reported and stressed the probability of *minimus* as a vector, and de Fluiter reported *culicifacies* from camps adjacent to the Mae Klong River.

In 1949, Thailand became deeply involved in malaria eradication efforts and thereafter a number of papers appeared on malaria and control efforts against *minimus;* then the only known vector (Thurman 1954; Griffith 1955; Ayurakit-Kosol and Griffith 1956, 1962; Griffith et al. 1957). During this same period Sandhinand (1951) reviewed the anophelines recorded from Thailand and reported the first collection of *jeyporiensis candidiensis* in Thailand (Chiang Mai). Iyengar (1953) conducted an extensive survey of filariasis and vector species on the flat southern plains area of Nakhon Si Thammarat, Pattani, Phatthalung and Surat Thani provinces. The only member of the Myzomyia Series collected was *aconitus*. In connection with the malaria eradication program in northern Thailand, Thurman and Thurman (1955) reported that *aconitus* made up 13% of a year's anopheline catch in a light trap in Chiang Mai. They also confirmed Sandhinand's (1951) record of *jeyporiensis candidiensis* with a few additional specimens. During the early 1950's the Thurmans (D. C. and E. B.) conducted extensive mosquito surveys in northern Thailand, until the death of Mr. Thurman from malaria in 1953. These studies culminated in a major revision of the mosquitoes of northern Thailand by E. B. Thurman (1959). Although the revision did not include the subfamily Anophelinae, anopheline records were included in appendices. These included the first reports of *filipinae, jeyporiensis jeyporiensis, majidi* and *varuna* from Thailand. The addition of these 4 nominal taxa gives a total of 9 taxa of the Myzomyia Series reported from Thailand by 1959, they are: *aconitus, culicifacies, filipinae, fluviatilis, jeyporiensis jeyporiensis, j. candidiensis, majidi, minimus* and *varuna*. Many species collected by the Thurmans are deposited in the USNM and were used during this study. Foote and Cook (1959) reported all of the above species and subspecies from Thailand except *j. jeyporiensis*.

In 1961 a new period of mosquito research began in Thailand with the establishment of the SEATO Medical Research Laboratory (SMRL), Bangkok. This organization undertook extensive mosquito surveillance projects and research on malaria. Since that time numerous papers have been published on experimental malaria studies and many used *minimus* as a laboratory vector. Some of these studies are reviewed under the Medical Significance section, others are beyond the scope of this study. Otherwise, a number of significant papers treating species in the Myzomyia Series have appeared since 1959. Tansathit et al. (1962) reported *aconitus* as one of the 2 most abundant anophelines at the Sattahib Naval Base, Chon Buri Province, and showed (by dissection) that *minimus* was the local vector of malaria parasites. Scanlon and Esah (1965) surveyed mosquitoes coming to human bait at different elevations

(305-829 m) in Chiang Mai Province and recorded *aconitus* and *jeyporiensis* only at the lowest elevation. Stojanovich and Scott (1966) published an illustrated key to the *Anopheles* mosquitoes of Thailand. However, the included larval and female key couplets did not treat *filipinae* and *majidi* and were usually based on only one character. Consequently, they were often unreliable due to overlapping variations. Another illustrated key to the female *Anopheles* of Thailand was published in the same year (Peyton and Scanlon 1966). This key was prepared after the examination and study of a large number of specimens and has been of considerable help to public health personnel in Thailand. This publication also included a checklist of *Anopheles* recorded from Thailand and the records of *aconitus*, *culicifacies*, *jeyporiensis candidiensis*, *minimus* and *pampanai* (first report for Thailand) were considered valid. Although this is apparently the first published record of *pampanai* in Thailand, I found several specimens from Chanthaburi and Chiang Mai provinces in the BMNH that were determined as *pampanai* by P. F. Beales or E. I. Coher and P. F. Beales in 1959, the same year *pampanai* was described. The records of *filipinae*, *fluviatilis*, *majidi* and *varuna* were considered doubtful and that for *jeyporiensis jeyporiensis* was considered a misidentification. Gould et al. (1967) established *aconitus* as a vector of malaria parasites in the central rice plains of Thailand. Scanlon, Peyton and Gould (1968) published an annotated checklist of the anopheline mosquitoes of Thailand. This publication contained nearly all previous references to a given species in Thailand and notes regarding the authenticity of those records, also the provincial distribution of the species in Thailand. Members of the Myzomyia Series received the same treatment and status as in Peyton and Scanlon (1966). Bram et al. (1968) reported the collection of several specimens identical to *minimus flavirostris* in central Thailand. This addition to the list made a total of 10 nominal taxa in the Myzomyia Series reported from Thailand. However, Scanlon, Reid and Cheong (1968) expressed considerable reservations about all of the species and subspecies in the Myzomyia Series recorded from Thailand. These authors noted that in Thailand: *aconitus* may have forms close to *minimus*, *flavirostris* and *varuna*; forms resembling *filipinae* and *varuna* were almost certainly *minimus*; only *jeyporiensis candidiensis* (not the nominate subspecies) was confirmed; and the entire Minimus Group badly needed revision. Reid (1968) listed *aconitus*, *culicifacies*, *jeyporiensis* (did not recognize *candidiensis* as subspecies, but as variety), *minimus*, *pampanai*, *majidi*, *filipinae*, *fluviatilis* and *varuna* from Thailand, but stressed that the records for the last 4 species needed confirmation. Reid (1970) further stressed the need for study of the Minimus Group in Southeast Asia and noted that the extent of variations (geographic or otherwise) and the geographic distributions for the species were poorly known. An illustrated key to the *Anopheles* larvae of Thailand was published by Rattanarithikul and Harrison (1973). This key, based partially on the incomplete results of the present study and following Peyton and Scanlon (1966), treated only *aconitus*, *culicifacies*, *jeyporiensis*, *minimus* and *pampanai* as valid records, and those for *filipinae*, *fluviatilis*, *majidi* and *varuna* as doubtful. These authors overlooked Chow (1970), who correctly pointed out *candidiensis* could not be considered a subspecies of *jeyporiensis*, and discussed the presence of both subspecies and intermediates of *jeyporiensis* in northern Thailand. Harrison and Scanlon (1975) treated members of the Myzomyia Series in a key to the adult female *Anopheles* in Thailand and only included the confirmed species, i.e., *aconitus*, *culicifacies*, *jeyporiensis*, *minimus* and *pampanai*. This last publication also included a discussion on the zoogeography of Thailand.

It is evident from the above that considerable confusion exists in the literature regarding the species of this series that occur in Thailand. This situation was not only caused by the unique zoogeographical position of this country, but also because: 1) records were based entirely on adult females instead of reared specimens with associated immature skins; 2) revisionary studies on the Minimus Group and the Myzomyia Series had not been attempted since the 1930's, hence reliance was necessarily placed on less variable species concepts developed from studies in other countries; and 3) adequate specimens for comparative study were not available in scientific depositories from such critical areas as India and Indonesia.

Medical Significance

The 11 Oriental members of the Myzomyia Series are perhaps the most economically significant assemblage of *Anopheles* in Asia. Thus far, 9 of the species have been incriminated by dissection of wild females as vectors of human malaria parasites, they are: *aconitus, culicifacies, filipinae, flavirostris, fluviatilis, jeyporiensis, mangyanus, minimus* and *varuna**. In addition, *aconitus, flavirostris, jeyporiensis, minimus* and *varuna* have been incriminated by dissection as vectors* of the human filarial parasite, *Wuchereria bancrofti,* and *culicifacies, jeyporiensis* and *varuna* are known vectors* of another human filarial parasite, *Brugia malayi* (Brug). Because of these vector capabilities and the importance of the associated diseases, many millions of dollars (U. S.) are spent annually for the control of species in this series.

The medical importance of the 5 species not known from Thailand, i.e., *filipinae, flavirostris, fluviatilis, majidi* and *mangyanus,* was briefly discussed above (p. 18-24). Major references discussing the importance of these species are: Covell (1944), Bonne-Wepster and Swellengrebel (1953), Horsfall (1955), Foote and Cook (1959), Sharma (1961) and Cabrera and Arambulo (1977).

Although 6 species (including 5 known vectors) of this series occur in Thailand, only *aconitus* and *minimus* have been confirmed as vectors in Thailand. The other 4 species, i.e., *culicifacies, jeyporiensis, pampanai* and *varuna,* may be too uncommon to play a major role in the transmission of human pathogens in Thailand. Brief summaries of the known or potential medical importance of the 6 species in Thailand are given below.

Anopheles aconitus was considered a primary vector of malaria parasites in Thailand as early as Simmons et al. (1944). However, such implications lacked confirmation until Gould et al. (1967) found 2 *aconitus* females positive by dissection in the rice plains just north of Bangkok. This area was known to be endemic for vivax malaria essentially to the exclusion of all other types, and these authors concluded that *aconitus* was apparently the vector. Additional positive specimens of *aconitus* have not been found in Thailand. Accordingly, Harinasuta et al. (1976) considered *aconitus* of minor importance in malaria transmission in Thailand. This interpretation is correct, because large forested areas still remain in Thailand where *An. dirus* Peyton and Harrison 1979, and *minimus* are responsible for the transmission of most human malaria parasites. However, in the future, when most of the forest

*These listings do not imply that they are vectors whenever or wherever they are found. Their respective vector capabilities in a given malaria or filariasis scenario are temporal and dependent on the interrelations of many factors.

tracts have been cut and converted to agriculture, the distribution and abundance of *aconitus* will increase, and its role in malaria transmission may increase. As discussed later, *aconitus* is well adapted to association with man and his crops. A situation has already developed on the flat Korat Plateau in northeastern Thailand that may be a forewarning of malaria problems in the future. Most of the forests on the plateau have been cut, usually eliminating or reducing the *dirus* and *minimus* populations. In the absence of these vectors, pockets of endemic malaria still exist on the plateau, usually in rice growing areas. Although the vector is currently thought (but unconfirmed) to be another species, *aconitus* is also common in these areas and should be suspected as a vector. *Anopheles aconitus* is primarily zoophilic when large mammals such as cattle or water buffaloes are present. However, this could change in the future, with increased mechanization and human population densities.

Experimentally, Bennett et al. (1966) demonstrated that *aconitus* can develop oocyst and sporozoite infections of certain strains of *Plasmodium cynomolgi* Mayer. Brug (1938), working in Indonesia, was able to infect experimentally, 68% of test *aconitus* with *Wuchereria bancrofti*. Atmosoedjono and Dennis (1977) found *aconitus* naturally infected with *W. bancrofti* in Flores, Indonesia.

Anopheles culicifacies was considered a vector of malaria parasites in Thailand as early as Anigstein (1932). Simmons et al. (1944) listed it with *aconitus*, as a primary vector in the plains areas of Thailand, and de Fluiter (1948) felt it was probably a vector in the prisoner-of-war camps in Kanchanaburi Province, during World War II. These incriminations, however, have never been confirmed by dissection, so currently *culicifacies* is not even considered a suspected or potential vector in Thailand (Harinasuta et al. 1976). This species is not very abundant and is currently confined to the northern and western river valleys in Thailand. However, based on specimens in the USNM, it may have been more widespread and abundant in the pre-DDT years. Bruce-Chwatt (1970) reported that DDT resistance in *culicifacies* has been detected in northern Thailand. This development may allow the species to become more abundant in Thailand. If this happens, *culicifacies* should be considered at least a potential vector when it is found in malarious areas. In India and Sri Lanka, DDT-resistant *culicifacies* have been responsible for nation-wide malaria outbreaks in recent years.

Anopheles jeyporiensis was first reported in Thailand in 1951 and subsequently, has been collected in only 4 provinces, and usually in association with cattle. The few specimens dissected for parasites were negative (SEATO Med. Res. Lab., unpublished data). Based on the above, *jeyporiensis* is not likely to be involved in the transmission of human pathogens in Thailand. Accordingly, it has not been treated as a potential vector by current authorities (Harinasuta et al. 1976). In certain earlier publications (e. g., Stojanovich and Scott 1966) it was considered a vector in Thailand, probably because of its vector roles in Vietnam and southern China (Toumanoff 1936, Jackson 1936a, Robertson 1941). *Anopheles jeyporiensis* is a confirmed vector of malaria parasites in both countries, causing serious malaria problems in Vietnam as late as the early 1960's (Chow 1970). This species is also recognized in southern China as a vector of periodic *Wuchereria bancrofti* and periodic *Brugia malayi* (Hawking 1973).

Anopheles minimus was considered the only vector of importance in Thailand by the National Malaria Eradication personnel for many years (Ayurakit-Kosol and Griffith 1962). Consequently, most malaria control efforts were based on behavioral traits of *minimus* until the late 1960's, when *dirus* (as *balabacensis* Baisas) was also recognized as a major vector in Thailand (Scan-

lon and Sandhinand 1965). Actually, *minimus* was first incriminated (by dissection) as a vector of malaria parasites in southern Thailand by Payung-Vejjasastra (1935). In subsequent years, particularly those shortly after World War II, thousands of anophelines were dissected for parasites and only *minimus* was found positive for sporozoites (Griffith 1955). During the same period (1945-49) reported malaria deaths in Thailand annually averaged over 45,000 in a population of approximately 18 millions, and annual malaria case rates were estimated at approximately 5 millions (Griffith et al. 1957).

The words "*minimus*" and "malaria" are almost synonymous in Thailand, even though *dirus* is now considered the major problem vector. Fortunately, the combination of DDT (also probably agricultural pesticides) and the alteration of the environment have reduced *minimus* densities and its distribution in Thailand. At the same time, however, increased tolerance to DDT has been detected in Thai *minimus* (Harinasuta et al. 1976) and this may be partially responsible for a resurgence of malaria cases in Thailand from 1970 to the present. This resurgence was originally considered primarily due to the chloroquine-resistant strains of *Plasmodium falciparum* (Welch), transmitted by *dirus*. In fact, experimental data (Wilkinson et al. 1972, 1976) suggest that *dirus* (as *balabacensis*) is more susceptible and develops more enhanced infections of chloroquine-resistant *P. falciparum* than does *minimus*. However, this can only be partially responsible for the malaria resurgence, because during the last 3 years the number of cases and prevalence of *P. vivax* (Grassi and Feletti), compared with *P. falciparum*, has increased drastically (Thailand National Malaria Eradication Program, unpublished data). The cause(s) for the *P. vivax* resurgence are currently unknown.

The role of *minimus* in the transmission of human filarial parasites in Thailand is apparently non-existent or very minor. Most human filariasis in Thailand is caused by *B. malayi* in the southern provinces where *minimus* is absent or uncommon. Two foci of *W. bancrofti* occur in Thailand, one in the south along the border with Malaysia and the 2nd west of Bangkok in Kanchanaburi Province adjacent to the Burma border. The mosquito vectors are uncertain in the first focus, and *Aedes (Finlaya) harinasutai* Knight, (1978b), a member of the Niveus Group, has been incriminated as the primary vector in the 2nd focus. During the initial studies in the Kanchanaburi focus, Harinasuta et al. (1970) found first stage *W. bancrofti* larvae in 2 female *minimus*, however, all infective (3rd stage *W. bancrofti* larvae were found in *Ae. harinasutai*. In southern China, *minimus* is recognized as a vector of periodic *W. bancrofti* (Jackson 1936b, Hawking 1973), however, *W. bancrofti* in the Kanchanaburi focus in Thailand is classified as a rural subperiodic strain.

Anopheles pampanai is apparently an uncommon mosquito with a patchy distribution in Thailand. Accordingly, there is little likelihood that it is involved in the transmission of human pathogens. In 1969, I collected a few adults in Buriram Province in an area with endemic *P. vivax*. This area lacked the usual vectors, *dirus* and *minimus*, but had other potential vectors, such as *aconitus, philippinensis* Ludlow [or *nivipes* (Theobald)] and *annularis* Van der Wulp. Mosquito dissection studies in the area were negative for malaria parasites. *Anopheles pampanai* is one of the 2 members of the Oriental Myzomyia Series from which human pathogens have never been isolated.

Anopheles varuna is a well known vector of malaria parasites in certain areas of the Indian subregion (Rao 1961). In Thailand, however, specimens of *varuna* confirmed by immature skins, have been collected only in Chiang Mai and Lampang provinces, although thousands of anopheline collections have been made all over the country during the last 20 years. Accordingly, *varuna*

is considered too rare in Thailand to be involved in the transmission of human pathogens.

Iyengar (1938) determined that *varuna* was a natural vector of *W. bancrofti* and *B. malayi* filaria in Kerala (= Travancore), India. However, Ramalingam (1975) considered *Culex quinquefasciatus* Say (= *fatigans* Wiedemann) and several *Mansonia* spp., respectively, the primary vectors of these 2 parasites in India.

KEYS TO THE SPECIES OF THE MYZOMYIA SERIES IN THAILAND*

FEMALES (and males where indicated)

1. Center of scutum covered with short white scales back onto scutellum; tarsomeres with distinct apical pale bands; foretarsomere 1 with pale band nearly 2.0 width of tarsomere diameter (♀ + ♂). *jeyporiensis* (p. 65)

   Center of scutum appearing nearly bare except for setae, or with slender seta-like pale scales back to scutellum; legs entirely dark or some tarsomeres with narrow apical pale bands or patches; foretarsomere 1 with pale band no wider than tarsomere diameter (♀ + ♂). 2

2(1). Remigium entirely or mostly dark-scaled; vein R_{4+5} usually dark except at base; female palpus with preapical dark band much longer than apical pale band (♀ + ♂). . . . . *culicifacies* (p. 52)

   Remigium entirely white or with few gray-black scales at apex; vein R_{4+5} usually with prebasal and preapical dark spots, and base, middle and apex pale; female palpus with preapical dark band approximately equal or shorter (may be absent) than apical pale band (♀ + ♂). . . . . Minimus Species Group . . . 3

3(2). Apex of remigium and vein R base with gray to black scales; costa base with humeral and presector pale spots; female proboscis dark-scaled (♀ + ♂). . . . . *pampanai* (p. 99)

   Apex of remigium and vein R base pale scaled; costa base without humeral pale spot**, with or without presector pale spot; female proboscis dark or with some pale scales. 4***

4(3)**. Proboscis entirely dark-scaled. 5

   Distal half of proboscis with pale or flavescent scales on dorsum and venter or confined to small ventral patch. 6

*Due to overlapping characters, females of *aconitus*, *minimus* and *varuna* are not always identifiable without associated immature skins. The key characters used here will identify about 90-95% of specimens of these species.

**The occurrence of humeral pale spots on *aconitus* increases in southern Thailand.

***Males of *aconitus*, *minimus* and *varuna* should be identified by associated immature skins.

5(4). Foretarsomeres 1-4 with very small dorsoapical pale patches; costa base with presector pale spot represented by at least 1, 2 pale scales; vein Cu_1 with 2 dark spots distal to m-cu crossvein. . . . . (p. 78) (in part)

Foretarsomeres entirely dark-scaled; costa base without presector pale spot; vein Cu_1 usually with one long dark spot distal to m-cu crossvein. . . . . *varuna* (p. 107) (in part)

6(4). Hind margin of wing with pale fringe spot at vein 1A; R_2 with median pale spot; 1A with 2 dark spots on distal half. . . *aconitus* (p. 33)

Hind margin of wing without pale fringe spot at vein 1A; R_2 dark except at base and apex; 1A with one long dark spot on distal half. 7

7(6). Foretarsomeres 1-4 with very small dorsoapical pale patches; proboscis with flavescent scales confined to ventral patch; costa base with presector pale spot represented by at least 1, 2 pale scales; vein Cu_1 with 2 dark spots distal to m-cu crossvein. *minimus* (p. 78) (in part)

Foretarsomeres entirely dark scaled; proboscis with flavescent scales on dorsum and venter; costa base without presector pale spot; vein Cu_1 usually with one long dark spot distal to m-cu crossvein. . . . . *varuna* (p. 107) (in part)

PUPAE

1. Seta 7-VI, VII shorter than, to slightly longer than 9-VI, VII, approximately 0.35-0.70 length of segment VI, VII lateral margins. . . 2

Seta 7-VI, VII much longer than 9-VI, VII, approximately equal or longer than segment VI, VII lateral margins. Minimus Species Group . . . 3

2(1). Paddle fringe not extending mesad of seta 1-P; 2-II with 5-8 branches; 2-III with 5-9 branches; 9-VIII with 14-19 branches. *culicifacies* (p. 52)

Paddle fringe extending mesad of seta 1-P to mesal angle of paddle; 2-II with 2-4 branches; 2-III with 3, 4 branches; 9-VIII with 7-11 branches. . . . . *jeyporiensis* (p. 65)

3(1). Seta 0-III-VII long, simple to 7 branched, usually 3, 4 branched on III-V; 0-IV-VII more laterad, directly cephalad of setae 4, 5, particularly on VI-VII. . . . . *minimus* (p. 78)

Seta 0-III-VII short, simple to trifid (usually simple); 0-IV-VII more mesad, directly cephalad of seta 2. 4

4(3). Paddle fringe not extending mesad of seta 1-P; paddle refractile margin short, extending 0.66-0.76 of distance from base to seta 1-P; 7-III with 5-9 branches; 7-IV with 5, 6 branches; 4-IV with 4-6 branches. *pampanai* (p. 99)

Paddle fringe extending as long or short filaments mesad of seta 1-P; refractile margin longer, extending 0.74-0.96 of distance from base to seta 1-P; 7-III with 2-5 branches; 7-IV, with 1-5 branches; 4-IV, with 1-4 branches. 5

5(4). Paddle fringe extending mesad of seta 1-P as widely spaced short filaments 0.3-0.5 length of filaments just laterad of 1-P, mesal filaments not extending to mesal angle of paddle; trumpet pinna distally rounded, venter convex at apex; sum of branches on both setae 1-III, 14-32; sum of branches on both setae 5-III, 9-22. *aconitus* (p. 33)

Paddle fringe extending mesad of seta 1-P as closely spaced long filaments equal in length to filaments just laterad of 1-P, mesal filaments extending to mesal angle of paddle; trumpet distally flattened, with venter of pinna concave at apex; sum of branches on both setae 1-III, 31-39; sum of branches on both setae 5-III, 22-37. *varuna* (p. 107)

LARVAE

1. Anterior tergal plate on III-VII very large, over 0.5 width of segment, enclosing small median posterior tergal plate. Minimus Species Group. . 2

Anterior tergal plates on III-VII smaller, less than 0.5 width of segment, not enclosing small median posterior tergal plate. 5

2(1). Seta 2-C simple*. 3

Seta 2-C with one to many fine or stout, short lateral barbs* 4

3(2). Seta 0-IV, V large with 2-6 branches, arising on segmental membrane posterolateral to anterior tergal plate; sum of branches on both 4-M, 8-11. . . . . *minimus* (p. 78)

Seta 0-IV, V small, simple, arising on anterior tergal plate 0.21-0.38 of distance from lateral margin to midline of plate; sum of branches on both 4-M, 4-6. . . . . *pampanai* (p. 99)

4(2). Seta 2-C with 9-18 short lateral barbs; 4-C with 2-5 branches (rarely simple); 3-T leaflets with short slender tips. . . *aconitus* (p. 33)

Seta 2-C with 1-4 short lateral barbs; 4-C simple (rarely bifid); 3-T leaflets with long tapering filamentous tips. . . . . *varuna* (p. 107)

5(1). Setae 2,3-C with numerous short lateral barbs; cephalic apex of median plate on spiracular apparatus with lateral arms; 4-C with 2-5 branches. . . . . *jeyporiensis* (p. 65)

Setae 2,3-C simple; cephalic apex of median plate on spiracular apparatus without lateral arms; 4-C simple. . *culicifacies* (p. 52)

*Occasional *varuna* larvae have both seta 2-C simple, but these have long slender apical filaments on 3-T leaflets, while the apices of 3-T leaflets on *minimus* and *pampanai* are short and blunt.

ANOPHELES (CELLIA) ACONITUS DÖNITZ

(Figures 3-9; Tables 1, 2, 6-8, 14)

Anopheles aconitus Dönitz 1902: 70 (♀*); Stanton 1915a: 162 (L*, = *albirostris*); Stanton 1915b: 252 (♀); Stanton 1922: 135 (E*); Barnes 1923a: 122 (distr.); Strickland 1924: 145 (♀*, L*, tax.).

Myzomyia aconita Dönitz, Theobald 1903: 30 (translation of original description); Swellengrebel and Swellengrebel-de Graaf 1920: 89 (♀).

Myzomyia albirostris Theobald 1903: 24 (♂, ♀*); Leicester 1908: 23 (♂, ♀, L).

N. brahmachari McKendrick and Christophers 1912b: 11 (*Lapsus calami* for "*M.* " = *Myzomyia brahmachari*, see type-data section for earlier uses of name as *nomina nuda*); Brahmachari 1911: 268 (♀, original description); Christophers 1912c: 8 (= *albirostris*).

Anopheles albirostris Theobald, Stanton 1912: 387 (L*); Christophers 1915: 392 (♂ genitalia*); Edwards 1915 *in* Ludlow 1915: 156 (= *aconitus*).

Anopheles minimus var. *aconita* of Christophers 1916: 475 (tax.)

Myzomyia aconitus albirostris of Mangkoewinoto 1919: 55 (♀, L, biol., vector status).

Anopheles (Myzomyia) aconitus Dönitz, Christophers 1924a: 51 (tax.); Sinton and Covell 1927: 305 (cibarium); Senevet 1931: 69 (P*); Puri 1931: 155 (L*); Christophers and Barraud 1931: 183 (E*); Barraud and Christophers 1931: 274 (tax.); Toumanoff 1936: 156 (♂, ♀, L); Crawford 1938: 86 (P*); Bonne-Wepster and Swellengrebel 1953: 365 (♂*, ♀*, L*, keys); Khin-Maung-Kyi 1971: 479 (distr.)

Anopheles (Myzomyia) funestus var. *aconita* of Carter 1925: 72 (♀, L*, tax.)

Anopheles (Cellia) aconitus Dönitz, Stone, Knight and Starcke 1959: 37 (tax.); Peyton and Scanlon 1966: 1 (♀*, key); Gould, Esah and Pranith 1967: 441 (vector status); Scanlon, Peyton and Gould 1968: 18 (checklist); Reid 1968: 320 (♂, ♀, P*, L*, E*, key, tax.); Rattanarithikul and Harrison 1973: 2 (L*, key); Knight and Stone 1977: 33 (tax.).

The 4th-stage larva and the pupa of this species are the easiest stages to identify with consistency. The large anterior tergal plates, barbed seta 2-C and branched 4-C make *aconitus* larvae distinct. The pupa has seta 7-VI, VII very long, 9-III-VII short, usually simple and mesad, and a poorly developed paddle fringe mesad of 1-P. These characters, plus those in the keys, will readily identify *aconitus* pupae. The adult should be identified on the basis of associated immature skins, because males of *aconitus* and *minimus* are often indistinguishable. When the classical *aconitus* characters are present, i.e. distal half of proboscis pale, vein 1A with 3 black spots and hind margin of wing with pale fringe spot at 1A tip, then females are easily identified. However, most characters on female *aconitus* are highly variable, including the above "classical" characters. These variations, plus *aconitus*-like variations found on *minimus* in Thailand, make females of these 2 species often unidentifiable without associated immature skins (see Variation sections).

FEMALE (Figs. 3-7, Tables 1, 6, 7). *Head.* Vertex with patch of erect white scales above interocular space, erect black scales laterally and on occiput; interocular space with several long tan setae near top, patch of very long white sinuous scales on each side forming frontal tuft, short white ocular scales laterally; clypeus bare; pedicel integument very light tan, with several minute setae in dorsomesal and ventrolateral patches; flagellomere 1 with white and gray scales on dorsal and mesal surfaces, flagellomere 2 usually

with few scales, flagellomere 3 may have 1-3 pale scales; proboscis basally with dark brown decumbent scales, distally with decumbent pale yellow scales, distal 0.25-0.65 usually dorsally and ventrally pale to bare labellum, rarely with only pale distoventral patch, or entirely dark; forefemur/proboscis ratio 0.84-0.92, 0.90 mean (10 females); palpus equal or slightly shorter than proboscis, with partially erect dark scales at base and on segment 2, remaining scales decumbent; palpus color pattern variable usually with 3 pale yellow bands, narrow basal band at segmental joint 2,3, variable median band on segment 3 apex and segment 4 base, variable apical band on segment 4 apex and segment 5 entirely pale; median and apical pale palpal bands often fused leaving only 2 pale palpal bands with apical band approximately 0.30-0.35 length of palpus (see Variation section). *Thorax.* Integument pale yellow to tan, central portion of scutum slightly gray with 3 dark lines in acrostichal and dorsocentral setal rows; fossa, scutal angles and supraalar areas darker; anterior promontory with long erect pale scales, shorter darker scales laterally at dorsocentral setal rows; scutum with pale yellow seta-like scales back nearly to scutellum; fossa without scales; scutal setae dark brown, long, in acrostichal, dorsocentral, prescutal, fossal, antealar and supraalar groups; prescutellar space bare; scutellum with anterior row of short, narrow, pale seta-like scales, posterior row of long dark brown setae; anterior pronotum with long dark setae; posterior pronotum bare; pleuron without scales, some sclerites may appear darker forming dorsal and ventral longitudinal dark bands; pleural setae: 1,2 propleural, 1,2 spiracular, 2-5 prealar, 2-4 upper and 3-5 lower sternopleural, 2-5 upper and 0 lower mesepimeral. *Wing.* Color pattern variable (see Variation section), pale markings usually yellow to dirty white, dark markings dark gray to blue-black, common pattern follows. Costa with sector, subcostal and preapical pale spots; remigium pale scaled; humeral crossvein bare; vein R base pale to presector dark spot; R sector pale spot and accessory sector pale spot fused, rarely separated by dark spot, approximately 2.0 length of sector pale spot on costa; R_1 with variable subcostal and preapical pale spots, subcostal spot infrequently reduced or absent, infrequently with accessory pale spot on preapical dark mark, tip pale-scaled; R_S-R_{2+3} with pale scales at origin, adjacent to R_{4+5} origin and at R_{2+3} fork, 2 basal spots frequently fused; R_2 with pale scales at origin, apex and middle of vein, 2 basal spots often fused; R_3 with basal and apical pale scales, median pale spot present more often than absent; R_{4+5} most commonly pale with small preapical dark spot; M with pale scales on basal 0.3-0.4, at r-m and m-cu crossveins and at M fork; M_{1+2} and M_{3+4} with white scales at origin and apex, M_{1+2} often with pale median spot; Cu pale-scaled except small subbasal dark spot; Cu fork dark or pale; Cu_1 normally with 3 black and 3 pale spots, pale spots at m-cu crossvein, between 2 most apical dark spots, and at apex, rarely median pale spot absent and vein primarily dark; Cu_2 dark or pale-scaled at base, with long pale mark to preapical dark mark on apical 0.33, apex pale-scaled; 1A primarily pale-scaled with small subbasal, median and preapical dark spot, infrequently median and preapical dark spots fused making apical 0.5 of vein dark; 1A rarely pale except one small subbasal dark spot, or dark except small pale area at base; fringe spots at wing apex highly variable; apical fringe spot fairly stable, starting at or above R_1 apex, usually extending down to include tip of R_2; R_3 tip usually with dark fringe; R_{4+5} tip usually with pale fringe; additional pale fringe spots include those adjacent to apices of M_{1+2}, M_{3+4}, Cu_1, Cu_2, 1A and on hind margin of wing basal to 1A; fringe spot at 1A and on hind margin of wing basal to 1A not constant. *Halter.* Stem pale, knob dark-scaled. *Legs.* Integument dark, with blue-black scales;

coxae without scales; upper midcoxa with 2-5 setae; forefemur normally not swollen; femora entirely dark, tibiae usually dark, midtibia may have small dorsoapical pale patch; foretarsomeres 1-4 with apical pale bands or dorsal patches, band or patch on 1 widest, but not more than width of tarsomere; foretarsomere 5 dark; mid- and hindtarsomeres like foretarsomeres, except pale bands or patches not as wide. *Abdomen.* Unicolorous light brown, covered with numerous light tan setae; setae darker distally particularly on venter; without scales.

MALE (Fig. 7). Like female except: *Head.* Antennal whorl setae longer, more numerous; pedicel enlarged, without minute setae; flagellomere 1 with few yellow-gray scales on mesal surface; proboscis without pale scales, slender, longer than female proboscis, usually curved slightly downward on distal half; forefemur/proboscis ratio 0.64-0.71, 0.67 mean (10 males); palpus with 2 apical segments flattened, clublike, with narrow dorsoapical patch of pale yellow scales on segment 3, dorsum of segment 4 pale-scaled except for few dark scales at base and on lateral margin to segment apex, dorsum of segment 5 pale-scaled except for few dark scales at base; palpal segmental joint 2,3 dark. *Thorax.* Integument yellow to orange brown; prealar setae 2,3. *Wing.* More slender than female wing, with fewer, darker scales; veins R_{4+5}, M_{1+2}, M_{3+4}, Cu, Cu_1, Cu_2, and 1A without plume scales on wing upper surface; tertiary fringe scales on caudal margin of wing extending basally from apex only to Cu_1-Cu_2 region; vein R_{4+5} usually with subbasal dark spot; Cu fork usually dark; 1A with distal half of vein dark-scaled; tip of 1A often without pale fringe spot. *Abdomen.* Segment VIII without scales. *Genitalia.* Basimere with ventrolateral light gray scales, dorsolateral black scales, with 4,5 large parabasal spines; claspette without lobes, with ventromesal spicules, long, large apical seta, stout lateral club and seta between apical seta and lateral club; apical seta longer than club, intermediate seta approximately equal length of club; lateral club fused with 3,4 basal stems; aedeagus narrow, dorsally curved, with 4,5 leaflets on each side of tip; largest leaflets with serrate edge on one side; tergum IX with weakly sclerotized angulate lateral lobes, median portion membranous with minute spicules, posterior margin concave; proctiger cone-shaped, membranous with minute spicules, covering aedeagus and most of claspettes, extending 0.67 distance to basimere apex.

PUPA (Fig. 8, Table 8). Integument clear to uniformly brown, usually clear or light tan, with clear paddles. *Cephalothorax.* On dark specimens, wing case with faint lines on veins and lateral 0.5 of antennal case darkly pigmented with distinct dark mark at each joint. *Trumpet.* On light specimens darker than cephalothorax, same color on darker specimens; simple, with deep meatal cleft, meatus 0.26-0.35 length of trumpet; pinna evenly rounded distally, not flattened with longitudinal ventral ridge and distally expanded. *Metanotal Plate.* Seta 10-MP simple to bifid. *Abdomen.* Seta 0-II-VII small, simple, infrequently bifid, positioned mesally and cephalad of 2-II-VII; 4-I with 6-10 branches; 9-I with 2-5 branches, approximately 1.0 length of segment I; 1-II with 8-21 branches; 2-II with 4-7 branches; 3-II, 1-4 branches; 6-II very long, simple; 8-II absent or small, simple to bifid; 9-II simple, very small, at posterolateral corner; 10-II absent or small, simple; 1-III with 7-17 branches; 2-III with 3-9 branches; 3-III, 1-4 branches; 4-III with 4-8 branches; 5-III with 7-11 branches; 7-III with 2-5 branches; 9-III small, pigmented, slender, with acute tip, 0.3-0.5 length of 9-IV; 1-IV with 7-9 branches; 4-IV, 1-4 branches; 6-IV with 2-5 branches; 7-IV, 1-4 branches; 9-IV, dark, often flattened, with acute tip, 0.19-0.37 length of segment V, 0.67-

0.90 length of 9-V; 1-V with 2-7 branches; 4-V with 3-6 branches; 9-V, 0.29-0.51 (usually 0.35 or more) length of segment V, 0.63-0.94 length of 9-VII, dark, usually flattened with acute tip; 1-VI with 2-5 branches, about 1.0 length of segment; 2-VI with 3-6 branches; 4-VI with 2,3 branches; 5-VI with 4-6 branches; 7-VI simple, very long, 0.95-1.17 length of segment VI; 9-VI dark, usually flattened with acute tip, 0.86-1.00 length of 9-VII, 0.41-0.48 length of segment VI; 1-4 branches; 2-VII with 2-4 branches; 4-VII simple or bifid; 5-VII with 3-7 branches; 6-VII very small, adjacent to 9-VII, simple or bifid; 7-VII simple, very long, 0.96-1.15 length of segment VII; 9-VII dark, usually flattened with acute tip, 0.38-0.47 length of segment VII; 9-VIII dark, flattened, with 7-13 close short branches arising from broad central stem. *Genital Lobe.* Clear to unicolorous brown, without bands of pigment. *Paddle.* Clear regardless of pigment on remainder of pupa; refractile margin long, 0.74-0.90 of distance from base to seta 1-P; paddle 1.40-1.55 as long as wide; lateral fringe gradually changing from small spines to filaments at 0.60-0.75 of distance from base to seta 1-P; paddle fringe extending slightly mesad of seta 1-P as short scattered filaments, not extending to mesal angle of paddle; 1-P simple, sinuous or with kinks, hooked at apex, when unstraightened, 0.33 or less length of paddle.

LARVA (Fig. 9, Table 14). Usually tan to gray-brown, without discernable color pattern, infrequently dorsal surface with dark central stippled pattern, caused by small internal spheroid bodies. *Head.* Color as for body, may have dark pattern on frontoclypeus; pattern consists of 2 transverse bands and 3 longitudinal bands; anterior transverse band at seta 4-C level, posterior transverse band at 5-7-C level; 2 transverse bands connected by semilateral longitudinal dark band on each side; posterior transverse dark band has caudally projecting longitudinal band at midpoint; anterior transverse band infrequently not centrally complete; antenna same color as head, 6.0 length of widest point, base slightly wider than tip, with stout dark spicules on mesal and ventral surfaces; seta 1-A short, simple, inserted on outer dorsal aspect, 0.17-0.24 from base; 2,3-A with one edge serrate; 4-A with 4-7 branches; 2-C with bases more widely separated than distance between bases of 2,3-C on one side; 2-C with 9-18 short lateral barbs; 3-C with 1-9 short lateral barbs, rarely simple; 4-C with 2-6 branches arising on basal 0.25 of seta, rarely simple, extending cephalad approximately to base of 2-C; 5-7-C long, with 5-C longest, reaching forward beyond base of 2-C; 8-C with 2-5 branches from base, rarely simple. *Thorax.* Usually without small submedian sclerotized plates on dorsum of thorax; sclerotized bases of setae 1,2-P separated or joined; 1-P with 19-24 branches; 2-P nearly 2.0 length of 1-P, with 10-14 branches; 3-P short simple, without sclerotized base; 4-P with sclerotized base, longer than 3-P; 5-P with sclerotized base, approximately equal or slightly longer than 4-P, with 36-45 short side branches; and brush-like tip; 8-P large with sclerotized base adjacent to sclerotized base of 9-12-P, with 29-33 branches; 9-P long, with 9-11 branches; 11-P short with 2-4 branches; 10,12-P very long, simple; 13-P with 4-8 thick rod-like branches; 1-M flattened, with large central stem and 30-39 lateral branches arising close together; 4-M short, with 3-5 branches arising near base; 3,5-M long (5-M longest), simple, arising side by side, without sclerotized bases; 6,7-M with 3-5 and 2-5 branches respectively, 6-M longest; 8-M with 18-24 branches; 9, 10-M very long, simple, 9-M rarely bifid; 12-M short, bifid, branched on basal 0.5; 3-T with very short thick stalk, 11-17 lightly pigmented leaflets; 3-T leaflets without shoulders, with narrowing apices, but blunt tips; 5-T large, on sclerotized base; 7,8-T large, on sclerotized bases; 9-T long, with

5-7 branches; 10-T long, simple; 11-T minute, simple; 12-T short, with 3, 4 branches from near base. *Abdomen.* Anterior tergal plates on III-VII very large usually 0.50-0.66 width of segment, enclosing small median posterior tergal plate on each segment; posterior margin of anterior tergal plate II convex, enclosing posterior tergal plate; lateral margins of anterior tergal plates usually tapering, not rectangular; segments II-VII usually with pair of small oval submedian plates caudal to large anterior plates; seta 0-II-VII small, 1-3 branches from near base, arising close to lateral margin of anterior tergal plate, either just off or just on plate; occasionally 0 found more mesal on plates, up to 0.3 but rarely more than 0.15 of distance from lateral margin to midline of plate; seta 1-I with narrow, lanceolate gray leaflets usually without shoulders; 1-II-VII with well developed leaflets with distinct shoulders and long fine filaments, leaflets dark gray-brown on basal portion, paler on shoulders and filament; 1-I with 12-14 leaflets; 2-I, 1-3 branches; 7-I long, with 24-28 branches; 11-I very large, with 4 branches from near base; 1-II with 16-19 leaflets; 7-II long, with 28-31 branches; 1-III with 17-23 leaflets; 7-III short, with 4-8 branches from near base; 13-III small, with 7-12 branches; 1-IV with 18-22 leaflets; 5-IV with 3-5 branches from near base; 6-IV with 3 branches; 13-IV with 4-8 branches; 1-V with 17-21 leaflets; 5-V with 5-8 branches from near base; 6-V with 3 branches; 13-V with 4, 5 branches; 1-VI with 17-21 leaflets; 5-VI with 6-9 branches from near base; 1-VII with 16-18 leaflets; 2-VII with 2-5 branches; 0-VIII small, simple or bifid, arising on integument posterolateral to tergal plate; 2-VIII with 8-11 branches. Pecten plate with 4-6 long and 6-9 short teeth, long teeth usually on each end with several interspersed among intermediate short teeth, long teeth with lateral serrations; seta 1-S large, with 6-8 branches, inserted just caudad of pecten plate; 2-S small, with 4-7 branches; inserted on pecten plate; apex of median plate sharp pointed, with narrow lateral arms; saddle on segment X with minute spicules; 1-X simple, long, 1.44-1.81 dorsal length of saddle; 2-X with 17-22 branches, most basal branches shorter than distal branches and straight, thick, narrowing abruptly to sharp thorn-like tip, most distal branches long, tapering gradually to small hooked tip.

EGG. Description from Reid (1968). "About 0.44 mm. long with more prominent points than in *minimus*, deck narrow and of fairly uniform width not narrowed towards the middle as in *minimus*, floats long about 4/5 the length of the egg compared with about 3/4 in *minimus*, with an average of 19 strong double-crested ribs." Additional references to the egg stage of *aconitus* are: Stanton (1922), Christophers and Barraud (1931), Walch and Walch-Sorgdrager (1934) and D'Abrera (1944).

TYPE-DATA. The holotype ♀ of *aconitus* was deposited in the Zoologisches Museum der Humboldt Universität, Berlin (German Democratic Republic), but the current status of this specimen is unknown. According to Theobald (1903) the "specimen" was preserved "in spirits" (? alcohol). Yamada (1925) was apparently the last mosquito taxonomist to examine the holotype, and he found it badly damaged with only one leg present. Christophers (1933) listed the "Type" of *aconitus* as unknown, while Stone, Knight and Starcke (1959) and Knight and Stone (1977) list it as present in the original depository. Reid (1968) lists more than one female, i.e. "Types", as deposited in Berlin. Dönitz obviously examined more than one specimen as he listed the habitat as "Sumatra (Kajoe-Tanam). Java (Willem I; Soekaboemi)," in the original description (p. 62-3), and later (p. 76-7) listed *aconitus* from 7 localities on Sumatra and 7 localities on Java. However, the translation (Theobald 1903) of the original description clearly states that one specimen from Kajoe Tanam,

Sumatra (near west coast, just north of Padang) was used for the description. Furthermore, Yamada (1925) discussed "the type" without any indication that more than one specimen was present. Therefore, I am considering that specimen the holotype of *aconitus*.

The original description of *aconitus*, with associated plates, and Yamada's discussion of his examination of the holotype leave no doubt as to the identity of this species. Further evidence mentioned in the original description and visible on the wing plate and also discussed in Yamada (1925), is the absence of a dark spot on R separating the sector pale spot from the accessory sector pale spot. *Anopheles aconitus* very rarely has this dark spot (at least in Thailand), while *minimus* often has it and *flavirostris*, which occurs with *aconitus* in Indonesia, usually has it. The holotype was also described as having 4 (pale) spots on anterior margin of the wing at equal distances from each other. The plate in Dönitz (1902) shows these spots as humeral, sector, subcostal and preapical, not sector, subcostal, preapical and apical (Theobald 1903). The absence of a presector pale spot in this arrangement is unusual, however, at least 25 Thailand specimens (♀) of *aconitus* were found with an identical costal spot pattern as the holotype.

Two synonyms of *aconitus* were listed by Knight and Stone (1977), i.e., *albirostris* Theobald and *brahmachari* McKendrick and Christophers (as Christophers). Theobald (1903) described *albirostris* from 2 excellent specimens. I have examined these 2 (♂ and ♀) syntypes in the BMNH and here designate the female as lectotype. The lectotype is pinned (minuten nadelin) on a cardboard stage, and is in near perfect condition except the left wing is broken off and is stuck by the base to the minuten. The lectotype has the following labels: (1st label - underside of cardboard minuten stage) - "HED, 1 pol . . . (undeciphered), Rest house, 16/V/02"; (2nd label) - "Kuala Lumpur, D. Durham"; (3rd label) - "*Anopheles alborostris* [*sic*] (Type) FVT. [Theobald's handwriting]; and (4th label) - "*Anopheles (Cellia) aconitus* Dönitz, det. B. A. Harrison." This specimen has the following characters in addition to those discussed in the original description. The right wing has a distinct presector pale spot and 2,3 pale scales on the caudal aspect of the costa where a pale humeral spot would occur. The left wing has the presector and a faint humeral pale spot less distinct. The distal half of vein 1A is entirely pale on both wings, and the palpus has a very narrow preapical dark band. The male paralectotype is also in excellent shape, with genitalia intact. This specimen has a locality label "Kuala Lumpur, New Road, Larvae", and the remaining labels as for the lectotype. The paralectotype has a humeral and presector pale spot on the left wing and only a presector pale spot on the right wing. The apical 0.35-0.40 of vein 1A is dark scaled on both wings and the hind margin of the wing lacks a pale fringe spot at the tip of 1A. There is one other female in the BMNH with a type-label on it under *albirostris*, however, this label is "var. Type" and refers to an unpublished Theobald manuscript name on a label below the specimen. I do not consider this specimen a paralectotype because it is labeled with a July collection date rather than May as stated in the original description, and does not have the label with "*Anopheles alborostris* [*sic*] (Type) FVT." written by Theobald, as do the lectotype and paralectotype.

The type-specimens of *brahmachari* from Calcutta, India, are listed by Reid (1968) as in the National Institute of Communicable Diseases, Delhi, India. I have not seen these specimens, but based on the original description of this species (Brahmachari 1911) it is probably a synonym of *aconitus*. The circumstances surrounding the naming of *brahmachari* were confusing. This

species was described, but unnamed, by Brahmachari in July 1911, in the "Indian Medical Gazette." In March 1912, there were 2 references to the name *brahmacharii:* (1) Christophers (1912a) refers only to *brahmacharii* without an indication (Arts..12, 16, ICZN-1964) or a reference to a genus; and (2) Christophers (1912b) refers to *M.* (= *Myzomyia*) *brahmacharii* with a reference to an earlier note in "Paludism", vol. 3 (1911). However, a page by page search of "Paludism", vols. 2 and 3 revealed no reference to Brahmachari's new species. It seems likely that Christophers meant to reference the new species in the "Indian Medical Gazette" instead of the journal, "Paludism". In September 1912, the name *M. brahmacharii* was used for the 3rd time in an "Editorial" section by McKendrick and Christophers (1912a, as editors) and again without a proper indication. The above 3 references to the name *brahmachari* do not fulfill the ICZN requirements for naming a species and therefore I consider them as *nomina nuda*. Finally, the name was used by McKendrick and Christophers (1912b, as editors) in a review of current literature that contained a proper indication to the original description. I consider this publication of the name as satisfying the ICZN requirements. Unfortunately, further problems remain. Previous authorities (Christophers 1933, Stone et al. 1959, Knight and Stone 1977) have attributed the name *brahmachari* to Christophers, however, the name was used in a "Current Literature" section of a journal with no listed authorship. A search of that entire volume (5) of "Paludism" revealed no statement giving Christophers sole authorship for that section. Therefore, since McKendrick and Christophers (in that order) were the editors for volume 5, "Paludism", I credit them with naming *brahmachari*. The 2nd problem with the accepted publication of this name involves an apparent inadvertent error (*lapsus calami*, Art. 32, ICZN), i.e., an incorrect spelling indicating the wrong generic abbreviation. In previous usages of the name (above *nomina nuda*) it was assigned to *M.* = *Myzomyia*, and *brahmachari* was spelled *brahmacharii*. In McKendrick and Christophers (1912b), however, the generic designation was "*N.*" which would mean *Nyssorhynchus* and *brahmachari* was spelled with only one "i". Since references before (Christophers 1912b, McKendrick and Christophers 1912a) and after (Christophers 1912c, 1916) this usage places this species in *Myzomyia*, I believe the "*N.*" appearing in McKendrick and Christophers (1912b) was an inadvertent printer or editorial error for "*M.*" The use of *brahmachari* with one "i" should probably stand, based on Art. 32, ICZN, since Christophers (1912c) also used the name with one "i."

DISTRIBUTION (Fig. 8). This species possibly has the widest distribution of any member of the Myzomyia Series in the Oriental region. Only *minimus* has a comparable range. Knight and Stone (1977) list the distribution for *aconitus* as "Oriental Region." A more concise description of its range follows. It extends from India, Nepal and Sri Lanka in the west to Hainan Island, People's Republic of China in the east, south through the Indochina-Malay peninsula into Indonesia as far east as Babar Island in the Lesser Sunda chain. A fairly accurate map depicting this range is found in Soerono et al. (1965). More specifically this distribution includes: BANGLADESH; BURMA; CAMBODIA; INDIA (Andaman islands, Andhra Pradesh, Assam, Bihar, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu and West Bengal); INDONESIA (Alor, Babar, Bali, Flores, Java, Kisar, Lombok, Pantar, Sulawesi, Sumatra, Sumba; Sumbawa and Timor); LAOS; MALAYSIA (Peninsular); NEPAL; PEOPLE'S REPUBLIC OF CHINA (Kwangtung, Hainan Island and Yunnan); PORTUGUESE TIMOR; SINGAPORE; SRI LANKA; THAILAND; and VIETNAM. Swellengrebel and Rodenwaldt (1932) record *aconitus* from the

eastern part of Kalimantan (= Indonesian Borneo), but this record needs confirmation, as *aconitus* has not been recorded in East Malaysia (northern Borneo) despite years of active mosquito surveillance programs.

Scanlon, Peyton and Gould (1968) recorded *aconitus* from 26 provinces in Thailand and claimed it is one of the most abundant species in Thailand, being found nearly everywhere collections have been made except in dense forested areas. During this study specimens of *aconitus* were examined from an additional 10 provinces and now, it is known from 36 of the 72 provinces in Thailand. I consider it ubiquitous in Thailand (Fig. 8). This species is recorded from the following provinces of THAILAND: Ayutthaya, Buriram, Chanthaburi, Chiang Mai, Chon Buri, Chumphon, Khon Kaen, Krabi, Krungthep Maha Nakhon, Lampang, Lop Buri, Mae Hong Son, Nakhon Nayok, Nakhon Ratchasima, Nakhon Si Thammarat, Nan, Narathiwat, Nonthaburi, Pathum Thani, Phangnga, Phayao, Phet Buri, Phrae, Phuket, Prachin Buri, Prachuap Khiri Khan, Ranong, Rat Buri, Rayong, Sara Buri, Satun, Surat Thani, Trang, Trat, Udon Thani and Yala.

A total of 13,302 *aconitus* specimens were examined during this study (1,229♂, 6,240♀, 639 larvae, 2,511 larval and 2,683 pupal skins). Specimens examined from Thailand include 351♂, 5,029♀, 597 larvae, 511 larval and 661 pupal skins from adult and immature collections; and 860♂, 1,165♀, 2 larvae, 1,981 larval and 2,007 pupal skins representing progeny from 98 females collected in Chumphon, Pathum Thani and Sara Buri provinces. Additional specimens (18♂, 46♀, 40 larvae, 19 larval and 14 pupal skins) were examined from the following countries: BURMA; CAMBODIA; INDIA; INDONESIA; MALAYSIA (Peninsular), includes the type-specimens of *albirostris* in BMNH; SRI LANKA; and VIETNAM.

VARIATIONS (Figs. 3, 6; Tables 1, 6-8, 14). A more classical diagnosis of an *aconitus* female would include the following characters: (1) proboscis pale on distal half; (2) palpus with narrow preapical dark band; (3) vein R_{4+5} without a prebasal dark spot; (4) vein 1A with 3 dark spots; and (5) wing margin with pale fringe spot adjacent to 1A tip. Most workers still rely on one to all of these characters to identify their specimens, however, none of these characters are 100 percent reliable. Among the earliest workers to suspect variations in *aconitus* were Mangkoewinoto (1919) and Swellengrebel and Swellengrebel-de Graff (1920). These workers found specimens intermediate to *aconitus* and *minimus* on Java and Sumatra. However, their intermediates, i.e., *aconita* var. *merak(cohesia)* Mangkoewinoto and *minimus* var. *aconitus* (Larval variety) of Swellengrebel and Swellengrebel-de Graff, should definitely be assigned to *flavirostris*, a Philippine species which is widespread in Indonesia, but was not recognized by workers there until Van Hell (1933). The former, *merak(cohesia)*, has been considered a synonym of *minimus* in recent years (Knight and Stone 1977). Among other early workers, Lamborn (1922) noted that the palpi of Malayan *aconitus* often lacked the preapical dark band and were entirely pale on the distal 0.33, while Strickland (1924) pointed out specimens in Assam with the proboscis nearly dark and the costa without a presector pale spot. Lamborn's work is particularly interesting because he was attempting to study variations by the examination of "in bred families" (= sibling broods). Unfortunately this study was terminated before completion. Possibly Strickland's major accomplishments in his paper were the use of associated larval skins to confirm the identity of the adults, and to point out that larval differences between *aconitus* and *minimus* in Assam were very constant.

Several papers published during the 1930's dealt with *aconitus* variations. Christophers and Puri (1931) noted the pale palpal variation (see Lamborn above), the infrequent absence of the 1A pale fringe spot and that a costal pre-

sector pale spot was usually missing on Indian *aconitus*. They also claimed that 2 characters, i.e., dark subbasal spot on R_{4+5} and 1A with 3 pale spots, were of little value on Indian *aconitus*. Of particular interest to this study is a paper by Barraud and Christophers (1931) on variations noted on 58 *aconitus* females collected in Bangkok, Thailand. These specimens had the distal 0.33 to 0.50 of the proboscis pale-scaled, base of the costa usually without humeral or presector pale spots, R_{4+5} without a black prebasal spot on 55/58 specimens, 1A with 3 dark spots except for one specimen, 1A pale fringe spot absent in a few cases, M_{1+2} usually without median pale spot and approximately 30% had the preapical dark palpal band absent. Two years later in his monograph on Indian anophelines, Christophers (1933) claimed that the best characters to differentiate *aconitus* from other members in the series were the pale proboscis and the pale fringe spot adjacent to vein 1A tip, and that the other wing markings were too variable. He noted that nearly a third of the Indian specimens had a dark prebasal dark spot on R_{4+5}. King (1932) and Christophers (1933) also gave some larval variations, the former primarily giving ranges of branching on certain setae, while the latter noted that seta 0 on the abdominal segments was usually at the edge of the tergal plate, but occasionally was internal to the posterior border of the plate. Toumanoff (1936) made an extensive comparison of wing variations on *aconitus* and *minimus* from Indochina (= Vietnam). His studies were based on several hundred wild females of each species and yielded so many wing variations that he concluded that the pale-scaled proboscis on *aconitus* was the only reliable character to distinguish the 2 species.

Several more recent authors (Macan 1948, Wattal et al. 1960, Reid 1968) have discussed *aconitus* variants or the general problem of identifying females of this species, but no attempt has been made since Strickland (1924) to analyze these variations using adults confirmed by associated immature skins, or by using progeny from known wild females.

Since adult females and larvae are the stages most likely to be collected in surveillance programs, these stages received the most attention during my search for variations and their frequency. A total of 1,302 females collected as adults or reared from 4th-stage larvae were identified as *aconitus* using published keys, then examined to determine the frequencies of 22 different variations. These females were collected or reared in Thailand between January 1968 and June 1970, and originated from provinces in 3 distinct regions of Thailand: (South) - 206 specimens from Chumphon, Krabi, Nakhon Si Thammarat and Ranong; (Central) - 663 specimens from Lop Buri, Nakhon Nayok, Pathum Thani and Sara Buri; and (North) - 433 specimens from Chiang Mai. The percentage of reared specimens also varied per region, i.e., South (11.4), Central (9.3) and North (59.1). Due to other research obligations and logistics the above adults and larvae were collected by irregular sampling, thus equivalent seasonal collections were not possible. An additional 1,165 female and 860 male progeny from 97 females collected in central Thailand (Pathum Thani and Sara Buri) and from 1 female from southern Thailand (Chumphon) were checked for the same characters as the feral adults. An examination of these F_1 progeny yielded results essentially the same as those obtained by Leeson (1940), working on *An. funestus* in Nyasaland (= Malawi), i.e., the wing patterns of F_1 progeny from a given female parent are highly variable and may or may not have the same pattern or even one approximating that of the female parent. Also, a given progeny brood may show a very wide spectrum of different wing, proboscis and palpal variations, or less commonly, all the members of the brood may be fairly uniform. One

very definite trend was detected in the progeny, they were definitely darker, based on spotting frequencies, than their parents and central and southern Thailand specimens. Their general appearance was often like northern specimens or even darker. Perhaps this can be attributed to the temperature of the water in the immature habitat, i.e., about 25°C in the facilities where the progeny were reared. Anopheline larvae, because of their normal horizontal body position immediately below the water surface, are normally subjected to the highest temperatures (may be as high as 45-50°C) in a given habitat that is exposed to sunlight. Culicine larvae, although occupying the same habitat(s), normally hang at an angle from the surface and often detach from the surface while feeding, thus escaping the high temperatures at or just below the surface. Marks (1954) found that a temperature increase in the larval habitat increased the amount of white scaling on the culicine mosquito, *Aedes pseudoscutellaris* (Theobald), while the amount of dark scaling increased with a falling temperature. Several authors working on anophelines have alluded to the influence of seasons on the color patterns observed on adults. Davis (1928) working on *Nyssorhynchus* species in South America, arrived at the conclusion that melanism was correlated with progressing distance from the equator and particularly with the seasons, being most prominent during the colder months. Leeson (1930), Gillies (1963) and Service (1964), working separately on members of the Funestus Complex in Africa, concluded that the degree of dark/pale scaling on certain wing veins was governed by the seasons. Service (1964) also showed that melanism on certain veins showed more correlation than would be expected if there was no interdependence and the pigment distribution was random. Several authors in the colder latitudes of India have noted cold weather variants of *An. fluviatilis*. De Burca and Forshaw (1947) noted increased frequencies of forked clypeal setae on larvae, and hypermelanic adults during the colder winter months. Ramakrishna (1954), Rahman et al. (1960) and Wattal et al. (1960) discussed specimens of *fluviatilis* captured during the cool-cold season with an extra dark band on the palpus. This band divides the apical pale band and these specimens have 4 pale bands on the palpus instead of the 3 pale bands which, in part, characterizes adult females of the Myzomyia Series.

Table 1 shows the ranges of frequencies for 13 characters selected for their past and present importance in differentiating this species. Several of the "diagnostic" characters discussed at the beginning of this section, i.e., R_{4+5} without a prebasal dark spot, 1A with 3 dark spots and wing margin with pale fringe spot adjacent to 1A tip, had a considerable range in frequency among the various regions of Thailand. The absence of pale scales on the proboscis was also detected on *aconitus* (progeny with immature skins) for the first time. This occurs at a very low frequency. Specimens having this character would have been identified, using published keys, as some other species, hence the lack of records for this character on wild females. The record of *filipinae* (based on one female) from Nepal (Pradhan and Brydon 1960) probably refers to an *aconitus* specimen with the proboscis dark. *Anopheles aconitus* is recorded from the same district as the *filipinae* record (Brydon et al. 1961), while *minimus* is not. I consider *filipinae* confined to the Philippines. In this study only a few *aconitus* (1-3%) had reduced pale scaling on the proboscis, however, such specimens could be confused with *minimus* specimens (6%) having pale scales on the venter of the proboscis. Female *aconitus* were also seen with the distal 0.60-0.66 of the proboscis pale, and several specimens had a small separate pale spot on the venter of the proboscis, basal to the normal pale scaled area. The palpal banding pattern was not surveyed because it was

TABLE 1. Frequency (*f*) of selected characters on feral females and progeny of feral female *An. aconitus* from Thailand.

Characters	Feral ♀♀ - Regions of Thailand						♀ progeny of 98 feral ♀♀ from Central and S. Thailand (1,165)	
	South (206)*		Central (663)		North (433)			
	f	(No.)	*f*	(No.)	*f*	(No.)	*f*	(No.)
Proboscis entirely dark	0.0	(0)	0.0	(0)	0.0	(0)	0.002	(2)
Proboscis with reduced ventral pale area	0.024	(5)	0.008	(5)	0.023	(10)	0.025	(29)
Costa with humeral pale spot (both)**	0.136	(28)	0.057	(38)	0.012	(5)	0.018	(21)
Costa with presector pale spot (both)	0.592	(122)	0.129	(86)	0.069	(30)	0.083	(97)
R sector and accessory sector pale spots separate (one)	0.0	(0)	0.005	(3)	0.007	(3)	0.012	(14)
R_1 with accessory pale spot (one) between Scp & Pap pale spots	0.019	(4)	0.020	(13)	0.118	(51)	0.129	(150)
R_2 with central pale spot (both)	0.971	(200)	0.958	(635)	0.880	(381)	0.931	(1,085)
R_{4+5} with prebasal dark spot (both)	0.058	(12)	0.190	(126)	0.432	(187)	0.496	(578)
M_{1+2} with central pale spot (one)	0.169	(35)	0.134	(89)	0.254	(110)	0.199	(232)
Cu fork pale (both)	0.607	(125)	0.318	(211)	0.074	(32)	0.037	(44)
Cu_1 with 1 long dark mark beyond m-cu crossvein (one)	0.009	(2)	0.003	(2)	0.014	(6)	0.0	(0)
1A with 2 dark spots (both)	0.024	(5)	0.097	(64)	0.162	(70)	0.196	(228)
1A without pale fringe spot (both)	0.005	(1)	0.089	(59)	0.231	(100)	0.251	(292)

*Total number of specimens examined.
**(One) or (both) = character on at least one wing or on both wings.

recognized as too variable for taxonomic use. However, approximately 25-30% of the feral adults exhibited the palpus entirely pale on the distal third and nearly all of the remainder had a narrow preapical dark band. Less than 1% (8/1,302) had a preapical dark band as wide as the preapical pale band. The character frequency trends seen in Table 1 suggest a north-south cline in the wing patterns of *aconitus*. Specimens from the south have more and larger pale areas on the wings than the more northern specimens. Actually a clinal relationship cannot be inferred from these data because the southern and northern specimens were collected during different seasons and under different climatic conditions. On the other hand, sufficient data have been published to give the picture of *aconitus* in Indonesia as usually very pale, i.e., with presector pale spot on costa, without prebasal dark spot on R_{4+5}, with 3 dark spots on 1A and with 1A pale fringe spot, while specimens from India are darker, usually without a presector spot on the costa, with a dark prebasal spot on R_{4+5}, 1A with 2 or 3 dark spots, and the 1A fringe spot is frequently absent. Since Thailand is intermediate to these 2 extremes, and is nearly 1,400 km long, some clinal trends should be detectable. Similar clinal trends involving anopheline leg banding patterns have been pointed out by Reid (1968) and Harrison and Scanlon (1975).

The frequency of some additional or unusual wing variations observed on wild female *aconitus* include: R_3 without pale median spot - 0.126 (26/206) southern specimens, 0.238 (158/663) central specimens and 0.321 (139/433) northern specimens; R_{4+5} almost entirely dark - 0.008 (4/1,302); Cu without basal dark spot - 0.048 (56/1,302); 1A without prebasal dark spot - 0.014 (18/1,302); 1A dark except at base - 0.031 (41/1,302); R-R_1 with extensive pale scales between subcostal and preapical pale spots - 0.004 (5/1,302); and R with accessory pale spot between sector and subcostal pale spots - 0.002 (3/1,302). Most of these variations were also observed on progeny specimens.

Several characters checked on the progeny were found more frequently on males than on females, they were: 1A with 2 dark spots 0.926 (796/860); R_{4+5} with prebasal dark spot 0.777 (668/860); 1A without pale fringe spot 0.358 (308/860); and Cu_1 with one dark spot distal to m-cu crossvein 0.029 (25/860). One character was found less frequently on male than female progeny, i.e., costa with pale presector spot 0.005 (4/860). These data show that a large proportion of male *aconitus* may have the same basic wing habitus as males of *minimus*. Thus, males of both species should be identified by associated immature skins.

A number of morphologically deformed variants were found among the wild females and adult progeny, but no attempt was made to isolate these traits. At least 5 of these variants appear to be equal to variants that have been isolated and are known to be heritable traits in *An. quadrimaculatus* Say (Kitzmiller and Mason 1967) and/or *An. stephensi* Liston (Aslamkhan et al. 1972). These 5 traits and their recovery rates were: (1) Short palps - 3/1,302 wild females, 43/1,165 progeny females and 6/860 progeny males; (2) Long palps - 1/1,302 wild females and 2/1,165 progeny females; (3) Wartoid or Warted palps - 4/1,165 progeny females and 15/860 progeny males; (4) Bent or Semi-beaked proboscis - numerous female and male progeny; and (5) Beaked proboscis - 1/860 progeny males. Six additional variants were recovered, of which 4 appear identical to or near previously described variants in other species. None of these are currently known to be heritable traits. These 6 traits are: (1) Anal vein interruption - 11/1,165 progeny females and 36/860 progeny males, with previous multiple recoveries in *Aedes aegypti* (Linnaeus) (Vandehey and Craig 1962), *An. quadrimaculatus* (Kitzmiller and Mason 1967)

and *An. stephensi* (Aslamkhan et al. 1972); (2) ?Unilateral or Uneven palps - 21/1,165 progeny females, previous multiple recoveries in *An. stephensi* (Aslamkhan et al. 1972); (3) R_3 interruption - 1/1,165 progeny females, previous multiple recoveries from *An. quadrimaculatus* (Kitzmiller and Mason 1967); (4) M_{3+4} interruption - 3/860 progeny males, with previous recoveries in 1♂ *An. quadrimaculatus* (Kitzmiller and Mason 1967) and 1♂ *An. stephensi* (Aslamkhan et al. 1972, as "M_2 Interrupted"); (5) M veins fused - 1/860 progeny males, on one wing, 2 veins totally fused except for small fork just prior to wing margin, no previous recoveries; and (6) Bowed tibia - 1/860 progeny males, all 6 tibiae strongly curved and bow-shaped, no previous recoveries. These variants may have future value as "markers" for cytogenetic studies.

Most of the variations detected in pupal characters concerned setal branching (see Table 8). However, the general color of *aconitus* pupae was very variable, ranging from nearly transparent to dark brown. The darkest specimens seemed to originate from still water habitats such as seepage marshes, seepage pools or fallow rice fields. Individual pupae were nearly always a uniform color and without a discernible pattern.

The majority of variation occurring on larvae of *aconitus* involved setal branching (Table 14). One structural variation noted on progeny larvae was a slight size reduction in the abdominal anterior tergal plates. Due to this reduction, seta 0 was often lateral and some distance from the edge of the plates, instead of adjacent to the edge or on the edge of the plates. Similar reductions in plate size have been observed on laboratory reared members of the Funestus Complex in Africa (Evans and Symes 1937, Service 1960). To the other extreme, specimens were observed with seta 0 considerably more mesad on the anterior tergal plates. On these specimens seta 0 may occur up to 0.3, but rarely more than 0.15 of the distance from the lateral margin to the midline of the plate. Such specimens could be confused with *varuna* and *pampanai* larvae except for the more diagnostic characters used in the key. Seta 4-C on *aconitus* characteristically has 2-6 branches from near the base, however, an examination of 491 whole larvae and larval skins from northern Thailand (Chiang Mai Province) revealed 0.043 (21/491) with 4-C simple on one side and 0.004 (2/491) with 4-C simple on both sides. Seta 3-T usually has rather slender tipped leaflets on *aconitus* and a few specimens were noted to have these leaflets more blunt as on *minimus*, but none were found with filamentous leaflets as on *varuna*. Several specimens were found with anomalous setae; these include: one specimen with 2 left 1-C; one specimen with left 2-C flattened on distal half, with brush tip; one specimen with barbs on 2-C with subbranches; one specimen with barbs on 3-C very stout, long, nearly 0.5 length of main stem; and several larvae with 3-C bifid at tip.

As can be seen, *aconitus* is extremely variable in Thailand, particularly the adult stage. All of the character variations studied appear to be of a continuous nature, with intermediate character states commonly observed. The examination of 1,165♀ and 860♂ progeny adults with associated immature skins yielded no trace of polymorphic characters and confirmed the suspected phenetic plasticity of this species. A comparison of character frequencies on progeny with those on wild adults and wild larvae, suggests that wing melanism and larval plate development may be influenced by ecological factors such as water temperature in the larval habitat. Regardless of any laboratory induced character changes, wild and progeny immatures, reared under laboratory conditions, retain the diagnostic characters for the species. Consequently, based on the stability of the immature characters, adults are best identified on the basis of associated immature skins. For field expedience, a majority of adult

females can be identified on the basis of (1) pale scales on distal half of proboscis, (2) vein 1A with 3 dark spots and (3) 1A with pale fringe spot. The proboscis character, as determined by Christophers (1933) and Toumanoff (1936), is the best available character for differentiating *aconitus* females.

TAXONOMIC DISCUSSION. *Anopheles aconitus* is the most commonly encountered member of the Minimus Group in Thailand, and also possibly the most variable. This variation is a major cause of identification problems. In southern Thailand it is usually paler than further north and readily identified, even though it commonly has presector or humeral pale spots or even both on the costa. Furthermore, *aconitus* may be the only member of this group still found in most of southern Thailand. In the large flat rice plains of central Thailand, *aconitus* is still usually distinct. However, specimens are collected infrequently, particularly in the foothill areas bordering the rice plains, that have vein 1A with 2 dark spots and 1A without apical pale fringe spots. These specimens have been confused in the past with *minimus* that have a pale ventral patch on the proboscis, or even *varuna* with a pale patch on the proboscis. *Anopheles minimus* commonly occurs in these foothill areas, but *varuna* is not known from this region of Thailand. A number of *minimus* variants similar to *aconitus* also occur in this region, making identifications even more complicated. In northern Thailand the identification problem intensifies with the occurrence of *varuna*. Both *aconitus* and *minimus* are darker in the north, particularly during the cool season (November-January), and both have variants that appear nearly identical to *varuna* in this area (Tables 6, 7). Nearly one-third of the *aconitus* reared from larvae collected in marginal areas of the Chiang Mai valley during November-December 1969 had reduced pale scaling on the proboscis and the wings darker than normal. These traits also occurred commonly on females collected during that month. These specimens were frequently almost identical to *varuna* with a pale patch on the proboscis, except that the foretarsomeres had narrow apical pale bands or dorsal patches, a character not seen on *varuna* specimens. Besides, female *varuna* often (11/22) have Cu_1 with one long dark mark beyond the m-cu crossvein, while northern Thai *aconitus* normally (427/433) have 2 dark spots beyond the m-cu crossvein on Cu_1, as does *minimus* (2,199/2,264). A number of these adults could not be identified with certainty without associated immature skins, and since *aconitus* and *minimus* are proven vectors of malaria pathogens in Thailand and *varuna* is a proven vector in India, this creates a very serious problem of identification.

Adults of *aconitus* ought never be confused with *jeyporiensis*, even though they have a number of similarities: vein 1A with 3 dark spots, 1A with pale fringe spot, banded tarsomeres and an accessory pale spot on R_1 between the subcostal and preapical pale spots. This last character is less common on *aconitus* (2-13%), while it occurred on 95.7% (44/46) of Thai *jeyporiensis* specimens. The basic colors of these 2 species are quite different, with *aconitus* being brown to black and creamy-white while *jeyporiensis* has a striking pattern of black and silver-white. *Anopheles jeyporiensis* also has distinct short white scales on the scutum and a black proboscis, 2 characters very different from *aconitus*.

Normally, *aconitus* cannot be confused with *pampanai*, however, an occasional specimen with 2 dark spots on 1A and without a 1A pale fringe spot may also have both humeral and presector pale spots on the costa. Such specimens can still be diagnosed as *aconitus* on the basis of the pale scales on the proboscis and the lack of a dark scale patch on the remigium apex - R base.

A number of previous authors have used various palpal banding length

relationships as key characters to separate members of the Minimus Group. As can be seen in Fig. 6, the palpal banding patterns on *aconitus*, *minimus*, *pampanai* and *varuna* from Thailand overlap and consequently, are unreliable.

Past workers in Thailand have primarily used the branching of seta 1-V-VII to differentiate pupae of *aconitus* and *minimus*. This character was found unreliable and should not be used to separate these 2 species. Although *aconitus* normally has multiple branching on these setae, i.e., 1-V (2-7), 1-VI (2-5) and 1-VII (1-4), *minimus* can also have multiple branching on them, i.e., 1-V (1-5), 1-VI (1-3) and 1-VII (1-4). A number of more reliable diagnostic characters were found, with the development and position of seta 0 on the abdominal segments possibly the best (see key and description). The number of branches on seta 1-II (*aconitus* 8-21, *minimus* 17-44), 3-II (*aconitus* 1-4, *minimus* 5-10) and 3-III (*aconitus* 1-4, *minimus* 5-11) are also good characters. Seta 9-III on *aconitus* is usually pigmented, short and stout, but unpigmented, long and needle-like on *minimus*. Reid (1968) noted that seta 9 (lateral spine) was usually shorter on *aconitus*. Measurements during this study show that *aconitus* has 9-IV, 0.19-0.37 the length of segment V, and 9-VII, 0.38-0.47 the length of segment VII, whereas these measurements for *minimus* are 9-IV, 0.35-0.44 of segment V, and 9-VII, 0.50-0.59 of segment VII. Two significant paddle characters include: (1) lateral paddle fringe on *aconitus* with short spines gradually changing to relatively short filaments, while on *minimus* the short spines usually change more abruptly into longer filaments; and (2) another character detected by Reid (1968) - seta 1-P length (unstraightened) shorter in relation to paddle length. Data from this study confirm this character, with 1-P on *aconitus* shorter (range 0.20-0.33, mean 0.26) than that on *minimus* (range 0.27-0.51, mean 0.39). The paddle refractile margin is slightly longer on *aconitus* (0.74-0.90), but that of *minimus* (0.63-0.85) broadly overlaps that of *aconitus*.

Actually it is more difficult to separate the pupa of *aconitus* from those of *pampanai* and *varuna*. In general, *aconitus* pupae have fewer setal branches than pupae of these 2 species. Besides the key characters, *aconitus* differs from *pampanai* by: (1) seta 10-MP (*aconitus* simple or bifid, *pampanai* 2-5 branches); (2) sum of branches on both setae 6-IV (*aconitus* 5-9, *pampanai* 10-15); (3) paddle refractile margin (*aconitus* 0.74-0.90, *pampanai* 0.66-0.76); and (4) paddle lateral spines (in *aconitus* a gradual change from short spines to short filaments, in *pampanai* an abrupt change from short spines to long filaments). In addition to the key characters, pupae of *aconitus* differ from those of *varuna* by: (1) sum of branches on both setae 6-IV (*aconitus* 5-9, *varuna* 8-13); (2) paddle refractile margin (*aconitus* 0.74-0.90, *varuna* 0.89-0.96); and (3) paddle lateral spines (*aconitus* 4.0-8.0 length of spine base width and extending 0.60-0.75 of distance from paddle base to seta 1-P, *varuna* (2.0-5.0 length of spine base width and extending 0.77-0.88 of distance from paddle base to seta 1-P).

Pupae of *aconitus* are easily separated from those of *culicifacies* and *jeyporiensis* by the key characters and branching of setae 4-I, 9-I (length also) and 1-III-IV. In addition, the paddle fringe will also separate these 3 species: *aconitus* with short sparse fringe mesad of seta 1-P, but not to mesal angle, *culicifacies* fringe not extending mesad of 1-P and *jeyporiensis* with dark distinct fringe mesal to 1-P extending to mesal angle.

The larva of *aconitus* may be the stage most differentiated from the other members of the Minimus Group. The combination of large anterior tergal plates, barbed setae 2, 3-C and 4-C with branches is very distinctive. Even if the anterior tergal plates were much smaller than normal, *aconitus* could

still be separated from *jeyporiensis* by the number of barbs on 2,3-C and by a simple 1-X on *aconitus*, while that of *jeyporiensis* is normally bi- or trifid distally. The convex posterior margin of anterior tergal plate II was found constant during this study, and that plate invariably enclosed the small median posterior tergal plate. This particular trait also seems to be constant on *filipinae* and *varuna*. Seta 0 on *aconitus* occupies an intermediate position between those species in the Minimus Group with this seta on the anterior tergal plate (*filipinae*, *mangyanus*, *pampanai* and *varuna*) and those with 0 off the plate (*flavirostris*, *fluviatilis* and *minimus*). On *aconitus*, 0 is usually adjacent to the edge and either barely on or barely off the plate, however, exceptions to this were discussed in the Variations section. Seta 1-I leaflets on *aconitus* are lanceolate without shoulders or with small shoulders, usually a mixture of both. This variable trait is also found on *culicifacies*, *filipinae*, *jeyporiensis* and *mangyanus*, while *flavirostris*, *fluviatilis*, *minimus*, *pampanai* and *varuna* have 1-I leaflets with distinct shoulders.

Additional characters, besides those discussed above and in the key, are available for distinguishing the larva of *aconitus* from those of the other members of the Myzomyia Series in Thailand. Like the pupal stage, larvae of *aconitus* generally have fewer setal branches than the other members of the Minimus Group. Additional characters to separate larvae of *aconitus* from *minimus* include: the number of branches on setae 8-C, 2-P, 9-P, 2-I, 5-IV-VI, 1,2-S (see chaetotaxy tables); and the development of the most basal branches on 2-X (see descriptions). Other characters to separate larval *aconitus* from *pampanai* include: the number of branches on 2-P, 8-P, 1-M and 8-M; anterior tergal plate II convex on *aconitus*, concave with separate posterior tergal plate on *pampanai;* 1-X length/saddle dorsum (midline) length, 1.44-1.81 on *aconitus* and 1.85-2.05 on *pampanai;* and development of 2-X basal branches, stout and straight on *aconitus* and slender and curved on *pampanai*. Additional characters to separate *aconitus* larvae from those of *varuna* include: the number of branches on 2-P, 8-P, 7-I-II, 13-III, 2-VIII and 2-S; and 1-X length/saddle dorsum (midline) length, 1.44-1.81 on *aconitus* and 1.85-2.16 on *varuna*.

The distinctiveness of *aconitus* in most stages suggests this species represents one extreme of the differentiation that has occurred in the Minimus Group. An analysis of 18 characters used during this study suggests *filipinae* is the most closely related species to *aconitus*, followed by *varuna*, *flavirostris*, *minimus* and *fluviatilis* in that order, with *mangyanus* and *pampanai* showing the fewest similarities.

BIONOMICS. *Anopheles aconitus* is a species that has adjusted very well to man's environmental alterations. Accordingly, the widespread distribution and general abundance of *aconitus* is probably due primarily to the spread of the human-rice monoculture system in the Orient. Originally *aconitus* immatures probably occurred primarily in grassy marshes with slow clear running water and along open streams and rivers with grassy margins. Man has greatly expanded these habitats by cutting forests and exposing streams, ditching for irrigation and by creating artificial grassy marshes in the form of rice fields. This species is now a definite associate of man in much of Asia on broad fertile plains, broad valleys, lumbered forest areas and even sparsely settled mountainous areas where rice fields occur. In Thailand, *aconitus* has been collected at elevations of 1-700 m and Mangkoewinoto (1919) recorded it (as *albirostris*) up to 853 m in Java. This species has not been reported from brackish water, but collections were made during this study along stream margins in Chiang Mai Province below hot springs which gave off a moderate sul-

phurous odor. The mineral-salt content of this water was not checked. Immatures of *aconitus* have been collected in the following habitats in Thailand: stream margins (major source), rock pools, nipa palm swamp, large pit, stream pools, large fresh water swamp, seepage pools or springs, small ditches, bog marsh, river margins, ground pools and stream margin below hot springs, rice fields (major source), fallow rice fields, pools in dry rice fields and from a stream 15 m inside a cave in almost total darkness. This variety of habitats closely matches those recorded by Gater and Rajamoney (1929) for this species in Malaysia. These authors also collected the species from an artificial container, a metal tub at a mining operation. Small sluggish streams with weedy-grassy margins constitute a very important habitat for *aconitus* in Thailand. Larvae of *aconitus* and *minimus* are commonly found together in this habitat in certain regions. However, in other areas where *minimus* populations are low or have disappeared, *aconitus* may be the only member of the Myzomyia Series present. This is especially true in southern Thailand, where *minimus* is now either uncommon or has been eliminated.

Based on larval distribution and abundance, females are apparently attracted to oviposit in more open, less shaded habitats than *minimus*. However, aquatic vegetation of some type, preferably emergent and grassy, partial shade, cool water and usually a slow current all seem to be important. Larvae were found in habitats with all types of vegetation, floating, submerged, emergent, dead leaves and sticks, green and brown algae. The largest numbers of larvae appear in the rice fields just prior to the harvest period in both Malaysia (Gater and Rajamoney 1929) and Java (Chow et al. 1960). This matches data accrued here, as *aconitus* is most abundant between October and February in the central rice plains area of Thailand. The wet monsoon usually ends in late November-early December in this region, and the rice harvest begins and continues into January. This species was least abundant in this region during April-July, coinciding with the last part of the hot-dry monsoon and the early part of the wet monsoon. Actually, *aconitus* adults were collected every month of the year in this region.

Adult female *aconitus* can be collected by various methods, including human bait, bovine bait, window traps (Chow et al. 1960), net traps with animal or human bait (Reid 1968), net traps with CO_2 (dry ice), light traps (Causey 1937, Thurman and Thurman 1955), light trap and CO_2 (Parsons et al. 1974) and nocturnal or diurnal (Wharton 1950) resting collections. The New Jersey light trap was very successful in collecting *aconitus* in the Chiang Mai area, where it constituted 13% (685/5,273) of a year's anopheline catch (Thurman and Thurman 1955). However, during this study live adults were needed for colonization, crossing and progeny rearing attempts, so only human and bovine bait, resting and net trap with CO_2 collections were used.

Previous studies have shown that *aconitus* is primarily zoophilic, exophilic and exophagic in Java (Chow et al. 1960) and Malaysia (Wharton 1953, Reid 1968). Data from Pathum Thani Province show that during November 1966 and January-March 1967 when *aconitus* females were offered a choice between human baits inside or outside houses, they selected the outside bait at a 8.34:1 ratio (1409:169) (Gould and Rutledge 1967). Additional data from nearly the same area in 1968-70, based on 500.7 man-hours of collecting and 1,262 specimens, yielded 2.72 *aconitus*/man-hr on human bait outside, 0.63/man-hr on human bait inside and 0.73/man-hr resting inside (at night). Excluding the resting data, this results in a choice of the outside bait at a 4.32:1 ratio. As expected, collections from bovine baits were found much more efficient for collecting *aconitus* than those from human baits. A total of 1,847 *aconitus*

were collected from bovines at the rate of 4.49/man-hr, while human bait attracted 1,802 at the rate of 0.92/man-hr. This means 4.88 *aconitus* were collected on bovines for each specimen taken on human bait. Comparative studies of the efficiency of bovine and human baits for *aconitus* were conducted at 2 localities in Sara Buri Province using the same times, places and weather, but often with different numbers of collectors (Table 2). Based on mosquitoes/man-hr, *aconitus* was most commonly collected from bovines at an 8.1:1 bovine:human ratio. The majority of *aconitus* adults were collected between 1900-2200 h. Very few collections were made beyond 2400 h, thus no comparison can be made with Chow et al. (1960) who found most of the feeding on man outdoors took place before 2400 h, while on cattle in sheds, between 2400-0600 h.

Evidence of the life span of feral *aconitus* in Thailand is inconclusive. Limited parity dissections were conducted in 2 areas in 1968-69. In Pathum Thani Province, where *aconitus* was incriminated (by dissection) as a vector of malaria parasites (Gould et al. 1967), only 0.211 (12/57) females were parous. However, a population sampled in Buriram Province, in March 1969 exhibited a relatively high parity rate, 0.657 (44/67). Of the 44 parous females in Buriram, 32 were gravid. Both the Pathum Thani and Buriram populations were exposed to a DDT house-spray program.

A check of 55 nulliparous females to see if the spermatheca contained sperm revealed 0.95 (52/55) fertilized. Thereafter wild females were presumed to be fertilized when brought into the laboratory for oviposition attempts.

Anopheles aconitus is susceptible to DDT and dieldrin except in Java and eastern Sumatra where it is considered the primary vector of human malaria parasites. Resistance to dieldrin in *aconitus* was first detected in Java in 1959-60, followed by resistance to DDT in 1962-63 (Soerono et al. 1965). Dieldrin resistance was detected in widely separated areas across Java and the eastern tip of Sumatra, while DDT resistance was confined to the central portion of Java. Central Javan populations were resistant to both insecticides. The records of dieldrin resistance included one area of eastern Java where agricultural use of insecticides apparently caused resistance (Soerono et al. 1965). In more recent reports, Brown and Pal (1971) have essentially repeated the report of Soerono et al. (1965). Harinasuta et al. (1976) indicated the DDT resistance is spreading into eastern Java.

Anopheles aconitus apparently has not been tested for insecticide (DDT) resistance in Thailand, where it is considered a vector in the central rice plains area.

Colonization of *aconitus* was attempted and a low level colony was established and maintained between 1968-70 using forced mating (Ow Yang et al. 1963). Rearing techniques differed only slightly from those described by Wilkinson et al. (1974). This colony was used primarily to produce adults for hybridization studies. Limited data from this project show that the oviposition frequency from artificially inseminated females was only 0.20, and the hatch frequency for eggs was 0.48. These figures are not too different from data obtained from the wild females isolated for progeny studies. Of 1,799 wild females allowed to blood-feed and isolated in oviposition vials only 0.14 (258) oviposited, producing 18,185 eggs for a mean of 70.48 eggs/female. The hatch frequency for the eggs was 0.68 (12,278). The time involved in egg hatch averaged 2.83 days for 760 eggs kept inside at ± 25° C.

Only a few instances of parasitism of *aconitus* have been recorded. Iyengar (1935, 1962) discovered the fungus, *Coelomomyces indicus* Iyengar, in larvae of several species including *aconitus*, in Bengal, India. A single

TABLE 2. Comparative efficiency of bovine and human bait for *An. aconitus* and *minimus* using paired* collections at 2 localities in Sara Buri Province.

I *aconitus* Locality	No. of paired collections	Bovine		Human		Ratio Bovine: human
		Specimens/ man-hr	*aconitus*/ man-hr	Specimens/ man-hr	*aconitus*/ man-hr	
Ban Nam Tone 10	43	1,453/260	5.59	254/325	0.78	7.2:1
Pukae	12	208/54	3.85	9/77	0.12	32.1:1
Totals	55	1,661/314	5.29	263/402	0.65	8.1:1
II *minimus* Locality	No. of paired collections	Bovine		Human		Ratio Bovine: human
		Specimens/ man-hr	*minimus*/ man-hr	Specimens/ man-hr	*minimus*/ man-hr	
Ban Nam Tone 10	43	1,875/260	7.21	348/325	1.07	6.7:1
Pukae	12	156/54	2.89	29/77	0.38	7.6:1
Totals	55	2,031/314	6.49	377/402	0.94	6.9:1

*Time, place and weather equal, but number of collections may differ.

aconitus larva from Ayutthaya Province was found infected with *C. indicus* during this study. This identification was confirmed by Dr. J. N. Couch, University of North Carolina, Chapel Hill. Jones (1950) found a very heavy infection of trematode mesocercariae in the thorax of 68% of sampled *aconitus* larvae in Sri Lanka. This parasite was named *Cercaria anophelini* Jones, and the mosquito larvae were presumed to be a 2nd intermediate host for the adult trematode. A number of larval hydrachnids were found attached to the intersegmental areas on adult *aconitus*, but no attempt was made to identify them. Ratanaworabhan (1975) recorded *Culicoides (Trithecoides) anophelis* Edwards, on blood engorged *aconitus* females in Chiang Mai Province. This biting-gnat is renowned for obtaining a meal through the abdominal conjunctivae of mosquitoes (Das Gupta 1964).

A complete discussion of crossing experiments between *aconitus* and *minimus* is found in the Hybridization Experiments section.

ANOPHELES (CELLIA) CULICIFACIES GILES

(Figures 2, 4-6, 10-12; Tables 3, 9, 15)

Anopheles culicifacies Giles 1901: 197 (♂, ♀); Liston 1901: 365 (♀*); Giles 1902: 317 (♂*, ♀*); Theobald 1902b: 379 (♀, tax., ♂-type = *turkhudi* Liston); James 1902: 33 (A*, L*, tax., distr., biol.); Christophers 1915: 392 (♂ genitalia*); Barnes 1923a: 122 (distr.); Anigstein 1932: 269 (distr.).

Anopheles listoni Giles 1901: 197 (♂, ♀) [senior primary homonym (Aug.) of *listonii* Liston 1901: 365 (Oct.)]; Giles 1902: 319 (♂*, ♀*); Theobald 1902b: 377 (♂, ♀, = *culicifacies*); James 1902: 33 (as *listonii*, ? = *culicifacies*); Christophers 1916: 457 (tax., = *culicifacies*).

Anopheles indica Theobald 1901: 183 (♀); James 1902: 33 (? = *culicifacies*); Theobald 1902b: 377 (♀, name emend. to *indicus*, = *culicifacies*).

Myzomyia culicifacies Giles, Theobald 1903: 39 (♀, L*, E*, tax.).

Myzomyia culicifacies var. *punjabensis* James 1911a, *in* James and Liston 1911: 72 (A*); Christophers 1916: 463 (= pigment anomaly).

Anopheles culicifacies adenensis Christophers 1924b: 296 (A, as variety); Christophers 1924a: 47 (tax., as var.); Evans 1938: 172 (♂*, ♀*, P, L*, E, tax., distr., as var.); de Meillon 1947: 99 (♂*, ♀*, P*, L*, distr., to species status); Mattingly and Knight 1956: 93 (tax., to subspecies status); Stone, Knight and Starcke 1959: 41 (tax., as ssp.); Gillies and de Meillon 1968: 104 (♂*, ♀*, P, L*, tax., as ssp.); Knight and Stone 1977: 37 (tax., as ssp.). [NEW SYNONYMY].

Anopheles (Myzomyia) culicifacies Giles, Christophers 1924a: 46 (tax.); Sinton and Covell 1927: 305 (cibarium*); Puri 1928b: 522 (L*); Christophers and Barraud 1931: 182 (E*); Puri 1931: 141 (L*); Senevet 1931: 66 JP*); Edwards 1932: 50 (tax.); Christophers 1933: 197 (♂*, ♀*, P, L*, E, tax., distr., biol.); D'Abrera 1944: 352 (E*); Bonne-Wepster and Swellengrebel 1953: 383 (♂*, ♀*, L*, biol.); Khin-Maung-Kyi 1971: 473 (distr., biol.).

Anopheles (Cellia) culicifacies Giles, Stone, Knight and Starcke 1959: 40 (tax.); Peyton and Scanlon 1966: 1 (♀*, key); Scanlon, Peyton and Gould 1968: 20 (checklist); Reid 1968: 311 (distr.); Aslamkhan and Baker 1969: 1 (Karyotype*); Rattanarithikul and Harrison 1973: 2 (L*, key); Knight and Stone 1977: 37 (tax.); Saifuddin, Baker and Sakai 1978: 235 (chromosomes*).

Of the 6 species of the Myzomyia Series that occur in Thailand, this is the easiest to identify. The adults can be identified by palpal banding, the dark remigium - R base and the dark vein R_{4+5}. The adults also have an unusual behavior trait that is useful in identification, i.e., they rest with the body horizontal to the surface like culicine mosquitoes, instead of perpendicular as most other anophelines. The pupa is very distinct for the series and is easily identified by the key characters. The 4th stage larvae are readily identified by the small anterior tergal plates, the median plate of the spiracular apparatus and the setal characters in the key. Additional characters of use are the small submedian plates on the abdominal segments and the simple seta 8-C. This species is like *aconitus* except for:

FEMALE (Figs. 2, 4-6, 10, Table 3). *Head.* Interocular space with 2 long brown setae near top, several long pale setae near bottom, short pale ocular scales laterally, without long pale scales forming frontal tuft; pedicel integument dark gray or brown, with several minute setae in dorsomesal and ventrolateral patches; flagellomere 1 with pale gray scales, remaining flagellomeres without scales; proboscis long with small brown decumbent scales; labellum nearly bare, paler than labium; forefemur/proboscis ratio 0.82-0.87, 0.84 mean (10 females); palpus slender, slightly shorter than proboscis, with decumbent scales; palpus with 3 pale bands, narrow basal band at segmental joint 2,3, narrow median band at segmental joint 3,4, apical band widest, including extreme tip of segment 4 and entire segment 5; palpal preapical dark band wider than either subapical or apical pale bands. *Thorax.* Integument light gray or tan, with darker longitudinal acrostichal line; anterior promontory with long slender erect pale scales, shorter pale scales at apices of dorsocentral setal rows; scutum with short curved seta-like pale scales between dorsocentral setal rows back to prescutellar bare space; fossa without scales; scutal setae long, dark brown, in acrostichal, dorsocentral, lateral prescutal, fossal, antealar and supraalar groups; prescutellar space bare; scutellum with anterior row of short dark setae, posterior row of long dark setae; pleural setae: 1,2 propleural, 0-2 spiracular, 3,4 prealar, 2-5 upper and 2-5 lower sternopleural, 5-15 upper and 0 lower mesepimeral. *Wing.* Color pattern variable (see Variations section), common pattern follows. Costa with humeral, presector, sector, subcostal and preapical pale spots; remigium dark scaled or with patch of pale scales; humeral crossvein bare; vein R with base dark, usually with pale presector spot, with sector pale spot, R_1 dark except variable subcostal, preapical and apical pale spots; R_S - R_{2+3} dark except small pale spots at origin and R_{2+3} fork; R_2 dark except small pale spots at origin and apex, infrequently with small median pale spot; R_3 dark except small pale spot at origin; R_{4+5} base with small pale spot, remainder dark, infrequently with small median pale spot or pale apex; M dark-scaled except small pale spot at m-cu crossvein and M fork; M_{1+2} base with small pale spot, remainder dark, infrequently apex with pale scales; M_{3+4} dark except small pale spot at base and apex; Cu dark except small pale spot midway to fork, base rarely pale; Cu fork dark-scaled; Cu_1 dark except small pale spot at m-cu crossvein and apex; Cu_2 base dark, with pale spot on basal half, apical 0.4-0.5 dark, rarely with pale apex; 1A dark except pale origin and small pale spot just before midpoint; apical pale fringe spot starting just above apex of R_1, length variable, extending to just below R_2, or only to just below R_1; additional pale fringe spots often present at apices of M_{3+4} and Cu_1, less frequently at apices of R_{4+5}, M_{1+2} and Cu_2; hind margin of wing basal to 1A apex without pale fringe spot. *Legs.* Integument pale; upper midcoxa with 2-4 setae; forefemur not swollen on basal half; femora, tibiae and tarsomeres long, slender with brown scales; tibiae apices may appear paler, tarsomeres without pale bands or patches. *Abdomen.*

Unicolorous dark brown or gray with brown setae, without scales.

MALES (Fig. 10). *Head.* Antennal flagellomere 1 with pale gray scales on mesal surface; forefemur/proboscis ratio 0.62-0.75, 0.66 mean (10 males); palpus with narrow pale bands at apex of segments 3-5. *Thorax.* Pleural setae: 2,3 upper and 2,3 lower sternopleural, 4-8 upper mesepimeral; pale seta-like scales on scutum not developed as on female, usually confined to cephalic half of scutum. *Wing.* Veins generally darker than those of female; costa with large humeral pale spot, usually without presector pale spot; 1A often appearing entirely dark; pale fringe spots usually present. *Genitalia.* Basimere often with narrow, brown scales laterally and ventrally on basal 0.33, with 5 parabasal spines; claspette with long apical seta approximately equal length of lateral club, shorter seta between apical seta and club; club (rarely 2 on each side) fused from 2-4 basal stems; aedeagus with 5,6 (rarely 4) or more leaflets on each side of tip; largest 3,4 leaflets with serrate edge on one side; tergum IX lightly sclerotized with rounded lateral lobes, covered with small spicules; proctiger membranous, cone-shaped without spicules, with parallel longitudinal wrinkles.

PUPA (Fig. 11, Table 9). Integument clear to tan, with patches of brown pigment on cephalothorax, metanotal plate and anterior lateral corners of segment 1 on darker specimens; coxa-trochanter cases particularly dark on mesal surfaces. *Cephalothorax.* Wing cases without distinct lines on veins, may have brown longitudinal stripes. *Trumpet.* Usually pale color, often paler than brown areas on cephalothorax on darker specimens, meatus 0.25-0.27 length of trumpet. *Metanotal Plate.* Seta 13-MP usually absent; if present simple or bifid. *Abdomen.* Seta 0-II-VII small, simple or bifid, mesad and usually cephalad of 2-II-VII; 9-IV-VII dark, long, usually cylindrical instead of flattened; 4-I with 2-5 branches; 9-I usually simple, rarely bifid, shorter than segment I; 1-II with 8-13 branches; 2-II with 5-8 branches; 1-III with 5-8 branches; 2-III with 5-9 branches; 4-III with 4-8 branches; 5-III with 6-8 branches; 7-III, 1-5 branches; 9-III small, usually pigmented, slender, 0.13-0.19 length of 9-IV; 1-IV with 3-7 branches; 4-IV with 3-6 branches; 7-IV, 1-4 branches; 9-IV, 0.37-0.54 length of segment V, 0.70-0.93 length of 9-V; 1-V simple; 4-V with 3-5 branches; 9-V, 0.53-0.68 length of segment V, 0.68-0.91 length of 9-VII; 1-VI longer than segment, simple; 2-VI with 3-5 branches; 4-VI, 1-3 branches; 5-VI with 3-5 branches; 7-VI simple, shorter, 0.38-0.71 length of segment VI; 9-VI, 0.85-1.00 length of 9-VII, 0.60-0.69 length of segment VI; 1-VII longer than segment, simple; 2-VII with 3-5 branches; 4-VII simple or bifid; 5-VII with 2-4 branches; 7-VII simple, shorter, 0.51-0.65 length of segment VII; 9-VII, 0.60-0.69 length of segment VII; 9-VIII with 14-19 branches arising from central stem; posterolateral angles of segment IX over paddle base more acute. *Paddle.* Refractile margin long, 0.78-0.96 of distance from base to seta 1-P; paddle 1.38-1.53 as long as wide; lateral fringe changing gradually from long spines to slender filaments at 0.75-0.90 of distance from base to seta 1-P; paddle fringe not extending mesad of seta 1-P; 1-P, 0.22-0.38 length of paddle.

LARVA (Fig. 12, Table 15). Tan to yellow-brown, without discernible color pattern. *Head.* Color as for body, with variable pattern of dark transverse and longitudinal lines on frontoclypeus ranging from anteriorly directed fork to spots to no pattern; antenna white to pale yellow, paler than head, long, slender, usually 6.50-7.67 as long as widest point, with short pale spicules on mesal and ventral surfaces; seta 1-A short, simple, inserted on outer dorsal aspect, 0.35-0.39 from base; 2-C long, simple; 3-C simple,

0.60-0.75 length of 2-C; 4-C simple, near length of 3-C, extending cephalad beyond bases of 2-C; 5-C much longer than 6, 7-C; 8-C simple. *Thorax.* Without small submedian plates on dorsum of thorax; sclerotized bases of setae 1, 2-P separated, infrequently narrowly connected; 1-P with 16-25 branches; 2-P with 9-14 branches; 9-P with 6-13 branches; 10, 12-P very long, simple; 11-P short with 2-5 branches; 13-P with 4-6 thin tapered branches; 1-M with 24-30 branches; 9, 10-M very long, simple; 12-M short, simple or bifid; 3-T with thick long stalk about 0.33 length of seta and 5-10 lanceolate leaflets with sharp filamentous tips; 9-T long, with 4-14 branches; 10-T long, simple. *Abdomen.* Anterior tergal plates on II-VII small, usually no more than 0.25 width of segments; posterior tergal plates present on III-VII, separate from anterior tergal plates; small oval submedian plates present on I-VII; seta 0-II-VIII small, simple or bifid, arising posterolaterad of anterior tergal plate and cephalad of seta 2 (except on VIII); 1-I with narrow lanceolate leaflets with long filamentous tips, leaflets with or without shoulders, or mixed; 1-II leaflets usually with shoulders, occasionally all lanceolate without shoulders; 1-III-VII with unicolorous light brown leaflets, distinct shoulders, long filaments; 1-II with 14-18 leaflets; 1-III with 15-21 leaflets; 6-IV with 3, 4 branches; 13-IV with 3-5 branches; 6-V with 3, 4 branches; 13-V with 3-5 branches; 1-VI with 13-22 leaflets; 1-VII with 12-20 leaflets; 2-VII with 4-8 branches; pecten plate with 3-5 long and 9-13 short teeth; 2-S with 6-9 branches; apex of median plate sharp pointed, but without separate lateral arms; seta 1-X simple, long, 1.30-1.63 dorsal length of saddle; 2-X with 14-19 branches, most basal branches long, with very fine, sinuous tapering tips, distal branches long, with very fine tapering tips, tips minutely hooked under high magnification.

EGG. Following description from Christophers (1933). "Whaleback-shaped. Upper surface about 1/3 width of egg, elongate oval or slightly hourglass-shaped. Ventral surface unornamented. Floats not touching margin of upper surface, occupying a little less than the middle 2/3 of the egg-length, and extending to about an equal distance from the two ends of the egg. Float-ridges about 15-18, moderately smooth and regular, and not crested as in *A. fluviatilis;* float-terminations rather large, rounded, somewhat flattened. Frill moderately broad, extending all round margin of upper surface, and striated throughout." D'Abrera (1944) described several variations from the above description. Other publications dealing with *culicifacies* eggs include Christophers and Barraud (1931) and Sweet and Rao (1938).

TYPE-DATA. The syntypes (1♂ and 1♀) of *culicifacies* are deposited in the BMNH. Theobald (1902b) pointed out that the ♂ syntype was actually *turkhudi* Liston, instead of *culicifacies*. Subsequent authors have agreed with this identification, and I confirmed it by examining the ♂ syntype in 1972. Accordingly, to avoid possible confusion in the future, I here designate the ♀ syntype as the lectotype for *culicifacies*. The lectotype has the following label data: (1st label - underside of cardboard minuten stage) - "Hoshangabad, D---- b----- [illegible], Feb. 21, 1901;" (2nd label) - "India, Col. Giles;" and (3rd label) - "*Anopheles culicifacies* (Type) Giles." The lectotype is in fair condition, with the left wing, both hindlegs and the right foreleg missing. Some characters worthy of mention are: palpus with wide preapical dark band; scutum with narrow pale scales back to prescutellar area; pleural setae: - 1 propleural, 1, 2 spiracular, 3, 4 upper and 2-4 lower sternopleural, 7, 8 upper and 0 lower mesepimeral, 4 prealars; coxae without scales, with 2, 3 upper midcoxal setae; right wing-costa with humeral pale spot, without presector pale spot, remigium and R-base dark scaled, R_{4+5} dark scaled except at base and apex, Cu_1 with one dark mark beyond m-cu crossvein, wing fringe possibly

with faint pale spots adjacent to tips of veins M_{3+4} and Cu_1 (uncertain because fringe is rubbed and has scales missing). There are 2 other specimens (♂ and ♀) from the same locality and date as the lectotype, however, these are not considered syntypes because they are not labeled "India, Col. Giles."

The syntypes of *listoni* are also in the BMNH. Giles (1901) did not mention the number of specimens involved in the description, but both ♂, ♀ parts were described. Two specimens (♂ and ♀) are here considered syntypes, and have identical labels: (1st label) - "Ellichpur, Barars, Jan. 1901, Lt. Glen Liston;" and (2nd label) - "*Anopheles Listoni*, Type, G. M. Giles." The female which is in excellent condition is here designated lectotype. The lectotype is nearly identical to the lectotype of *culicifacies* and only differs in minor points: costa humeral pale spot larger, apical pale fringe spot on left wing extends down to R_2 and wing margin on both wings with pale fringe spot adjacent to tip of Cu_1. An examination of this specimen (♂ also) confirms that *listoni* Giles is an obvious synonym of *culicifacies*.

Theobald (1901) described *indica* based on a single female. This specimen (holotype) is in the BMNH and is in fair-good condition, with the right midleg and 2 hindlegs missing. The holotype has the following label data: (1st label - underside of cardboard minuten stage) - "madras, in house, 9-12-99, GC [illegible, possibly Cornwall's initials];" (2nd label) - "Capt. Cornwall, Madras;" and (3rd label) - "Indica, Type, Theo." This specimen is very similar to the lectotype of *culicifacies* and only differs by having: costa with presector pale spot (both wings) in addition to humeral spot, apical fringe spot on right wing extending down to R_2 and left wing margin without pale fringe spots at M_{3+4} and Cu_1. My examination of this specimen reiterates that *indica* Theobald is an obvious synonym of *culicifacies*.

James (1911a) described var. *punjabensis*, on the basis of the reduced preapical (4th) dark spot on the wing costa. In the original description several specimens were mentioned and one specimen was described as entirely lacking the preapical dark spot. This last specimen, a female, may be the only surviving specimen from the original description and is currently in the BMNH. Possibly other specimens still exist in Indian depositories, thus, the BMNH specimen should retain its syntype status for the time being. This specimen has the following label data: (1st label) - "*culicifacies* variety *punjabensis*;" and (2nd label) - "B. M., 1924·277." The pin also has a BMNH "Type" label on it, but that does not mean it is the holotype, since the early BMNH personnel also put "Type" labels on all syntypes. This specimen is in poor condition, with the head (including palps and proboscis) glued to the cardboard minuten stage, the legs and wing on the left side missing and the remainder glued to the base of the minuten. This specimen is obviously an aberrant *culicifacies*, as pointed out by Christophers (1916 = as pigment anomaly). The wing has the following characters of interest: base of costa with only humeral pale spot, without presector spot; remigium with few pale scales on distal half; base of R dark-scaled; and hind margin of wing without pale fringe spots. The wing is identical to many specimens of *culicifacies* I have seen except for the extensive pale scaling on the distal half of the costa and on R_1.

Christophers (1924b) described variety *adenensis* and supposedly deposited a type ♂, type ♀ and paratypes in the BMNH. However, only 1♂ and 1♀ (both labeled "type") are currently in the BMNH. I am considering these 2 specimens as syntypes and here designate the ♀ as lectotype. The lectotype is in excellent condition and has the following labels: (1st label) - "*A. culicifacies* var. *adenensis* Type ♀ S. R. C. 23.4.24;" (2nd label) - "Daral Amir, Aden

Hinterland, Coll. Khazan Chand, Bred from larvae collected in well 8.7.14;" and (3rd label) - "B. M. 1924.277." This nominal taxon has existed under varying status, having risen from a variety to species and then reduced to subspecies, its most recent status (Knight and Stone 1977). The variety was originally established because the costa had broader pale spots than Indian *culicifacies*, however, variety *punjabensis* has extremely wide pale costal spots and was originally based on more than one specimen. De Meillon (1947) elevated *adenensis* to species status, but specimens with intermediate characters from Socotra (Leeson and Theodor 1948) cast doubt on this action. Mattingly and Knight (1956) reduced *adenensis* to subspecies status on the basis that it was a geographical representative and might overlap with the nominate subspecies in Oman. More recently, Gillies and de Meillon (1968) retained it as a subspecies and noted that a pale fringe spot at the apex of Cu_2, when present, will distinguish adults of subspecies *adenensis* from the nominate subspecies. They also said the larva of *adenensis* was distinct because it had seta 1-I leaflets without shoulders and 1-II leaflets infrequently with shoulders. However, some adults of *culicifacies* from Thailand have fringe spots at Cu_2 and wide pale spots on the costa. Thai larvae do occur with 1-I leaflets with or without shoulders; usually a mixture. Seta 1-II leaflets on Thai larvae nearly always have shoulders. Larval skins from Hodeidah, Yemen (K. L. Knight, collector) had most 1-I leaflets narrow and without shoulders, however, a few leaflets did have small shoulders. I also found one Thai *culicifacies* larva with one of the long mesopleural setae distally split on each side. This character was illustrated by de Meillon (1947) for *adenensis*, but not seen by Mattingly and Knight (1956). The larval head pigmentation patterns that Leeson (1948) used to separate *culicifacies* from *adenensis* in Oman are not valid. Both patterns seen by Leeson plus intermediates and heads without a pigmented pattern are commonly encountered on Thailand larvae. The adults for the Hodeidah, Yemen larval skins were also examined and found to be typical *culicifacies*. Based on an examination of the type-specimens and finding *adenensis*-like characters on some Thailand specimens, *adenensis* is placed in synonymy under *culicifacies*. The specimens of *culicifacies* from the Arabian Peninsula or Eritrea do not exhibit characters consistently distinct from those on more eastern *culicifacies* and thus, should be considered nothing more than variants. Specimens of *culicifacies* living in this region are existing near the edge of this species' distribution, and must exist under very rigid selection pressure in less than optimum conditions.

DISTRIBUTION (Fig. 11). The distribution for *culicifacies* is not typical for Oriental Myzomyia species and is comparable only to that of *fluviatilis*. Apparently *culicifacies* is a temporary pool mosquito, hence its wide distribution from Ethiopia (Eritrea) across the dry Middle East to Vietnam. Even in the more humid eastern end of its range it is found only in those sections of the countries having distinct wet and dry monsoon seasons. A more concise description of the distribution of *culicifacies* follows: AFGHANISTAN; BAHRAIN; BANGLADESH; BURMA; ETHIOPIA (Eritrea); INDIA; IRAN; IRAQ; LAOS; NEPAL; OMAN; PAKISTAN; PEOPLE'S DEMOCRATIC REPUBLIC OF YEMEN (includes Socotra); PEOPLE'S REPUBLIC OF CHINA (Yunnan); SRI LANKA; THAILAND; UNITED ARAB EMIRATES; VIETNAM; and YEMEN ARAB REPUBLIC. This species is ubiquitous in India, but further east it has a more restricted distribution. It has been found only in the northern half of Burma, Thailand, Laos and Vietnam and the southern part of Yunnan Province (P. R. China). In this region it is primarily found in broad mountain valleys where it commonly occurs along the margins of small streams and in pools in dry river

beds during the dry season.

Scanlon, Peyton and Gould (1968) recorded this species from only 6 provinces of Thailand. They omitted records of *culicifacies* from 6 other provinces listed by Anigstein (1932). I concur in this action, as there is obvious confusion in the Anigstein records between his *culicifacies*, *listoni* and *minimus*. Anigstein does not identify the author of his *"listoni"*, which could be *listoni* Giles = *culicifacies*, but more likely applies to *listonii* Liston = *fluviatilis*. If the latter is true, he readily separated the larvae of *fluviatilis* (= *listonii*) from those of *minimus*, although in 1932, differentiating characters were unpublished. Besides, the record of *fluviatilis* in Thailand is currently suspect. It is interesting to note that Anigstein (1932) collected *aconitus* and *culicifacies*, but not *minimus* in Tung Song, Nakhon Si Thammarat, while Payung-Vejjasastra (1935) incriminated *minimus* as the vector of human malaria parasites in Tung Song just 3 years later and did not record *culicifacies*. Personal collecting in the vicinity of Tung Song in 1969 yielded only *aconitus*. Accordingly, I am not accepting the records of *culicifacies* from Nakhon Si Thammarat or Sara Buri (as Tap Quang). No specimens of *culicifacies* from Sara Buri Province were found in the Regional National Malaria Eradication Office in Phra Phutthabat, Sara Buri and repeated collections in the Thap Kwang (= Tap Quang) area during this study yielded only *aconitus* and most commonly *minimus*. Anigstein (1932) did not record *minimus* from this locality, only *listoni* and *culicifacies*, further evidence suggesting an erroneous identification. Several of Anigstein's northern Thailand records were confirmed by D. C. and E. B. Thurman during the 1950's. Fortunately the Thurman material was deposited in the USNM and available for study. Specimens of *culicifacies* were examined from 4 provinces in addition to those recorded by Scanlon, Peyton and Gould (1968). I consider the following province records valid for *culicifacies* in THAILAND; Ayutthaya, Chiang Mai, Chiang Rai, Chon Buri, Kanchanaburi, Lampang, Lamphun, Mae Hong Son, Nan and Tak. Interesting circumstances surround the Ayutthaya record, where larvae were found only in 1963, between teak logs in large rafts on the Chao Phrya River. The logs had floated down (in rafts) from the northwestern provinces and had apparently transported the *culicifacies* from that area. Repeated subsequent collections in that locality and adjacent localities of Ayutthaya failed to find additional specimens of *culicifacies*. The initial record of *culicifacies* from Kanchanaburi came from de Fluiter (1948), who recorded it from the Chungkai prisoner-of-war camp during World War II. This camp site was apparently near the Mae Klong river in a relatively flat valley area. There are no preserved specimens from that period, however, in February 1978, I collected *culicifacies* larvae along the margin of the Mae Klong river, just 12 km west of the town of Kanchanaburi. Numerous specimens (Thurman collection) are in the USNM from adjacent Tak Province. No specimens are apparently available to support the Chon Buri record, hence, that record is accepted here on a questionable basis. The extensive study by Scanlon and Sandhinand (1965) in the Khao Mai Kaeo area of Chon Buri did not record *culicifacies*. The southeastern corner of Thailand adjacent to Chon Buri has a more Malaysian weather pattern with extensive rainfall and tropical wet forests, which apparently is not favorable for *culicifacies*. Of possible significance, *culicifacies* has not been recorded due east of this area in Cambodia (Harrison and Klein 1975), but has been recorded in Vietnam south of the 17th parallel by Stage (1958), Do-Van-Quy and Tran-Van-Mau (1971) and Grothaus et al. (1971). These southern Vietnam records are all associated with mountains which extend into Vietnam from Laos, but do not extend across

Cambodia from Thailand.

The distribution of *culicifacies* in Burma is depicted by Khin-Maung-Kyi (1971). This species has not been recorded from as far south in Burma as in Thailand (Kanchanaburi and Tak provinces).

A total of 940 *culicifacies* specimens were examined during this study (176♂, 245♀, 139 larvae, 132 larval and 248 pupal skins). Specimens examined from Thailand include 149♂, 208♀, 130 larvae, 102 larval and 239 pupal skins. Additional specimens (27♂, 37♀, 13 larvae, 9 larval and 9 pupal skins) were examined from the following countries: BURMA; ETHIOPIA; INDIA (includes the type-specimens of *culicifacies*, *listoni*, *indica* and var. *punjabensis* in the BMNH); IRAN; NEPAL; PAKISTAN; PEOPLE'S DEMOCRATIC REPUBLIC OF YEMEN (includes the type-specimens of variety *adenensis* in the BMNH); SRI LANKA; YEMEN ARAB REPUBLIC.

VARIATIONS (Fig. 2; Tables 3, 9, 15). Adult females of *culicifacies* were found to be considerably more variable than previously suspected. Based on earlier publications (Christophers 1933, Peyton and Scanlon 1966), the wing of this species has typically been illustrated with the costa having a large humeral pale spot, but without a presector pale spot and the hind margin of the wing with pale fringe spots only at M_{3+4} and Cu_1. As can be seen in Table 3, wings of the Thailand specimens often did not agree with that pattern. Thai specimens usually had humeral and presector pale spots on the costa and only Cu_1 usually had a pale fringe spot, while pale fringe spots infrequently occurred at the apices of other veins. Specimens without pale fringe spots on the hind margin of the wing were not uncommon. As discussed previously (Type-data), a pale fringe spot at Cu_2 was considered diagnostic for subspecies *adenensis* by Gillies and de Meillon (1968), however, over 7% of the Thai specimens had this spot. Several specimens had pale fringe spots at M_{1+2}, M_{3+4}, Cu_1 and Cu_2 which made them appear very similar to *sergentii* (p. 62). However, the latter species does not have the remigium - R base with black scales, as does *culicifacies*. While the remigium was nearly always entirely dark-scaled on Thai specimens, a patch of pale scales on the median or distal portions of the remigium was more common on specimens from Iran and the Yemen Arab Republic. The western specimens usually had more conspicuous pale scales on the scutum, however, individuals were seen fromThailand that compared with the Yemeni and Iranian specimens. The number of upper mesepimeral setae was also found highly variable, ranging from 5-15. One specimen from Yemen Arab Republic had 15 of these setae, but since several specimens from Thailand had 12, 13, this was not considered significant. Over 95% of the Thai specimens had R_{4+5} black except at the base, which confirms the value previously assigned this character by Peyton and Scanlon (1966). The palpal banding pattern for *culicifacies* was very stable in comparison to the other members of the series. All specimens also exhibited black scales at the base of vein R. All Thai specimens had the base of Cu dark-scaled, but 4/11 Iranian specimens had a small pale spot at Cu base. Wattal et al. (1960) recorded several specimens from India without pale spots on the costa basal to the sector pale spot. This variation was not seen on Thai specimens.

Several unusual characters were also observed including: costa entirely pale basal to presector pale spot - 0.005 (1/198); R with accessory pale spot between the sector and subcostal pale spots - 0.005 (1/198); and short palpi - 0.005 (1/198). This last trait may be heritable, as discussed under *aconitus*.

Variations were less common on males than females. Generally the wing veins on males were darker; i.e., with pale spots smaller or absent. The base of the costa usually had a humeral pale spot, but no presector pale spot.

TABLE 3. Frequency *(f)* of selected characters on feral females of 3 geographic populations of *An. culicifacies*.

Characters*	Iran (11)**		India-Pakistan (14)		Thailand (198)		Range between populations (percent)
	f	(No.)	*f*	(No.)	*f*	(No.)	
Remigium with pale scales	0.364	(4)	0.0	(6)	0.030	(6)	0-36.4
Costa without humeral pale spot	0.0	(0)	0.071	(1)	0.0	(0)	0- 7.1
Costa with presector pale spot	0.182	(2)	0.286	(4)	0.525	(104)	18.2-52.5
Costa with prehumeral pale spot	0.364	(4)	0.0	(0)	0.061	(12)	0-36.4
Costa without humeral dark spot	0.0	(0)	0.0	(0)	0.116	(23)	0-11.6
R base without pale spot	0.0	(0)	0.071	(1)	0.010	(2)	0- 7.1
R_2 with median pale spot	0.091	(1)	0.0	(0)	0.056	(11)	0- 9.1
R_{4+5} with median pale spot	0.091	(1)	0.0	(0)	0.045	(9)	0- 9.1
M_{1+2} with pale fringe spot	0.0	(1)	0.0	(0)	0.025	(5)	0- 2.5
M_{3+4} with pale fringe spot	0.091	(1)	0.071	(1)	0.318	(63)	7.1-31.8
Cu stem dark scaled to fork	0.0	(0)	0.0	(0)	0.061	(12)	0- 6.1
Cu_1 with pale fringe spot	0.818	(9)	0.429	(6)	0.662	(131)	42.9-81.8
Cu_2 with pale fringe spot	0.091	(1)	0.0	(0)	0.076	(15)	0- 9.1

*Character on at least one wing.
**Total number of specimens examined.

Pale fringe spots on the hind margin of the wing were usually absent, or very faint. Vein 1A was often entirely dark-scaled and Cu was frequently dark, to include the fork. Christophers (1933) described the male without scales on the basimere, however, some males had long narrow light brown scales in ventrolateral aspect.

The majority of pupal variations concerned setal branching (see Table 9). Seta 9-IV, although varying in length (0.70-0.83) in comparison to 9-V, was always slender and sharp-pointed like 9-V. This character is very important for keying *culicifacies* pupae to the Myzomyia Series. The paddle fringe invariably ended just laterad of seta 1-P, making *culicifacies* the only other Myzomyia species besides *pampanai* in the Oriental region that does not have a paddle fringe mesad of 1-P. Seta 1-V-VII was nearly always long and simple, rarely bifid.

Most larval variations involved setal branching (see Table 15). As noted in the description, the head pigmentation was variable, however, most specimens had no dark pigmentation on the head or only small spots behind the frontal setae (5-7-C). Occasional specimens had darker, more extensive patterns to include the open anteriorly directed "tuning fork" design illustrated by Gillies and de Meillon (1968) for subspecies *adenensis*. The apex of the median plate on the spiracular apparatus was checked on a large number of specimens, and none of the plates had lateral arms as seen on Minimus Group species. Seta 13-P was noted to have more slender branches on *culicifacies* than on *jeyporiensis* and the Minimus Group species. Occasional specimens were found with stouter branches but usually this seta has a distinctive shape on *culicifacies*. The small dorsal submedian plates on the abdominal segments of *culicifacies* were often only faintly pigmented and very difficult to find. These small paired plates are highly characteristic for the Oriental Myzomyia Series and are particularly useful in identifying *culicifacies* and *jeyporiensis*.

Russell and Rao (1942b) examined *culicifacies* from a non-malarious area and a malarious area in India to determine if morphological, biological or epidemiological differences existed between the *culicifacies* in those areas. Their study did not detect such differences and they concluded that differences in the *culicifacies* population densities in the 2 areas were primarily responsible for the differences in malaria transmission rates. In the wild-caught or reared specimens examined during this study, I found no evidence indicative of more than one species. Some east-west clinal trends in wing scale patterns and scutal scale density may exist in *culicifacies*; but, because of the few specimens examined here, they were not obvious and deserve further study. Accordingly, I am considering *culicifacies* a species that exhibits a considerable number of continuous variations in the wing characters. No evidence was found for discontinuous (polymorphic) variation.

TAXONOMIC DISCUSSION. Adults of *culicifacies* are probably the most easily identified members of the Myzomyia Series in Thailand. This species not only has a unique culicine-like resting posture, but also has an easily recognized combination of characters: (1) palpus with very wide preapical dark band and short apical and preapical white bands; (2) remigium - R base with black scales; (3) R_{4+5} usually black except at base; (4) tarsomeres entirely dark; and (5) hind margin of wing rarely with more than 2 pale fringe spots. These characters combined with a fragile, yellow-brown culicine-like appearance make *culicifacies* very distinct in Thailand.

The pupal stage of *culicifacies*, although easily separated from other members of the Myzomyia Series, may be easily confused with pupae of species in the Neocellia and/or Pyretophorus Series. The pupa of *culicifacies* has seta

1-V-VII long and simple, generally few branches on most setae and lacks a fringe on the paddle mesad of 1-P, all characters that generally describe most pupae in the series Neocellia and Pyretophorus. However, as noted in the key, pupae of *culicifacies* can be separated from these by the length and branching of seta 9-I, number of branches on 1-II and the length and shape of 9-IV in comparison with 9-V. This last character is usually easily seen and is often sufficient for placing *culicifacies* pupae in the proper series.

The larva of *culicifacies*, because of its simple setae 2-4, 8-C and small anterior tergal plates on the abdominal segments, can be confused with larvae of species in the Pyretophorus Series. Both characters used in the key (9-M and submedian plates on abdomen) are almost impossible to see on living specimens, and are difficult to use even with properly mounted specimens. The median plate of the spiracular apparatus on *culicifacies* is unusual in that it lacks lateral arms. The only other Oriental Myzomyia species with a similar median plate is *majidi* which was illustrated by Puri (1931). The median plate of *culicifacies* was apparently first illustrated by Carter (1925). The shape of 3-T and its leaflets on *culicifacies* are also unusual. This seta usually has a very short stem and has widely spread leaflets on most other species in the Myzomyia Series.

Anopheles culicifacies is apparently not very closely related to any other member of the Oriental segment of the Myzomyia Series. A study of adult, pupal and larval characters suggests that its closest affinities are with *dthali* and *sergentii*, 2 Palearctic - North African - Mediterranean representatives of the Myzomyia Series that extend eastward to Pakistan. These affinities suggest *culicifacies* is not native to Southeast Asia and probably originated in the Pakistan-Western India region. The reason it is so successful in the tropical regions of India, but not in countries east of India is not understood.

BIONOMICS. *Anopheles culicifacies* is uncommon or absent in most areas of Thailand, consequently only limited biological data are available for this species in Thailand. In India and Sri Lanka, however, *culicifacies* has been considered the primary vector of human malaria parasites for years, and many biological studies have been published. Consequently, most of the biological information presented here is based on work done in India. There are at least 3 references (Covell 1944, Muirhead-Thomson 1951, Bhatia and Krishnan 1961) which extensively cover the bionomics of *culicifacies*, particularly the last reference.

This species is usually considered a plains or river valley mosquito, however, it has been collected at elevations up to 2,286 m in Pakistan and has been found a vector of malaria parasites between 1,524-1,829 m in Pakistan (Bhatia and Krishnan 1961). Stage (1958) reported *culicifacies* in Vietnam only in the highlands at elevations over 914 m. In Thailand this species has been collected at less than 10 m elevation (Ayutthaya), but these larvae were apparently transported from higher elevations (see p. 58). All other collections in Thailand were made between 35-960 m elevation.

The primary larval habitats for this species in India are fresh water irrigation channels, rain pools, pools in river beds, freshly dug pits or holes in the ground and wells. In southern India, Russell and Rao (1940) found *culicifacies* larvae the most commonly encountered species in a wide variety of natural habitats. They found *culicifacies* uncommon in rice fields and then only in old fallow fields or very new rice fields. The absence of larvae in mature rice fields was apparently due to adult oviposition behavior. Gravid females apparently require a clear area without vertical obstructions to perform a "hovering" dance 1-2 cm above the water, dropping eggs singly

onto the water while on the wing after sunset (Russell and Rao 1942a). Singh (1974) classified *culicifacies* as a monsoon species because of its prevalence during the wet monsoon season, however, areas of heavy rainfall are not as favorable as areas with moderate or even scarce rainfall (Bhatia and Krishnan 1961). Larvae of *culicifacies* have been collected in Thailand from: stream margins (usually small streams), pools in sand bars or sandy banks, stream pools (usually small), small rice fields (new), road ruts in a marsh and footprints, with 90% coming from the first 3 habitats. Many of the collection sites were associated with irrigation ditches or streams in cultivated fields (e.g., tobacco, rice) and in or very near villages. The water in the habitats was always temporary, fresh, clear, stagnant or with a slow current and with partial or no shade. The habitats contained all types of vegetation, such as submerged, emergent, floating, also dead leaves and often had abundant green algae. There were several collections from small stream margins in secondary deciduous forests, however, these were all within 500 m of cultivated lands and houses.

One interesting behavioral observation made on *culicifacies* larvae in Thailand concerns their long periods of submergence when disturbed from the surface. Whereas most other anophelines in a pool, e.g., *vagus* Dönitz, return to the surface very shortly after being disturbed, *culicifacies* larvae remained immobile on the bottom for up to 3-5 minutes. This behavior pattern makes *culicifacies* larvae more difficult to collect and would definitely bias abundance indices. *Anopheles jeyporiensis* larvae also exhibit a lengthy submergence behavior. Larvae of *culicifacies* in comparison to *minimus*, are apparently well adapted for existing in open sunlit pools. Muirhead-Thomson (1940c) found that while 4th-stage *minimus* larvae had a thermal death point of 41° C, i.e., killed by a 5 minute exposure to 41°C, larvae of *culicifacies* had a thermal death point of 44°C. His studies showed that a shallow still-water ricefield in Assam had a surface temperature that repeatedly reached or exceeded 41°C during the hot season, but did not reach 44°C.

Most collections of *culicifacies* in Thailand have been larval; however, the few adult collections indicate that New Jersey light traps and bovine bait collections are more productive than human bait collections. Resting collections were relatively unproductive.

The swarming and mating behavior of *culicifacies* has been studied at least twice (Russell and Rao 1942a, Reisen and Aslamkhan 1976). These studies revealed that: (1) swarming occurs in the evening over dry land during the crepuscular period; (2) swarms are composed primarily of males; (3) the swarms were very compact; (4) females fly into the swarm where mating occurs; (5) copulation lasts up to 31 seconds and was completed in flight; and (6) most mating females had taken a partial blood meal before entering the swarm. Bhatia and Krishnan (1961) reviewed previous studies that suggest many *culicifacies* females require more than one blood meal for oviposition. Reisen and Aslamkhan (1976) found that a given female may take as many as 3 blood meals between emergence and the first oviposition. This behavior enhances the chances of *culicifacies* ingesting human parasites. However, Büttiker (1958a) presented evidence that in some specimens of *culicifacies* multiple feedings may also be involved in a period of quiescence, instead of ovariole development. These mosquitoes were thought to pass the dry season in a state of "semihibernation" or "partial quiescence."

Although there is an abundance of literature regarding indoor-outdoor resting behavior by *culicifacies*, there is practically no literature regarding indoor-outdoor biting behavior of this species. Apparently *culicifacies* is

primarily endophagic, based on the high densities of resting engorged adults found inside human and bovine shelters. Summarized records from the pre-DDT era in India (Bhatia and Krishnan 1961) indicate *culicifacies* readily fed on man in the absence of bovines, but was primarily zoophilic. Precipitin tests of engorged females from a pre-DDT treated area and a post-DDT treated area showed a total lack of human feeding in the latter area (Bruce-Chwatt et al. 1966). Earlier tests (Bhatia and Krishnan 1961) revealed that *culicifacies* was very likely to feed in one shelter, then fly to another to rest. This behavior resulted in significant proportions of females collected in cattle shelters being positive for human blood. Russell and Rao (1942b) determined that when dealing with a species that is primarily zoophilic like *culicifacies* there must be a critical density reached before transmission of human malaria parasites will occur. This helped explain why certain areas with *culicifacies* were not malarious.

A few earlier Indian workers also found some *culicifacies* adults resting outdoors during the day in such places as caves, concrete cisterns and in thatching on cattle sheds. Rajendram et al. (1950) found larvae and adults of this species in jungle areas of Ceylon that were as far as 8-10 km away from the nearest human habitation. Since *culicifacies* is known to have a flight range of about 1 km to nearly 3 km (Bhatia and Krishnan 1961), these specimens must be considered representative of true sylvatic populations. Büttiker (1958b) found substantial numbers of male and female *culicifacies* in Ceylon resting during the daytime in tree holes, termite mounds and among overhanging tree roots on river banks.

During the late 1950's-early 1960's, after nearly 10 years of the malaria house-spray program, *culicifacies* was found resistant to both dieldrin and DDT in western India (Pal 1964). After resistance developed, the density of *culicifacies* in western India slowly returned to the high pre-spray levels, but without a return of human malaria. This situation led several investigators to wonder if behavioral changes were involved. Shalaby (1965) discovered that DDT-resistant *culicifacies* from Gujarat State were short-lived when compared to susceptible specimens. Garrett-Jones (1964) and Shalaby (1969) determined that contact between this species and man had essentially ceased as evidence indicated the resistant strain was nearly entirely zoophilic. Brown and Pal (1971) pointed out that *culicifacies* is irritated more by DDT than most other anophelines and obviously avoids or spends less time in sprayed huts. Clarke et al. (1974) reported DDT resistant *culicifacies* in Sri Lanka and listed the other areas where DDT resistance occurs: Afghanistan, Burma, India (Bihar, Bujarat, Madhya Pradesh, Maharashtra, Mysore, Rajasthan and Uttar Pradesh), Nepal and Pakistan. Bruce-Chwatt (1970) reported that DDT resistance was detected in *culicifacies* in northern Thailand. This report has been confirmed by personal communication with representatives of the Thailand National Malaria Eradication Project.

Russell and Rao (1942a) had limited success in colonizing *culicifacies* in a large outdoor cage. More recently Ainsley (1976) colonized this species in 30 cm and 60 cm square cages. Precise temperature, humidity and light conditions were very critical for the success of these indoor colonies. Although natural mating maintained the colonies, Ainsley detected some changes in the mating behavior of both sexes.

Saifuddin et al. (1978) described and illustrated the polytene chromosomes of colonized *culicifacies* from female ovarian nurse cells. The chromosomes of *culicifacies* are specifically distinct, yet still similar to the chromosomes of other members of the subgenus *Cellia* that have been described. No natur-

ally occurring aberrations were found on the chromosomes of their laboratory strain.

A few parasites other than *Plasmodium* have also been recorded from *culicifacies*. Sinton (1917) found 9 of 40 larvae in India with trematode metacercariae encysted in the abdomen and thorax. This parasite was named *Agamodistomum sintoni* by van Thiel (1922). Sinton (1932) summarized the helminthic infections found in Indian mosquitoes up to that time, and added new records which included: larval nematodes (*Mermis* sp.) found entangled in the malpighian tubules of a female *culicifacies;* and a female *culicifacies* with about 60 encysted metacercariae of a trematode he considered equal to *Agamodistomum sintoni*. Jones (1950) found 40% of hundreds of *culicifacies* larvae in Ceylon infected with the cercarial (probably mesocercariae) stage of a trematode which he named *Cercaria anophelini*. Jones concluded the mosquito probably served as a 2nd intermediate host for this parasite. Bhatia and Krishnan (1961) summarized parasitic infections reported from *culicifacies*, and these included reports of a trypanosome infection in adult salivary glands, nematodes in adults and larvae and a fungal (Chytridinae) infection.

ANOPHELES (CELLIA) JEYPORIENSIS JAMES

(Figures 2, 4-6, 13-15; Tables 4, 10, 16)

Anopheles jeyporiensis James 1902: 32 (A*, L*); Christophers 1915: 392 (♂ genitalia*); Christophers 1916: 468 (tax., type-info.); Christophers 1924b: 297 (tax., distr.); Toumanoff 1931a: 958 (♀*, L*, distr., biol.); Chow 1970: 47 (tax., biol.).

Pyretophorus jeyporensis Theobald 1903: 66 (♂*, ♀*, L*, E*); Giles 1904: 35 (A, L, as *jeypurensis*); Theobald 1907: 70 (A, = *jeyporiensis* James). [JUNIOR SECONDARY HOMONYM].

Pyretophorus jeyporiensis James, James 1911b: 52 (A).

Anopheles candidiensis Koidzumi 1924: 98 (A); Christophers 1924a: 49 (? = *listonii* Liston); Edwards 1932: 51 (tax., = *jeyporiensis*).

Anopheles (Myzomyia) jeyporiensis James, Christophers 1924a: 51 (type-info.); Sinton and Covell 1927: 305 (cibarium); Puri 1928a: 514 (A, L*); Puri 1928b: 522 (L, tax.); Puri 1931: 157 (L*); Senevet 1931: 55 (P*); Christophers and Barraud 1931: 183 (E*); Christophers 1933: 220 (♂*, ♀*, P, L*, E, distr., biol.); Macan 1948: 243 (tax.); Bonne-Wepster and Swellengrebel 1953: 386 (♂*, ♀*, L*, distr.).

Myzomyia jeyporiensis var. *candidiensis* (Koidzumi), Yamada 1925: 490 (tax., specifically mentions not equal to subspecies).

Anopheles (Myzomyia) aconitus var. *tonkinensis* Toumanoff 1931b: 576 (♂, ♀, L); Toumanoff 1931a: 958 (= *jeyporiensis*); Toumanoff 1936: 167 (♀*, L, as *jeyporiensis* var.); Toumanoff and Hoang-Tich-Try 1937: 986 (♀*, as *jeyporiensis* var., ? = *candidiensis*); Senevet 1947: 214 (= *jeyporiensis* var. *candidiensis*).

Anopheles (Myzomyia) jeyporiensis var. *candidiensis* Koidzumi, Christophers 1933: 225 (♀*, L, tax., distr.); Ho 1938: 396 (♂*, ♀*, distr.); Bonne-Wepster and Swellengrebel 1953: 392 (♀*, L): Khin-Maung-Kyi 1971: 480 (tax., distr., biol.).

Anopheles (Myzomyia) jeyporiensis candidiensis Koidzumi, Russell, Rozeboom and Stone 1943: 116 (♀, L, key, to ssp. status); Thurman 1959: 121 (distr.).

Anopheles jeyporiensis candidiensis Koidzumi, Sandhinand 1951: 37 (distr.); Thurman and Thurman 1955: 222 (distr.); Foote and Cook 1959: 122 (♀*, L*, key); Chow 1970: 47 (to var. status).

Anopheles (Cellia) jeyporiensis James, Stone, Knight and Starcke 1959: 44 (tax.); Reid 1968: 312 (tax., distr.); Rattanarithikul and Harrison 1973: 2 (L*, key); Knight and Stone 1977: 42 (tax.).

Anopheles (Cellia) jeyporiensis var. *candidiensis* Koidzumi, Stone, Knight and Starcke 1959: 45 (tax.); Reid 1968: 312 (keys); Knight and Stone 1977: 43 (tax.) [NEW SYNONYMY, see Taxonomic Discussion section].

Anopheles (Cellia) jeyporiensis candidiensis Koidzumi, Peyton and Scanlon 1966: 1 (♀*, key); Scanlon, Peyton and Gould 1968: 22 (checklist); Chow 1970: 47 (without subgeneric desig., to var. status) [see Taxonomic Discussion section]; Klein 1977: 116 (distr.).

Adults of *jeyporiensis* are easily recognized by the scutal pale scales, banded tarsomeres, pale fringe spot at apex of vein 1A, dark proboscis and the sharp pattern of white and black scales on the wings. The pupa is often uniform tan to light brown, with the paddle pigmented and with a fringe mesad of seta 1-P, and is easily identified by the key characters. The 4th-stage larva of *jeyporiensis* is readily identified by the abdominal plates and barbs on setae 2-4-C. *Anopheles jeyporiensis* is like *aconitus* except for:

FEMALE (Figs. 2, 4-6, 13, Table 4). *Head.* Pedicel integument tan; flagellomere 1 with broad white scales on dorsal and mesal surfaces, flagellomeres 2, 3 may have several pale gray scales; proboscis with small dark brown decumbent scales; labellum nearly bare, paler than labium; forefemur/proboscis ratio 0.82-0.89, 0.86 mean (10 females); palpus with 3 pale bands, narrow basal band at segmental joint 2, 3, narrow median band on segment 3 apex; apical band narrow to wide (see Variations section), on variable portions of segment 4, and segment 5. *Thorax.* Integument dark brown, central portion of scutum ash-gray with 3 dark lines in acrostichal and dorsocentral setal rows, fossa and scutal angles dark; anterior promontory with long erect white scales, with short dark scales laterad of dorsocentral setal rows; scutum with flattened lanceolate white scales between dorsocentral setal rows back to scutellum; several pale lanceolate scales frequently along dorsal margin of supra-alar setal row; fossa infrequently with 1, 2 pale scales; scutellum with anterior row of lanceolate to short seta-like white scales, posterior row of long dark brown setae; pleural setae: 1 propleural, 0-2 spiracular, 2-4 prealar, 2-4 upper and 3-7 lower sternopleural, 3-7 upper and 0 lower mesepimeral. *Wing.* Color pattern variable (see Variations section), bright with sharp contrast between light and dark spots, common pattern follows. Costa with humeral, presector, sector, subcostal and preapical pale spots; remigium white-scaled, often with gray scales at apex; vein R with base white-scaled or with gray scales adjacent to remigium, pale beyond base to presector dark spot, sector pale spot and accessory pale sector spot fused and long, rarely divided by dark spot; R_1 with variable subcostal and preapical pale spots, with accessory pale spot on preapical dark area (rarely absent), tip pale-scaled, R_S-R_{2+3} usually with white scales at origin, adjacent to R_{4+5} origin and R_{2+3} fork; R_2 with white scales at origin, midpoint of vein and apex, often with basal and median white spots fused, infrequently without median white spot; R_3 with basal, median and apical white scales, median white spot often absent; R_{4+5} with basal, median and apical white scales, median pale area variable, rarely absent, prebasal dark spot often absent; M usually with white scales on basal 0.2-0.3, at crossveins and M fork; M_{1+2} and M_{3+4} with white scales at origin

and apex, M_{1+2} often with pale median spot; Cu primarily white-scaled with dark prebasal spot, fork dark-scaled (rarely pale); Cu_1 normally with 3 black and 3 white spots, white spots at m-cu crossvein, between 2 most apical dark spots, and at apex, rarely median pale spot absent and 2 most apical dark spots fused; Cu_2 dark at origin, with white scales to midpoint, distal 0.5 mostly black-scaled with apex pale; 1A primarily white-scaled with 2 or 3 black spots, small black spot present or absent on basal 0.3-0.4, apical 0.5-0.6 typically with 2 black and 2 white spots (apex white), infrequently apical 0.5-0.6 with long black mark and apex white; 1A rarely entirely pale except one small black spot, or entirely black except small pale area at base and pale apex; apical fringe spot starting at or above R_1 apex, extending to include tip of R_2; additional pale fringe spots include large spot at apices of R_3 and R_{4+5}, spots at apices of M_{1+2}, M_{3+4}, Cu_1, Cu_2, 1A and on hind margin of wing basal to 1A; 1A pale fringe spot constant (219 females). *Legs*. Integument dark, with dark brown scales, forecoxa may have several dark scales, upper midcoxa with 2-4 setae; forefemur slightly swollen on basal 0.75; femora entirely dark, tibiae dark except small dorsoapical pale patch; foretarsomeres 1-3 with apical pale bands, band length on 1 may be 2.0 tarsomere width, foretarsomeres 4, 5 dark; midtarsomeres 1-3 with apical pale bands approximately of equal length to tarsomere width, midtarsomeres 4, 5 dark; hindtarsomeres 1-4 with apical pale bands approximately of equal length to tarsomere width, hindtarsomere 5 dark. *Abdomen*. Unicolorous dark gray-brown with long tan setae, without scales.

MALE (Fig. 13). *Head*. Antennal flagellomere 1 with few pale gray scales on mesal surface; forefemur/proboscis ratio 0.65-0.70, 0.67 mean (10 males); palpus with narrow pale apical band on segment 3, large pale spot on distomesal aspect of segment 4, distal 0.8-0.9 of segment 5 pale. *Wing*. (see Variations section). Remigium and base of vein R usually with patch of gray scales; R usually with dark spot dividing sector pale area into 2 pale spots; 1A with distal 0.5-0.6 dark-scaled except pale apex. *Genitalia*. Basimere with broad gray-brown scales on ventrolateral aspect, with 5 parabasal spines; claspette with one large apical seta longer than lateral club, intermediate seta between apical seta and club equal to length of lateral club, occasionally with small seta ventromesal to apical seta; stout knob-like club on claspette fused from 3, 4 basal stems; aedeagus with 4, 6 leaflets on each side of tip, largest 2-4 leaflets with serrate edge on one side; proctiger membranous.

PUPA (Fig. 14, Table 10). Integument light tan to dark brown, paddles light tan. *Cephalothorax*. Light brown specimens with distinct brown vein lines on wing case and darker brown area between trumpets. *Trumpet*. Darker than cephalothorax on light specimens, same color on darker specimens; meatus 0.27-0.39 length of trumpet. *Metanotal Plate*. With dark brown areas on lighter specimens; seta 10-MP simple. *Abdomen*. Seta 0-II-VII small, simple, mesad and cephalad of 2-II-VII; seta 9-IV-VII dark, usually flattened with acute tip; 9-I simple, shorter than segment I; 1-II with 5-8 branches; 2-II with 2-4 branches; 9-II very small, simple, rarely bifid; 1-III with 4-6 branches; 2-III with 3, 4 branches; 4-III with 2-4 branches; 5-III with 3-6 branches; 7-III, 1-3 branches; 9-III small, faintly pigmented, often stout with blunt tip, 0.13-0.29 length of 9-IV; 4-IV, 1-3 branches; 7-IV, 1-3 branches; 9-IV fairly short, 0.14-0.29 length of segment V, 0.44-0.75 length of 9-V; 1-V, 1-3 branches; 4-V, 1-3 branches; 9-V, 0.25-0.43 length of segment V, 0.50-0.71 length of 9-VII; 1-VI simple or bifid; 2-VI, 1-3 branches; 4-VI simple; 5-VI, 1-3 branches; 6-VI simple, usually longer than 9-VI; 7-VI short, simple or bifid, 0.35-0.54 length of segment VI; 9-VI, 0.73-0.93 length of 9-VII, 0.37-0.50 length of segment VI; 1-VII simple or bifid; 2-VII, 1-3

branches; 4-VII simple or bifid; 5-VII, 1-4 branches; 7-VII short, simple, 0.42-0.55 length of segment VII; 8-VII simple or bifid; 9-VII, 0.38-0.51 length of segment VII; 9-VIII with 7-11 branches. *Genital Lobe.* Unicolorous light tan to brown. *Paddle.* Light tan; refractile margin long, 0.84-0.97 of distance from base to seta 1-P; paddle 1.51-1.67 as long as wide; lateral fringe changing gradually from spines to filaments at 0.77-0.88 of distance from base to seta 1-P; spines on lateral edge widely spaced; paddle fringe extending mesad of 1-P to mesal angle of paddle; 1-P, 0.19-0.25 length of paddle.

LARVA (Fig. 15, Table 16). Light brown to dark brown, without color pattern. *Head.* Frontoclypeus with color pattern varying from 3, 4 small brown spots on caudal area to 2 broad dark transverse bands and single large dark spot; anterior transverse band just caudad of seta 4-C level, posterior transverse band through 5, 6, 7-C level, large dark spot medial and caudal to posterior transverse band; antenna same color as darker areas on frontoclypeus, slender, 5.90-7.58 length of widest point, with dark spicules primarily on mesal and ventral surfaces; 1-A short, simple, inserted on outer dorsal surface 0.23-0.28 from base; 4-A with 3-6 branches; 2-C long, with 20-25 short lateral barbs; 3-C slightly more than 0.5 length of 2-C, with 15-20 short lateral barbs; 4-C split into 2-5 branches near base, extending cephalad approximately to base of 2-C; 8-C with 2-4 branches; 15-C with long stem, 2-4 short branches near tip. *Thorax.* Sclerotized bases of setae 1, 2-P fused; 1-P with 23-35 branches; 2-P with 10-15 branches; 9-P with 10-12 branches; 11-P with 3-5 branches; 10, 12-P long, simple; 1-M long, with 35-53 branches; 4-M with 3, 4 branches; 6-M with 2-4 branches, length of 5-M; 9, 10-M simple; 12-M short with 2, 3 branches; 3-T with 10-19 thin lanceolate leaflets arising from thick stalk approximately 0.20 length of seta, leaflets with blunt tips; 9-T with 11-14 branches; 10-T simple; 12-T with 2-5 branches. *Abdomen.* Anterior tergal plates on III-VII moderately large, 0.3-0.5 width of segments, not enclosing small median posterior tergal plates; anterior tergal plate II often fused with small posterior tergal plate; small oval submedian plates often absent, when present, on IV-VII (usually VI-VII); seta 0-II-VII small, simple, arising cephalad of seta 2 and posterolaterad of anterior tergal plate; 1-I with light brown leaflets, with or without shoulders; 1-II-VII leaflets brown, usually with shoulders and fairly short filaments, 1-II leaflets occasionally lanceolate and without shoulders; 1-I with 10-16 leaflets; 1-II with 12-17 leaflets; 13-III fairly large with 4-9 branches; 6-IV with 3, 4 branches; 13-IV with 4-9 branches; 6-V with 3, 4 branches; 13-V with 4, 5 branches; 1-VII with 14-19 leaflets; 2-VII with 3-5 branches; 2-VIII with 10-13 branches; small ventral plate often present adjacent to 14-VIII; pecten plate with 4, 5 long and 7-9 short teeth; seta 1-X with 2, 3 branches on distal 0.5, rarely simple, 1.27-1.70 length of dorsal margin of saddle; 2-X with 15-18 branches, most basal branches shorter than distal branches, straight, thick, tapering abruptly to sharp thorn-like tip, most distal branches long, curved, tapering gradually to small hooked tip.

EGG. Following description from Christophers (1933). "Not of whaleback type. Upper surface broad, as broad as width of egg, slightly narrowed in middle portion, anterior demarcated area somewhat broader than posterior. Lower surface unornamented. Floats touching margin of upper surface, occupying about middle half of egg or slightly more; float ridges 13-17; float-terminations large, round; frill moderately broad, striated, ending in distinct tags at junction with floats." Other publications describing *jeyporiensis* eggs are Theobald (1903) and Christophers and Barraud (1931). The latter authors also illustrate the egg from lateral and dorsal views.

TYPE-DATA. There has been considerable confusion in the literature regarding the type-specimens for this species. This was caused primarily by the same species being described as new with essentially the same name by 2 different authors using different specimens. Theobald (1907) explains this as follows, " It was described by Capt. James shortly before Vol. III. of the work appeared. His description did not reach me till some time afterwards, specimens having been sent him by Drs. Stephens and Christophers as well as to myself to describe." Consequently, *jeyporiensis* James 1902 and *jeyporensis* Theobald 1903, were not always differentiated (e.g., Stone et al. 1959). James (1902) listed 2 localities in the original description, i.e., "The Jeypur State" (now southern most tip of Orissa State) and "the central Provinces (Nagpur)" (now Maharashtra State). The type-specimen(s) for *jeyporiensis* James is/are probably non-extant, *not* in the BMNH as listed in Stone et al. (1959) and Knight and Stone (1977). Further, these last 2 references also list the type-locality as "Nagpur, Jeypur State (Central Provinces)," which is incorrect. Christophers (1916) listed the type for *jeyporiensis* James as a specimen labeled "Castle Rock 1902" and *"jeyporiensis"* by James, that was in the Central Malaria Bureau, Kasauli, and the types for *jeyporensis* Theobald as in the BMNH. However, Christophers (1924a) changed the type-locality for James' species to "Patingi, Jeypore Hills, Madras Presidency, India" without explanation, or word on the location of the type-specimen. Christophers (1924a) also noted that Theobald described his species from the same locality based on 3 females and 2 males, of which a male and female type were deposited in the BMNH. Christophers (1933) essentially repeated his 1924 information, but changed the type-locality to read "Patingi, Jeypore Hill Tracts, Vizagapatam Dist." I have not been able to obtain further information regarding the location of a type-specimen for *jeyporiensis* James.

There are several points regarding the original description and wing illustration (James 1902) that need clarification. The major problem is that the wing illustration looks more like *aconitus* than *jeyporiensis*, and since *aconitus* occurs in that area of India (Prakash and Husainy 1974a), a mixup was possible. The illustrated wing lacks 3 common *jeyporiensis* characters: humeral and presector pale spots on the costa and a pale accessory spot on the R_1 preapical dark mark. However, the wing possesses 2 characters typical for *jeyporiensis*, but rarely seen on *aconitus*, i.e., vein R_{4+5} has a long basal dark mark and the distal half of Cu_2 is dark scaled. Furthermore, I have seen infrequent *jeyporiensis* specimens without humeral and presector pale spots and many specimens from India do not have an accessory pale spot on the preapical dark mark of R_1. Therefore, I accept the illustrated wing as representing *jeyporiensis*. The original description clearly says, "palpi are the same as those of *A. fluviatilis*," which cannot apply to *aconitus*. James apparently overlooked the narrow bands on the tarsomeres, because he described the legs as "unbanded." Aside from these points, the larval description and illustration clearly suggest *jeyporiensis* rather than *aconitus*. In the absence of a type-specimen for *jeyporiensis* James, and after considering the above points, I believe the original description and illustrations indicate that *jeyporiensis* James is conspecific with the current concept of *jeyporiensis*.

In 1972, I examined the type-specimens of *jeyporensis* Theobald in the BMNH. Although one male and one female have "type" labels, Theobald (1903) clearly stated this species was described from 3 females and 2 males, which was also noted by Christophers (1924a). These specimens should all have syntype status since a holotype was not designated. Actually there are 4 females and one male in the BMNH with labels written in Theobald's hand that read

"India, Dr. Christophers." However, the ink on the label of one female is different from the others, and that specimen has an additional label "Recd from F. V. Theobald, 1907-29" not on the others. This female probably represents a later accession from Christophers and thus, should not be considered a syntype. Therefore, there are 3 females and one male that I consider syntypes of Theobald's species in the BMNH. As indicated above one female and the one male syntype have "type" labels. These 2 also have an additional label with a Theobald manuscript name that is very similar to the type-locality, Patingi, and beneath this "Type Theobald." The female with the label bearing the Theobald manuscript name and "Type Theobald" is here designated the lectotype for *jeyporensis* Theobald. The lectotype has the following characters: palpus with preapical dark band nearly twice as long as apical pale band; R_1 with accessory pale spot on the preapical dark mark; costa base with humeral and presector pale spots; scutum with prominent narrow pale scales; tarsomeres with narrow apical bands; and the hind margin of the wing with a pale fringe spot at 1A apex. These characters all fit the current concept of *jeyporiensis* James, thus, I consider *jeyporensis* Theobald a synonym (also junior secondary homonym) of *jeyporiensis* James.

The type-specimens for *candidiensis* Koidzumi and variety *tonkinensis* Toumanoff are unknown and probably non-extant. The descriptions and subsequent literature regarding these 2 nominal taxa indicate they are identical, and I consider both as synonyms of *jeyporiensis* James (see Taxonomic Discussion section for further discussion regarding the status of *candidiensis*).

DISTRIBUTION (Fig. 14). *Anopheles jeyporiensis* has a wide distribution in India and extends eastward across the Indochina Peninsula and southern China to Taiwan. This distribution includes: BANGLADESH; BURMA; CAMBODIA; HONG KONG; INDIA (Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal); LAOS; NEPAL; PEOPLE'S REPUBLIC OF CHINA (Chekiang, Fukien, Kwangsi, Kwangtung including Hainan Island and Yunnan); TAIWAN; THAILAND; and VIETNAM. Apparently, it has not been collected in Sri Lanka (Carter 1950). The above distribution results from the combination of the 2 previously recognized nominal taxa, *jeyporiensis* and *candidiensis*. Contrary to Christophers (1933), the variation corresponding to *candidiensis* is common throughout much of peninsular India (Menon and George 1950, Wattal 1961) and the variation previously considered restricted to India, i.e., *jeyporiensis*, is recorded from Burma (Macan 1948, Khin-Maung-Kyi 1971) and Vietnam (Chow 1970). I have collected specimens corresponding to this form in Thailand and Hong Kong along with the *candidiensis* variation and intermediates. Chow (1970) pointed out that 2 subspecies cannot exist sympatrically, and he reduced *candidiensis* from a subspecies to varietal status. However, I have decided to synonymize "variety" *candidiensis* as explained in the Taxonomic Discussion section, hence the combined distribution range.

Sandhinand (1951) first recorded *jeyporiensis* in Thailand from Chiang Mai Province, and Thurman and Thurman (1955) reported specimens collected by light traps in Chiang Mai during 1952-53. These initial specimens were reported as *jeyporiensis candidiensis*. Thurman (1959) recorded *jeyporiensis jeyporiensis* from northern Thailand without further explanation, however, Scanlon, Peyton and Gould (1968) noted this "report of the nominate form from Chiang Mai was apparently based on a personal communication from Dr. V. Notananda." Scanlon, Peyton and Gould (1968) reported all records of *jeyporiensis* from Thailand were from Chiang Mai Province, and that they

had no evidence that the nominate form occurred in Thailand. Since 1968, several additional collections of *jeyporiensis* were made and now this species is recorded from the following provinces of THAILAND: Chiang Mai, Lampang, Mae Hong Son and Phayao. One large immature collection was made in Amphur Mae Rim, Chiang Mai Province in 1969, from which a large number of adults with associated immature skins were reared. Included in this reared material were several specimens with palpal variations more like those described for *jeyporiensis* James, several specimens with intermediate palpal characters and the majority with palpal variations like those described for *candidiensis* Koidzumi. Accordingly, Rattanarithikul and Harrison (1973) did not recognize *candidiensis* in their larval key for Thailand.

In adjacent countries *jeyporiensis* is reported from Loikaw District, Kayah State, Burma (Khin-Maung-Kyi 1971) which is next to Mae Hong Son Province, Thailand. In Cambodia this species is known from 2 provinces, Kompong Chhnang (Harrison and Klein 1975) and Snuol (Klein 1977). Records from Vietnam list *jeyporiensis* only from the highlands below the 17th parallel (Nguyen-Thuong-Hien 1968), while Lefebvre (1938) records it from the northern parts of Laos (Luang Prabang, Phong Saly and the Tranninh Plateau).

The habitats and life requirements that determine the distribution of *jeyporiensis* are poorly understood. East of India this species seems somewhat restricted to hilly or mountainous regions where it is most commonly collected in large seepage marshes, or semi-permanent seepage water at the bases of hills. Quite possibly malaria house-spray programs in the last 20-25 years have severely altered the distribution and abundance of *jeyporiensis* outside of India. However, based on the literature, *jeyporiensis* probably was not widely distributed or abundant in Thailand, Cambodia, southern Vietnam and possibly southern Laos even before the malaria spray program. The only areas east of India where it has been reported abundant correspond to the area enclosed by the 20°-25° N latitude lines that includes northern Burma, Laos and Vietnam and southern China from Yunnan to Fukien.

A total of 1,215 *jeyporiensis* specimens were examined during this study (120♂, 264♀, 382 larvae, 231 larval and 268 pupal skins). Specimens examined from Thailand include 44♂, 50♀, 121 larvae, 72 larval and 81 pupal skins. Additional specimens (76♂, 214♀, 211 larvae, 159 larval and 187 pupal skins) were examined from the following countries: CAMBODIA; HONG KONG; INDIA (Assam, Orissa--includes type-specimens of *jeyporensis* in BMNH, and Tamil Nadu); NEPAL; PEOPLE'S REPUBLIC OF CHINA (Kwangtung); and TAIWAN. In 1969 many *jeyporiensis* (63♂, 170♀, 207 larvae, 153 larval and 187 pupal skins) were collected in the New Territories (Sai Kung District), Hong Kong and are now deposited in the USNM.

VARIATIONS (Figs. 2, 6; Table 4, 10, 16). *Anopheles jeyporiensis* adults, like the other Myzomyia species in the Orient, have many variable adult characters that have caused confusion. Chief among these is the variable palpal banding pattern that gave rise (in part) to both synonyms *(candidiensis* and *tonkinensis).* If as Christophers (1933) suggested, one palpal variation was found in India and the other variation was found only east of India, some status might be accorded these variations. However, as noted by Macan (1948) and Khin-Maung-Kyi (1971) in Burma, Rattanarithikul and Harrison (1973) in Thailand, Menon and George (1950) in southern India (Kerala), Christophers (1933) in west India (Bombay) and my observations on Hong Kong specimens, both variations plus intermediates typically occur together. This situation, over such a wide area negates any possibility, based on palpal variations, of these being different subspecies. Menon and George (1950) made a statistical analysis

of the palpal variations on 354 female *jeyporiensis* collected in Kerala (as Travancore), southern India. From these they recognized 4 distinct palpal patterns (as groups): (1) with very long preapical dark band; (2) equal to *jeyporiensis* James; (3) intermediate with more pale scales than (2); and (4) equal to *candidiensis* Koidzumi. Group (1) was represented by 50 specimens, (2) by 138, (3) by 104 and (4) by 62. By plotting their results they showed that all 4 groups were on a common axis which passed through the mean for the whole sample. They concluded that variation of the palpus was proceeding in 2 opposite directions from the type-form (group 2), and that since variation had proceeded along a common line from the type-form, the groups should be considered gradations in the variations of the type-form and not as true varieties (e.g. *candidiensis*). Similar studies have not been conducted elsewhere. Based on the specimens I have seen, the frequency of the wide preapical dark band appears much higher in the specimens on the Indian end of the distribution, while the variation with the narrow preapical dark band has a higher frequency on the eastern end of the distribution. A cline may be involved, or possibly the more melanic specimens were exposed to cooler temperatures as larvae. Regardless of the cause, I feel the palpal variations in *jeyporiensis* are continuous and do not warrant names. These palpal variations on *jeyporiensis* are certainly no more striking than those illustrated (Fig. 6) for *minimus*. A very similar pattern of palpal variations on *subpictus* Grassi, from India and further east, was pointed out by Reid (1968).

Table 4 presents the frequency ranges for 12 wing characters found on *jeyporiensis* from Thailand, Vietnam and Hong Kong. Two of the characters in Table 4 were nearly always present on females. These characters, (1) hind margin of wing with pale fringe spot adjacent to 1A apex and (2) R_1 with accessory pale spot in preapical dark mark, are useful in identifying *jeyporiensis*. The R_1 pale accessory spot was used by Toumanoff (1931a) and Toumanoff and Hoang-Tich-Try (1937) to separate Vietnamese specimens from Indian specimens. This spot is apparently less frequent on females from India (5 to 10 specimens examined). Another variable character that has been used frequently in keys is the number of dark spots on vein 1A. Previously, *jeyporiensis* has usually been characterized with 3 dark spots on 1A, however, data in Table 4 show that 1A commonly has the basal dark spot missing or the 2 distal dark spots fused into one long dark spot. Toumanoff and Hoang-Tich-Try (1937) also found many Vietnamese specimens with the 2 distal 1A black spots fused. The basal pale spots on the costa (humeral and presector) were found very stable. Only one specimen was seen lacking both of these spots and thus, matching the wing illustrated in the original description (James 1902).

One new character was found on the wing that will help identify many specimens of *jeyporiensis*. Female specimens often have gray or gray-brown scales at the apex of the remigium and on the base of R (29-59%, Table 4). These scales are easily overlooked, however, their presence is highly significant since the only other Myzomyia species with dark scales on these areas are *culicifacies* and *pampanai*. This character was also present on 18/20 Thai and 3/5 Hong Kong males.

Christophers (1933) mentioned that Indian specimens often lacked apical pale bands on fore- and midtarsomere 3, while specimens identified with *candidiensis* usually had bands on these tarsomeres. Nearly all of the specimens I examined had either a band or dorsal pale spot at the apices of these tarsomeres, however, insufficient Indian specimens were seen for a meaningful comparison. Reduction in pale leg banding is already well documented for

TABLE 4. Frequency *(f)* of selected wing characters on feral adult *An. jeyporiensis* from Thailand, Vietnam and Hong Kong.

Characters*	Thailand		Vietnam	Hong Kong
	♀♀ (46)**	♂♂ (20)	♀♀ (17)	♀♀ (156)
	f (No.)	*f* (No.)	*f* (No.)	*f* (No.)
Costa without humeral pale spot	0.130 (6)	0.0 (0)	0.0 (0)	0.013 (2)
Costa without humeral and presector pale spots	0.0 (0)	0.0 (0)	0.0 (0)	0.006 (1)
Remigium and R base with gray-brown scales	0.587 (27)	0.90 (18)	0.294 (5)	0.295 (46)
R with sector and accessory sector pale spots separate	0.522 (24)	1.00 (20)	0.059 (1)	0.058 (9)
R_1 with accessory pale spot on preapical dark mark	0.957 (44)	1.00 (20)	0.882 (15)	0.968 (151)
R_2 with median pale spot	0.283 (13)	- ***	1.00 (17)	0.994 (155)
R_3 with median pale spot	0.239 (11)	- ***	0.941 (16)	0.846 (132)
R_{4+5} without basal dark spot	0.022 (1)	- ***	0.471 (8)	0.103 (16)
M_{1+2} with median pale spot	0.196 (9)	- ***	0.941 (16)	0.667 (104)
1A without basal dark spot	0.522 (24)	0.20 (4)	0.471 (8)	0.654 (102)
1A with distal half dark scaled	0.609 (28)	1.00 (20)	0.059 (1)	0.244 (38)
1A with pale fringe spot	1.00 (46)	1.00 (20)	1.00 (17)	1.00 (156)

*Character on at least one wing.
**Total number of specimens examined.
***Not checked.

several species of *Anopheles* from India (Reid 1968; Harrison and Scanlon 1975).

Several other wing variations on females were detected that had low frequencies, they are: R with a pale spot between sector and subcostal pale spots - Thailand (1/46), Vietnam (1/17) and Hong Kong (4/156); R_{4+5} almost entirely black - Thailand (1/46); Cu fork pale - Vietnam (1/17) and Hong Kong (9/156); 1A almost entirely pale - Hong Kong (2/156); 1A dark except at base - Hong Kong (1/156). One morphologically deformed variant (anal vein interruption) was found on a Thai female. The cytogenetic value and heritability of this trait were discussed under *aconitus*.

Tables 10 and 16 represent setal branching variations on the pupae and larvae of *jeyporiensis*. Both stages are usually pigmented brown, which is consistent with other species typically found in seepage marshes with dark mucky bottoms. The pupal paddle is somewhat unusual because it is also pigmented (usually tan). The pupa of *majidi* also shows this trait. Seta 9-IV on *jeyporiensis* is shorter than is usual in this series (see series key) and consequently this species may key to Neocellia. Although 9-IV is only 0.44-0.75 the length of 9-V on *jeyporiensis*, it retains the same shape as 9-V (cf. Neocellia spp.). Seta 1-V-VII on *jeyporiensis* is more variable than on *culicifacies*. It is usually simple on *culicifacies*, but is often bifid or trifid on *jeyporiensis*.

The number of lateral barbs on larval setae 2, 3-C are important in separating this species from *aconitus*. These barbs, although varying in number, are always longer and more numerous than those on *aconitus*. Christophers (1933) suggested the barbs on 3-C were fewer and stouter on larvae from east of India than on Indian *jeyporiensis*. Due to the lack of Indian specimens I have been unable to check this character. The posterior tergal plate on II was found separate or attached to the anterior tergal plate. Some specimens also had a small median ventral plate that was usually closely associated with 14-VIII. Seta 1-X on the saddle was either bifid or trifid on all specimens checked, with the division occurring on the distal half of the seta. An anomalous seta 6-II with only 9 branches was found on one larvae. This seta normally has 23-31 branches.

Adult palpal and wing variations on *jeyporiensis* may create occasional difficulty in identifying this species, however, these variations do not alter the stability of the scutal and leg key characters. The immature characters for identifying *jeyporiensis* are highly reliable and quickly differentiate this species from other members of the Myzomyia Series. The only problem area with immature identification may lie in keying *jeyporiensis* pupae to the Myzomyia Series.

TAXONOMIC DISCUSSION. The resolution of the status of the nominal taxon *candidiensis* was a major objective of this study. Although sufficient Indian specimens were not available for study, published reports have shown that *jeyporiensis* is as variable in India as elsewhere. Discrete populations of *jeyporiensis* or *candidiensis* (based on palpal banding patterns) were not found during this study. In Vietnam large numbers of both *jeyporiensis* and *candidiensis* were reported from the high plateau and mountain jungle-covered areas (Nguyen-Thuong-Hien 1968). This report did not mention intermediates nor what the palpal banding parameters were for both types, but did note that the only difference between the 2 types was morphology, otherwise their biology and rates of infection with malaria parasites were identical. The behavioral-biological aspects of the 2 variations from Vietnam were recently tabulated by Chow (1970). I believe a close examination of such situations will reveal both

of these variations (and intermediates) in any given large sample. These variations were continuous rather than discontinuous in all samples checked to date, thus they cannot be considered polymorphic. The frequencies of the respective variations (i.e., *jeyporiensis*, *candidiensis* and intermediates) may vary considerably from one population to another, or from one subregion of the Orient to another. Such shifts in variation frequencies are probably much more common in mosquitoes than currently realized and are often clinal. In Asia a number of shifts in variation frequencies are already known in *Anopheles*, these include: increased abdominal scaling on *maculatus* Theobald (Reid et al. 1966) [involves synonym *willmorei* James, which, in my opinion, does not deserve the varietal status continued by Reid (1968) and Knight and Stone (1977)]; reduction in pale leg bands on Indian specimens of *argyropus* (Swellengrebel), *peditaeniatus* (Leicester) and *nigerrimus* Giles (Reid 1968, Harrison and Scanlon 1975); reduction in the pale palpal bands on Indian *subpictus* (Reid 1968); reduction in wing fringe spots (Reid 1968) and pale leg bands (Harrison 1973) on Indian and Sri Lanka *barbumbrosus* Strickland and Chowdhury; increasing pale scales on the remigium and scutum on Iranian and Arabian *culicifacies;* and variations in the humber of basal costal pale spots on *aconitus*, *culicifacies* and *minimus*. These frequency changes are apparently a reflection of selection pressure on the same species living under different environmental conditions. The palpal variations on *jeyporiensis* exist together over a wide geographical area (India to Hong Kong) and obviously cannot be considered subspecies as pointed out by Chow (1970). However, they also should not be called varieties as proposed by Chow and previous authors for *candidiensis*. The term variety is an outdated holdover from the era of the morphological type concept and has no place in modern systematics, which is rooted in population biology. Accordingly, as Mayr (1969) pointed out, varietal names (e.g., names for individual variants, discrete or discontinuous variations or aberrant individuals) have no standing in nomenclature (Art. 1, 1964 ICZN). Mayr also lists several other categories not deserving varietal names. The variation of *jeyporiensis* that was originally named *candidiensis* is nothing more than a widespread variation that occurs with varying frequency in different regions of the Orient. Specimens with palpal characters as described for *candidiensis* are no longer entitled to a latinized varietal name according to the ICZN, and are no more distinct than the various palpal variations described here for *aconitus* and *minimus*, the cold weather 4-banded palpal variation found on *fluviatilis* (see under *aconitus* Variation section) or the leg, wing, palpal and scutal variations with changing frequencies listed above.

Although *jeyporiensis* is relatively uncommon and has a restricted distribution in Thailand, it still should cause very few identification problems. Adults are readily recognized by the key characters, the sharp contrasting black and white wing pattern, the pale fringe spot at the apex of vein 1A, the dark proboscis, the usually narrow preapical pale palpal band and gray-brown scales on the remigium-R base. The spotting pattern on 1A should not be used to identify this species.

The 4th larval and pupal stages are also easily identified, particularly the former. The larva is easily recognized by the following combination of characters: (1) only one metathoracic pleural seta (9-T) branched; (2) abdomen with moderate size anterior tergal plates, separate posterior tergal plates and infrequently with small paired submedian plates on IV-VII (usually VI-VII); (3) setae 2, 3-C with numerous lateral barbs and 4-C branched; (4) 3-T with blunt tips on leaflets; (5) median plate on spiracular apparatus with lateral arms; (6) seta 1-X bifid or trifid on distal half; and (7) seta 2-X with most basal branches straight

thick, tapering abruptly to sharp thorn-like tip.

The pupal stage is probably more difficult to key to the Myzomyia Series than to identify to species within the series. The pupa can be recognized by the following combination of characters: (1) seta 9-I simple and shorter than segment I; (2) seta 1-II with only 5-8 branches; (3) 2-II with 2-4 branches; (4) 2-III with 3, 4 branches; (5) 9-IV same shape as 9-V; (6) 7-VI, VII short, not more than 0.6 the length of segment; (7) 9-VIII with 7-11 branches; (8) paddle with small lateral spines changing gradually to filaments distally; (9) paddle refractile margin 0.84-0.97 of distance from base to seta 1-P; and (10) paddle fringe extending mesad of 1-P to mesal angle.

Anopheles jeyporiensis apparently is not closely related to any other Oriental Myzomyia species. The adults have a number of characters similar to those of *majidi*, however, the larval characters of these 2 species are very different. There are also a number of similarities between the adults and larvae of *aconitus* and *jeyporiensis*, but the pupae are quite distinct and *jeyporiensis* is not a member of the Minimus Species Group in which *aconitus* belongs. Since *aconitus* appears to be one extreme of the Minimus Group, perhaps *jeyporiensis* is distantly related to the Minimus Group through *aconitus*. These similarities, however, are not sufficient to place *jeyporiensis* in this group.

This may be a species of subtropical, rather than tropical origin. In some areas it extends into tropical areas (India), but in the remainder of its range it is confined to more northern latitudes or higher elevations. It is apparently a more sylvan species than some of the other members of the series, and commonly exists in marshes and seeps in forested areas.

BIONOMICS. Very little biological information is available for *jeyporiensis* in Thailand. Consequently, most information in this section comes from work in other countries.

Covell (1944) summarized the larval habitats for *jeyporiensis* to include slow running water, river margins, streams with grassy margins ditches, swamps, rice fields, seepage outcrops, especially in foothill areas. Macan (1948) found *jeyporiensis* larvae in Burma in easily overlooked marshes, i.e., those where emergent vegetation is very thick and the water was not apparent until it accumulated around the foot with each step. In India (Tamil Nadu), Rahman et al. (1975) found larvae of this species in irrigation channels with grassy margins, and in sandy pools beside a river. Based on these and other references and personal experience the larval habitat for *jeyporiensis* can best be described as: clear cool fresh water, slow moving or nearly stagnant, with abundant vegetation often of all kinds, but particularly with emergent grass, often with mucky, silty bottom and usually with partial to heavy shade. This shade requirement is usually filled by emergent vegetation, not trees or other objects. Such habitats can be temporary or permanent, and semipermanent to permanent seepage pools (outcrops, marshes, etc.) at the base of hills seem to fill all of these requirements and be a favored oviposition site. Water ranging from 23-33°C (optimum 28°C) has been noted as ideal for *jeyporiensis* (Wattal 1961). This temperature range basically eliminates *jeyporiensis* from most rice fields during the hot monsoon season. Accordingly, this species seems to be most abundant near the end and just after the rainy season when cooler weather arrives. Most collections of *jeyporiensis* from rice fields occur at the end of the growing season and particularly after the rice has been cut and pools remain in the fields (Jackson 1936a) or in fallow rice fields with seepage water. This is definitely a hill-mountain-high plateau species which has been found at elevations up to 1,829 m in India and probably does not occur in plains areas such as those surveyed in India (Tamil Nadu) by Russell and Rao (1940)

or the central rice plains or Korat Plateau rice plains in Thailand. Larval collections in Thailand have been from seepage habitats, particularly a large seepage marsh in Mae Rim District, Chiang Mai Province, at about 320 m elevation. In Sai Kung District, New Territories, Hong Kong, the following sites yielded larvae: ditches beside rice fields (2); small rice field (1); small stream margin (4); large stream margin (3); seepage pool (1); and seepage marsh (3). Although only 4 of 14 collections were made from seepage water habits, those 4 accounted for about 90% of 160 adults reared and 207 whole larvae of *jeyporiensis* preserved from Hong Kong. The grassy stream margins sampled in Hong Kong were often densely populated by *minimus* larvae but only occasionally yielded *jeyporiensis* or *maculatus* Theobald. All immature collections in Hong Kong were made between 1-250 m elevation. The best site was a large seepage-bog-marsh in a fallow rice field, 1 m above sea level at the base of a hill next to the beach in a protected bay. This site had a large dike on the beach side to prevent salt water from entering the field at high tide. In some places this fresh water bog was less than 10 m from the small waves on the beach. I have only been able to find one other reference indicating collections of this species at elevations of 20 m or less (18 m, Stage 1958). Apparently this does not usually occur in more southerly latitudes. As noted earlier, *jeyporiensis* is very abundant in the hilly regions of southern China between 20-25°N latitude. Based on my experiences in Thailand and Hong Kong, seepage pools, springs, bogs or marshes at the bases of hills are by far the most productive collection sites for *jeyporiensis* immatures.

Anopheles jeyporiensis larvae were found to have a submergence behavior very similar to that described above for *culicifacies*. This involves a long submergence, up to 5 minutes, when they are disturbed and dive to the bottom. In several instances larvae were observed holding on to a bottom substrate such as algae by their mouthparts and suction by an eye dropper dislodged them only with difficulty. When these larvae were dislodged they often retained strands of algae in their mouths. An excellent method, previously developed by E. L. Peyton in Thailand, was used to overcome this behavioral trait and speed up the collection. This involved a vigorous stamping by the collector, which rapidly turned the water into a thick silty solution. The collector then stood still and watched as the dark larvae of *jeyporiensis* came to the surface. This technique also is suitable for other anophelines that are easily flushed from the surface. This submergence behavior may be partially responsible for the few immature collections of *jeyporiensis* in northern Thailand. It definitely makes larval collections of this species more difficult and less likely than for other anopheline species.

Female *jeyporiensis* can be collected by light traps, human or bovine bait, but the best method is probably the resting collection. This species is definitely endophilic and probably endophagic, although it can be taken in outdoor biting collections. Christophers (1933) noted this species is commonly taken in houses and cattle sheds and Covell (1944) said it was most common in the latter. Prakash and Husainy (1974a) also found it most common in cattle sheds in India. However, Stage (1958) noted that where *minimus* and *jeyporiensis* occurred in Vietnam they represented more than 80% of the total catch in houses. Nguyen-Thuong-Hien (1968) reported *jeyporiensis* highly endophilic in Di-Linh, Vietnam, with 97% taken indoors prior to insecticide treatments. In that report the ratio of adults entering human habitations to those in animal shelters was 24: 1 (16, 848/701), and the peak entry time was between 0100-0300 h. Most females (98%) were found resting on the bottom 1 m of the walls. In 1969 numerous females were found resting in mud-plaster cattle sheds in the

New Territories, Hong Kong, both at night and from 0800-0930 h in the morning. Differences in the resting behavior of this species as reported above probably reflect differences in the structure and design of human habitations and cattle sheds from one region to the next. For example, cattle sheds in Thailand are often breezy with thatched sides or simply under the human habitation, while cattle sheds in Hong Kong are compact with plaster walls and well protected from the wind. These differences, like similar differences in human house construction create entirely different microhabitats which based on temperature, humidity, desiccation rate, are or are not suitable for a mosquito resting site. Too often mosquito behavior is treated as entirely independent of man's manipulations, when frequently it is a direct response to a biologically favorable situation created by man.

Conflicting results have also been published regarding the feeding behavior of *jeyporiensis*. Christophers (1933) reported it feeds freely on man, and Wattal (1961) and Chow (1970) list it as anthropophilic, however, Bruce-Chwatt et al. (1966) presented precipitin test-data showing otherwise. Actually the data presented by the first 3 authors were basically pre-insecticide, while those of Bruce-Chwatt et al. (1966) probably included specimens from post-spray surveys. Differences in feeding behavior should be anticipated when dealing with populations of a widespread species. This species appears to be endophagic and Khin-Maung-Kyi (1971) lists the peak biting time in Burma as between 2330-0300 h. Currently, there are insufficient data to establish the biting behavior of *jeyporiensis* in Thailand.

Pal (1964) noted that *jeyporiensis* densities in India were not affected by insecticide treatments. In Vietnam, however, where *jeyporiensis* made up 16.1% of the total anophelines collected before spraying in 1960, its densities dropped to very low levels after spraying (Nguyen-Thuong-Hien 1968). Nguyen-Thuong-Hien (1968) also presented preliminary data showing *jeyporiensis* highly susceptible to DDT. Chow (1970) presented data for Vietnam *jeyporiensis*, showing the LC_{50} and LC_{100} of DDT (%) as 0.65-0.70 and 4.0, respectively, and LC_{50} and LC_{100} of dieldrin (%) as 0.07 and 0.2, respectively.

Besides malaria parasites, filariae of *Brugia malayi* and *Wuchereria bancrofti* have been found in *jeyporiensis* in The People's Republic of China (Hawking 1973). Jackson (1936b) recorded a *W. bancrofti* infection rate of 1.9% in *jeyporiensis* from Hong Kong. Feng (1933) reported *Herpetomonas culicis* in 1 or 30 *jeyporiensis* from Amoy, China. *Culicoides anophelis* was reported as attacking *jeyporiensis* by Ratanaworabhan (1975).

ANOPHELES (CELLIA) MINIMUS THEOBALD

(Figures 3-6, 16-18; Tables 2, 5-7, 11, 17)

Anopheles minimus Theobald 1901: 186 (♀*); Theobald 1907: 126 (? = *Pyretophorus*); Theobald 1910: 85 (type-info.); Christophers 1916: 473 (tax.); Barnes 1923a: 123 (distr.); Strickland 1924: 149 (♂*, ♀*, P, L*, = *funestus*); Evans 1930: 587 (♂*); Liu, Fang and Hu 1959: 154 (♀*, L*, tax.); Krishnaswami 1961: 91 (biol. distr.); Khin-Maung-Kyi 1970: 205 (biol., distr., vector status).

Anopheles vincenti Laveran 1901: 993 (♀); Theobald 1910: 84 (tax.); Edwards 1932: 52 (tax., ? = *minimus*); Christophers 1933: 216 (tax., ? = *aconitus*); Treillard 1934: 750 (tax., ? = *minimus*); Reid 1947: 88 (type-info., = *minimus*).

Anopheles formosaensis I Tsuzuki 1902: 288 (♂, ♀); Dönitz 1903: 233 (renamed); Christophers 1916: 473 (= *minimus*).

Anopheles christophersi Theobald 1902b: 378 (♀*); Edwards 1913: 222 (tax.); Christophers 1915: 380 (♂*); Edwards 1915, *in* Ludlow 1915: 156 (= *minimus*).

Anopheles aconitus var. *cohaesa* Dönitz 1903: 233 (*nomen novum* for *formosaensis I* Tsuzuki, Feb. 1902, *non formosaensis II* Tsuzuki, Feb. 1902).

Pyretophorus minimus (Theobald), Giles 1904: 21, 36: Theobald 1910: 38 (in part).

Myzomyia christophersi (Theobald), Theobald 1907: 51 (tax.).

Myzomyia christophersi var. *alboapicalis* Theobald 1910: 25 (♀); Ludlow 1915: 156 (= *christophersi*); Edwards 1915, *in* Ludlow 1915: 156 (= *minimus*); Christophers 1916: 474 (? = *aconitus*); Christophers 1924a: 50 (= *minimus*).

Myzomyia minima (Theobald), Swellengrebel and Swellengrebel-de Graaf 1920: 88 (♀); Yamada 1925: 447 (♂, ♀, tax.); Treillard 1934: 750 (tax.).

Anopheles (Myzomyia) minimus Theobald, Christophers 1924a: 49 (tax.); Sinton and Covell 1927: 305 (cibarium); Puri 1931: 148 (L*); Christophers and Barraud 1931: 183 (? E*); Christophers and Puri 1931: 488 (♂, ♀*, L, distr.); Edwards 1932: 52 (tax.); King 1932: 485 (♂*, ♀, L*); Morishita 1932: 331 (E*); Christophers 1933: 209 (♂*, ♀*, P, L, E); Toumanoff 1936: 149 (♂, ♀*, L, tax.); Ho 1938: 393 (♂*, ♀*, distr.); Bonne-Wepster and Swellengrebel 1953: 369 (♂*, ♀*, L*); Hara 1959: 110 (♀ genitalia*); Khin-Maung-Kyi 1971: 477 (distr.).

Anopheles minimus subsp. *X* Baba 1951: 11 (= unavailable name per Art. 11 (g) i, ICZN).

Anopheles (Cellia) minimus Theobald, Stone, Knight and Starcke 1959: 49 (tax.); Peyton and Scanlon 1966: 1 (♀*, key); Scanlon, Peyton and Gould 1968: 25 (checklist); Reid 1968: 314 (♂*, ♀*, P*, L*, E*, key, tax.); Rattanarithikul and Harrison 1973: 2 (L*, key); Knight and Stone 1977: 46 (tax.).

The pupa and 4th-stage larva of *minimus* are the diagnostic stages for identification in Thailand. The earlier records (see Taxonomic Discussion section) of *fluviatilis* in Thailand are not accepted here based on variations observed in *minimus*, thus, difficulties in separating the immature stages of these 2 species are not important. Consequently, larvae or pupae possessing large, branched and laterally placed seta 0 on the abdominal segments can be immediately identified as *minimus*. On the other hand, females of *minimus* do not possess totally reliable characters, but, 90-95% of any given group of specimens from Thailand can usually be identified by the above key and the characters presented below. Adult males should be identified by associated immature skins because wing characters on male *aconitus*, *minimus*, *pampanai* and *varuna* are often nearly identical. In particular, *aconitus* males normally have vein 1A with 2 dark spots as found on *minimus* males, and the pale fringe spot at the apex of 1A, when present on male *aconitus*, is very hard to see. The egg and its variations are poorly known, and for this reason should not be used to identify *minimus*. This species is similar to *aconitus* except for:

FEMALE (Figs. 3-6, 16, Tables 5-7). *Head.* Antennal flagellomeres 1,2 with pale scales on mesal surfaces, flagellomere 3 often with pale scales; proboscis with slightly erect dark scales at base, usually dark decumbent

scales on remainder, infrequently with small distoventral patch of pale scales; forefemur/proboscis ratio 0.84-0.90, 0.87 mean (10 females); palpus with dark erect scales at base and on segment 2, with decumbent scales on remainder; palpus color pattern highly variable, usually with 3 silver-white bands, banding similar to *aconitus*, except the 2 most apical pale bands are usually nearly equal length and separated by a dark band nearly equal to the pale bands; apical 0.30-0.35 may be entirely white or primarily dark-scaled (see Variations section). *Thorax*. Integument brown, central portion of scutum nearly solid ash-gray, may have faint dark longitudinal lines in acrostichal and dorsocentral setal rows; fossa, scutal angles and supraalar areas dark brown; scutum with white, curved, slightly flattened seta-like scales back to scutellum, scales more prominent and obvious than those on *aconitus;* fossa usually without scales, infrequently with 1, 2 pale scales; supraalar region often with several pale scales along mesal margin; prescutellar space bare, at least immediately cephalad of scutellum; pleural setae: 1 propleural, 1-3 spiracular, 2-4 prealar, 3 upper and 3, 4 lower sternopleural, 3-8 upper and 0 lower mesepimeral. *Wing*. Color pattern highly variable (see Variations section), pale markings white to silver-white, dark markings blue-black, common pattern follows. Costa with presector, sector, subcostal and preapical pale spots; remigium and R base pale to presector dark spot; R sector pale spot and accessory pale sector spot fused, or frequently separated by dark spot; preapical pale spot on C and R_1 infrequently reduced or absent; accessory pale spot on R_1 preapical dark mark rare; R_S-R_{2+3} usually with pale scales at origin, adjacent to R_{4+5} origin and at R_{2+3} fork, but pale spots rarely fused; R_2 and R_3 with pale scales at origin and at tip; R_{4+5} with prebasal and preapical dark spots of variable size, base and apex pale, median pale area variable; M_{1+2} usually dark except origin and tip; Cu normally with prebasal dark spot and fork dark scaled; Cu_1 normally with 3 dark and 3 pale spots, pale spots at m-cu crossvein, between 2 most apical dark spots and at apex, infrequently median pale spot absent and vein primarily dark; Cu_2 dark at origin; 1A usually with base pale, small prebasal dark spot followed by pale area, distal 0.5-0.6 dark-scaled, rarely very pale, dark except at base or with 3 pale areas; fringe spots at wing apex variable and generally similar to those on *aconitus;* R_3 tip usually with pale fringe, dark fringe spot usually between R_2 and R_3 tips; 1A tip usually without pale fringe spot; hind margin of wing basal to 1A tip often with small patch of pale tertiary fringe scales, but primary and secondary fringe scales infrequently pale. *Legs*. Forefemur slightly thicker than other femora; tarsomeres with same pattern of dorsoapical pale patches as *aconitus*, but patches smaller, less obvious, often absent on hindtarsomeres. *Abdomen*. Unicolorous gray or brown, covered with numerous light tan setae.

MALE (Fig. 16). Like *aconitus* male except: *Head*. Antennal flagellomere 1 with gray scales on mesal surface; forefemur/proboscis ratio 0.65-0.75, 0.69 mean (10 males); palpal pale areas silver-white instead of light yellow. *Thorax*. Scutal integument gray centrally, brown laterally; pale white seta-like scales obvious, extending back onto scutellum, more prominent than on female; prealar setae 2-5; lower sternopleural setae 3-6; upper midcoxal setae 2-6. *Wing*. Costal presector pale spot present or absent; R with sector pale and accessory pale sector spots often separated by dark spot; R_2, R_3, M_{1+2}, M_{3+4} usually without median pale spots; Cu_1 frequently dark distal to m-cu crossvein; tip of 1A without pale fringe spot. *Genitalia*. Basimere with brown to black scales; claspette usually with 1, 2 short setae ventromesad of long apical seta; lateral club fused from 2-4 basal stems, rarely divided into 2 separate clubs on each side; aedeagus usually with 3-5 leaflets on each side,

smallest leaflets like short spines; tergum IX with broadly rounded lateral lobes, median membranous portion covered with minute spicules; proctiger membranous, with nearly parallel longitudinal wrinkles, without minute spicules.

PUPA (Fig. 17, Table 11). Integument clear to light brown, darker specimens with darkest pigmented areas on wing case, between trumpets and on metanotal plate; paddles usually clear or light tan. *Cephalothorax.* Moderately pigmented specimens with distinct vein lines on wing case. *Trumpet.* Dark on light specimens; meatus 0.24-0.39 length of trumpet. *Metanotal Plate.* Seta 10-MP with 2,3 branches. *Abdomen.* Seta 0-III-VII long, strongly developed, usually with 2-7 branches (infrequently simple) on III-V, long with 1-3 branches on VI-VII, positioned laterally on segments IV-VII, laterad of seta 2 and more directly cephalad of setae 4, 5; 9-IV-VII darkly pigmented, with finely tapered sharp tip, often flattened and curved; seta 3-I with 2-4 branches; 4-I with 7-9 branches; 9-I with 3-5 branches; 1-II with 17-44 branches; 2-II with 4-7 branches; 3-II with 5-10 branches; 8-II absent or small, simple; 9-II small, simple, rarely bifid; 10-II absent or small, simple; 1-III with 11-26 branches; 2-III with 6-10 branches; 3-III with 5-11 branches; 4-III with 4-7 branches; 5-III with 9-13 branches; 7-III with 3-7 branches; 9-III clear, same color as segment integument, needle-like, 0.2-0.4 length of 9-IV; 1-IV with 6-13 branches; 4-IV, 1-6 branches; 7-IV, 1-5 branches; 9-IV, 0.35-0.44 length of segment IV, 0.63-0.88 length of 9-V; 1-V, 1-5 branches (usually simple); 4-V with 3,4 branches; 9-V, 0.43-0.64 length of segment V, 0.65-0.89 length of 9-VII; 1-VI, 1-3 branches (usually simple); 2-VI with 3-6 branches; 4-VI, 1-3 branches; 5-VI with 4-7 branches; 7-VI simple, very long, 0.85-1.24 length of segment VI; 9-VI, 0.9-1.0 length of 9-VII, 0.50-0.72 length of segment VI; 1-VII, 1-4 branches (usually simple); 2-VII with 3-5 branches; 4-VII, 1-3 branches; 5-VII with 2-7 branches; 7-VII simple, very long, 0.83-1.11 length of segment VII; 9-VII simple, rarely bifid, 0.50-0.59 length of segment VII; 9-VIII with 7-14 branches. *Paddle.* Usually light tan; refractile margin intermediate, 0.63-0.85 of distance from base to seta 1-P; paddle 1.40-1.55 as long as wide; lateral fringe changing rather abruptly from spines to filaments at 0.5-0.7 of distance from base to seta 1-P; paddle fringe extending mesad of seta 1-P as short clear filaments, to mesal angle; seta 1-P, 0.27-0.52 length of paddle.

LARVA (Fig. 18, Table 17). Gray to dark brown, without distinct color pattern. *Head.* With brown pattern on frontoclypeus like *aconitus* except anterior transverse dark band absent and anteriorly projecting lateral longitudinal bands end approximately at seta 4-C level, pattern very similar to musician's tuning fork, incomplete on paler specimens; antenna often brown, particularly on distal 0.67, often paler on basomesal 0.33, 6.13-6.67 as long as widest point, with dark spicules on mesal and ventral surfaces; 1-A inserted on outer dorsal aspect, 0.18-0.30 from base; 4-A with 5-9 branches; 2-C simple, long; 3-C simple, 0.50-0.67 length of 2-C; 4-C simple (rarely bifid on one side), extending cephalad beyond base of 2-C; 6-C with 12-15 branches; 8-C usually dendritic, with 5-10 branches; 9-C with 4-7 branches, not dendritic; 15-C with 7-11 branches. *Thorax.* Usually with 1,2 pairs of small submedian sclerotized plates on dorsum of mesothorax, plates of a pair may be fused; sclerotized bases of setae 1,2-P usually separate, if fused, narrowly connected; 1-P with 18-28 branches; 2-P with 13-19 branches; 9-P with 10-15 branches; 10, 12-P long, simple; 11-P short, with 2-5 branches; 1-M with 24-32 branches; 4-M with 3-6 branches; 3, 5-M simple, with small sclerotized bases, bases may be fused; 9, 10-M long, simple; 12-M simple to trifid, branching on

distal half; 3-T with short thick stalk, 12-18 light brown lanceolate leaflets with blunt tips; 9-T with 4-10 branches; 10-T long, simple; 11-T small simple or bifid; 12-T with 3-5 branches from near base. *Abdomen.* Anterior tergal plates on II-VII very large, usually 0.55-0.75 width of segment, enclosing small median posterior tergal plate; occasionally posterior tergal plate separate on II-III (particularly II) and posterior margin of anterior tergal plate II concave; lateral margins of anterior tergal plates tapered, often broadly rounded; small oval submedian plates usually present on I-VII, separate from anterior tergal plate, infrequently absent; 0-III-VII well developed, largest on IV-V, arising just off, but adjacent to posterolateral edge of anterior tergal plate, infrequently arising on tergal plate adjacent to edge on VI, VII; 0-III, VI-VII, with 1-3 branches from near base, usually bifid; 0-IV-V with 2-5 branches (usually 3) from near base; 1-I-VII with brown, well developed leaflets with distinct shoulders and long slender filaments, leaflets often with dark pigment patch just basal to shoulders; seta 1-I with 11-16 leaflets; 2-I with 3-6 branches; 9-I with 5-7 branches; 1-II with 13-18 leaflets; 5-III with 5-8 branches; 9-III with 6-8 branches; 13-III with 6-11 branches; 6-IV with 3 branches; 13-IV with 5-7 branches; 5-V with 9-11 branches; 6-V with 3 branches; 13-V with 3-5 branches; 1-VII with 16-21 leaflets; 2-VII with 2-4 branches; 2-VIII with 8-14 branches; pecten plate with 4-7 long and 6-10 short teeth; seta 1-S with 8-12 branches; 2-S with 7-11 branches; seta 1-X simple, long, 1.24-1.84 dorsal length of saddle; 2-X basal branches curved, with slender filamentous tips.

EGG. Not well known and needing further study. The following is from Reid (1968). "Length about 0.41 to 0.43 mm with 18-25 ribs on the floats." Other references are Morishita (1932) (upon which Reid based his description) and Wu (1936). Christophers and Barraud (1931) were not certain of the identity of the *minimus* (?) eggs they illustrated.

TYPE-DATA. This species was described from a single female in Dr. Rees' collection from Pokfulam, Hong Kong (Theobald 1901). The specimen was still extant in 1907 because Theobald (1907) noted, "The type is too denuded to place it generically until fresh material is received." However, Theobald (1910) notes "The type of this species I placed in the British Museum collection as far as I can remember. It is not there now, however." Yamada (1925), while examining types in European museums, notes "type of *minimus* Theobald has been probably lost." I found no trace of the type in the BMNH in 1972. The holotype of *minimus*, unless it still exists in a private collection should be considered non-extant. Actually since this species was well described and cannot be confused (see Taxonomic Discussion regarding *fluviatilis*) with any other species in the vicinity of Hong Kong, a type-specimen is not currently essential. If a neotype is ever needed, numerous adults with associated immature skins collected only 20-22 km from Pokfulam (Hong Kong Island) in Sai Kung District, New Territories, are deposited in the USNM.

The type-specimens (syntypes) of *vincenti* Laveran, are located in the Institut Pasteur, Paris (PIP), where Reid (1947) found them. These specimens (3 females) are mounted in balsam on a slide under one coverslip with 2 additional females (probably *jeyporiensis*). This slide has the following label data: "A. vincenti, H^{O}Tonkin, Van Linh"; and was labeled "Type material" by Reid in 1946. I examined these specimens in 1972 and agree with Reid's, identification of them as *minimus*. Two additional Laveran slides labeled *vincenti* are also in the PIP, and each contains 6 adults. Beside *minimus* and *jeyporiensis* there also appear to be specimens of *vagus* or *subpictus* and *maculatus* on these 2 slides. These 2 slides are not considered type-material because they bear labels, "Dong Dang, Tonkin", which was not mentioned in the

original description. The name *vincenti* is a junior synonym of *minimus* by only 6 days. Theobald's Volume I (containing *minimus* description) and II were "tabled" and released for sale on 23 November 1901, while Laveran's names (including *vincenti*) were published (available) as of 29 November 1901.

The syntypes of *formosaensis I* consist of one female and one male mounted in balsam (?) on separate slides. Both slides have the following labels: (1st label) - in Japanese, undeciphered; (2nd label) - "Recd. From F. V. Theobald 1910-396;" (3rd label) - "A. formosaensis I. Tsuzuki;" and (4th label on underside of slide) - " = *minimus* see Christophers Ind. Med. Res. Mem. 3, p. 49. 1924." The last label appears to be J. A. Reid's handwriting. The female is here designated as lectotype. This specimen has: the apical pale, preapical pale and preapical dark palpal bands nearly of equal length; proboscis dark scaled; base of costa without presector or humeral pale spots; vein 1A with 2 dark spots and without a pale fringe spot on the wing margin; vein R without separate accessory sector pale spot; vein R_{4+5} with large subbasal dark spot; and vein Cu_1 with 2 dark spots distal to m-cu crossvein. These are all characters commonly found on *minimus*, therefore I am considering this nominal taxon a synonym of *minimus*. According to the ICZN (Stoll et al. 1964) the renaming of this nominal species to variety *cohaesa* by Dönitz (1903) was unjustified. Possibly Dönitz considered *formosaensis I* and *formosaensis II* as homonyms, however, in Art. 32(c) of the code these would be incorrect original spellings that do not satisfy the provisions of Art. 26(b). If the numerals are spelled out in Latin [Art. 26(b)] and joined to the end of "formosaensis," the names are quite different and cannot be considered homonyms.

The description of *christophersi* was based on 2 females from "Duars India" (Theobald 1902b). Both specimens are in the BMNH, one female in excellent condition (except rubbed scutum and a trace of fungal hyphae) on a pin mount, while the other female is represented by only 2 wings, each dry mounted under a coverslip on a separate slide. The pinned syntype has the following label data: (1st label) - "Duars, Calcutta, Christophers;" (2nd label) - "Anopheles christophersi (Type) Theobald;" and (3rd label) - my personal *minimus* identification label. The label data for the syntype wing slides follows. The right wing slide has 2 labels; (1st) "Culicidae " [Theobald's handwriting in ink] " = minimus" [in pencil]; and (2nd) "Culicidae" [machine printed] "♀ wing from the "Duars' India 'Malarial carrier'" [Theobald's handwriting]. The slide with the left wing has 2 labels: (1st) - "Anopheles christophersi n. sp. ♀ Theobald" [Theobald's handwriting]; and (2nd) - "Duars India, Malaria carrier, Desc. Royal Soc. Lond." [Theobald's handwriting]. The left wing slide is apparently the one shown for *christophersi* on plate 5 in the original description. An additional female from "Duars Christophers" was also found in the BMNH, however, this specimen (covered with fungal hyphae) was not marked as a type by Theobald and is not considered a syntype. According to recommendation 74B, ICZN, a syntype which has been figured, e.g., left wing slide above, should be chosen as the lectotype for a species. I will not follow this recommendation in this case for the following reasons: (1) the only syntype that can definitely be identified is the pinned female, because wing characters (other syntype) are not diagnostic for members of this group; and (2) I am assuming that the 2 above wings (slides) came from the same specimen, and if so, the right wing has at least one *aconitus*-like character, i.e., 3 dark spots on 1A, thus, since *aconitus* does occur in the "Duars" area the identify of these wings is questionable. Accordingly, I here designate the pinned female syntype of *christophersi* as lectotype for this nominal species. This specimen is readily identified by its combination of labels (above). The lectotype agrees with *mini-*

mus in nearly every respect, i.e., no pale scales on proboscis, 1A with 2 dark spots on both wings and without apical pale fringe spots, costa with presector pale spot on both wings, R_{4+5} with prebasal and preapical dark spots and palpi with preapical dark band about half the width of the apical and preapical pale bands.

The holotype for variety *alboapicalis* Theobald, 1910, is also located in the BMNH. This female has the following label data: (1st label) - "Type;" (2nd label) - "Myzomyia listoni var. alboapicalis n.v. type F. V. T.;" (3rd label) - "Meenglas, Jalpaiguri, Duars, India 3-VII-1907, C. Wallich;" (4th label) - "Recd. from F. V. Theobald 1910-396;" and (5th label) - my personal *minimus* identification label. The specimen is in poor condition with only 2 hindlegs and one midleg remaining. In addition, the head with proboscis and palpi (antennae lost) is glued to a cardboard minuten stage below the remainder of the specimen. Theobald described this variety because of the "two very broad white apical bands, almost uniting" on the palpi. This can be seen from one side, however, the preapical dark band is wider when viewed from the other side. Theobald apparently overlooked a patch of pale scales on the venter of the proboscis, which caused Christophers (1916) to consider this specimen as possibly equal to *aconitus*. I have examined this specimen and it cannot be *varuna* because it has dorsoapical pale scales on the midtarsomeres and a separate accessory sector pale spot on vein R. I have not seen these 2 characters on *varuna*. The majority of characters indicate it is *minimus* with a ventral patch of pale scales on the proboscis (see Variations section).

DISTRIBUTION (Fig. 17). *Anopheles minimus*, like *aconitus*, has a very wide distribution in the Orient. However, *minimus* seems better adapted to temperate conditions and occurs up to 30°N latitude in India and the People's Republic of China, and probably does not occur further south than 6°N latitude. In contrast, *aconitus* thrives in Indonesia on and south of the equator, and probably only manages to reach 25-26°N latitude in Nepal. The range of *minimus* appears to extend from Uttar Pradesh down to the northeastern tip of Andhra Pradesh in India across the Indochina-Malay peninsular countries down to the Thai-Malay border and north across the People's Republic of China (up to 30°N latitude) to Taiwan and the Ryukyu islands. A more precise distribution follows: BANGLADESH; BURMA; CAMBODIA; INDIA (Andhra Pradesh, Assam, Bengal, Bihar, Orissa and Uttar Pradesh); JAPAN (Ryukyu islands - Miyako and Yaeyama Gunto); LAOS; PENINSULAR MALAYSIA (Perlis); NEPAL; PEOPLE'S REPUBLIC OF CHINA (Chekiang, Fukien, Hunan, Kiangsi, Kwangsi, Kwangtung including Hainan Island, Kweichow, Szechwan and Yunnan); TAIWAN; THAILAND; and VIETNAM. The above distribution is quite conservative in comparison to that of some other authors, e.g., Reid (1968). This difference is due, in part, to the elevation of *flavirostris* to species status (Baisas 1957, 1974), which eliminates the Philippines and Indonesia from the *minimus* distribution. Although there are old published records of *minimus* sensu stricto, based on adults, from Sumatra and Java, I suspect these will prove to be *flavirostris* when the pupal stage (diagnostic for these 2 species) is examined. Another reason the above distribution is conservative is because I used only confirmed records (Christophers and Puri 1931, Christophers 1933) of this species from India. Christophers (1933) also noted other unconfirmed records from southern India and Sri Lanka (as Ceylon) and more recent authors, e.g., Krishnaswami (1961), have tended to use the broader distribution. More recent large scale collections from Madras (Reuben 1971, Rahman et al. 1975), Madhya Pradesh (Prakash and Husainy 1974a) and Sri Lanka (Harrison et al. 1974) failed to collect *minimus*, and thus support the Christophers and Puri

(1931) distribution of *minimus* in India. Carter (1950) noted that he had not seen *minimus* from Sri Lanka (as Ceylon) even though Christophers (1933) recorded it from there. Most of the southern Indian records for *minimus* originated during the period 1915-30, when there was considerable controversy about the names of the members of the Minimus Group. These early records were probably based on *varuna*, which looks very much like *minimus* and was not described until 1924.

The first references to *minimus* in Thailand were Barnes (1923a, b), who collected one female in Bangkok. This record was simply repeated by Christophers and Puri (1931), however, Anigstein (1932) found *minimus* common in the northern and certain southern regions of Thailand. Payung-Vejjasastra (1935) incriminated (by dissection) *minimus* from Nakhon Si Thammarat (Tung Song), as a vector of human malaria parasites. Causey (1937), using a light trap, confirmed Barnes' earlier record of *minimus* from Bangkok, but was not able to find larvae of this species. De Fluiter (1948) and Wilson and Reid (1949) reported they collected *minimus* in the vicinity of prisoner-of-war camps in western Thailand (Kanchanaburi) during World War II, and that they suspected this species was a vector of malaria parasites at that time. In 1949, an intensive antimalaria campaign was started in Thailand which rejuvenated mosquito surveillance programs. Consequently, as noted by Scanlon, Peyton and Gould (1968), there are records of *minimus* from many Thailand provinces in the files of the Ministry of Public Health. Scanlon, Peyton and Gould (1968) recorded *minimus* from 12 provinces in Thailand, and an additional 8 provinces can be added to the list from this study. This species is recorded from the following 20 provinces of THAILAND: Chiang Mai, Chon Buri, Kanchanaburi, Lampang, Loei, Lop Buri, Mae Hong Son, Nakhon Nayok, Nakhon Ratchasima, Nakhon Sawan, Nan, Phattalung, Phitsanulok, Phrae, Prachin Buri, Rayong, Sara Buri, Trang, Ubon Ratchathani and Yala. The specimens from Trang (collected in 1959-60) were found in the Malaria Eradication Training Center collection, Manilla, Philippines, and the BMNH. The old records of *minimus* from Krungthep Maha Nakhon (= Bangkok) are not continued here, as the environment in the central rice plain area surrounding Bangkok has been drastically altered in the last 30 years, and *minimus* has not been recorded from the area since Causey (1937).

Anopheles minimus is known as an inhabitant of hilly regions with small cool clear-water streams and this is precisely the habitat in which it most often occurs in Thailand. This species should be expected in most foothill-mountainous areas. In the past *minimus* was probably able to invade broad valley areas, e.g., Chiang Mai, Bangkok and southern Thailand, but in recent years increasing pollution and the DDT house-spray malaria control program have eliminated it from such less typical habitats. One area which clearly shows this trend is most of southern Thailand where *minimus* is now either very uncommon or has been eliminated. Iyengar (1953) did not collect *minimus* during his filariasis survey in southern Thailand, and personal collections in 6 southern provinces in 1969 failed to produce any specimens of *minimus* (see Bionomics section). Sandosham et al. (1963) failed to find *minimus* in Perlis, Malaysia, just south of the Thai border, where Reid (1950b) first recorded this species in Malaysia, and speculated that *minimus* in Perlis had been eliminated by the malaria spray program. The distribution of *minimus* on the Korat Plateau is unknown due to limited collections. Since the plateau is primarily a flat rice growing region, *minimus* is probably absent in most areas and confined to the hilly-mountainous border or isolated hilly areas. Additional information pertinent to the distribution of this species can be found

in the BIONOMICS section.

A total of 16,049 *minimus* specimens were examined during this study (1,575♂, 6,951♀, 1,100 larvae, 2,981 larval skins and 3,442 pupal skins). Specimens examined from THAILAND include 479♂, 5,652♀, 603 larvae, 954 larval skins and 1,148 pupal skins from adult and immature collections; and 765♂, 854♀, 77 larvae, 1,387 larval skins and 1,572 pupal skins representing progeny from 137 females collected in Sara Buri Province. Additional specimens (331♂, 445♀, 420 larvae, 610 larval skins and 722 pupal skins) were examined from the following countries: BURMA; CAMBODIA; HONG KONG; INDIA; JAPAN (Ryukyu islands - Miyako and Yaeyama Gunto); PENINSULAR MALAYSIA (Perlis); NEPAL; PEOPLE'S REPUBLIC OF CHINA; TAIWAN; and VIETNAM. Included among these last specimens were the type-specimens of *formosaensis I, christophersi,* and var. *alboapicalis* in the BMNH and the type-specimens of *vincenti* in the PIP. Included in the Hong Kong specimens were 312♂ and 398♀ with associated immature skins and 420 larvae which were collected and reared in Sai Kung District of the New Territories, in 1969. These specimens were collected specifically for a study of variations occurring on topotypic *minimus* specimens (see Variations section).

VARIATIONS (Figs. 3, 6; Tables 5-7, 11, 17). This is another highly variable species, which because of its variability and similarities to other members of the Myzomyia Series, has often been misidentified. These variations can cause *minimus* to resemble *aconitus, flavirostris, fluviatilis, mangyanus* or *varuna* with all degrees of intermediacy. Since *minimus* is a renowned vector of human malaria parasites this identification problem can be a real hindrance to public health officials.

Early workers such as Christophers (1916), Iyengar (1924) and Strickland (1924) recognized *minimus* as variable, however, due to taxonomic instability and vacillating synonymy listings their definition of *minimus* is uncertain. In the 1930's, this instability was mostly resolved by: Evans (1930), who showed that *funestus* from Africa was distinct from the Oriental species; King (1932), who evaluated variations found on females, male genitalia and larvae of *minimus* and who firmly established the identity of the 3 Philippine members of the series; Edwards (1932), whose catalog resolved most of the problems of synonymy; and Christophers (1933), whose thorough descriptions and species treatments remain a major reference to this day. Christophers recognized *minimus* as having variable palpal banding (but not pale on distal third or like those of *fluviatilis*), proboscis dark or with small ventral pale area, vein 1A rarely with a pale fringe spot, the costa presector pale spot very constant, Cu_1 usually with 2 dark spots beyond the m-cu crossvein and the remaining wing characters too variable. Toumanoff (1936) conducted an analysis of variations occurring on the wings of 400 wild female *minimus* from northern Vietnam compared with 100 females from southern Vietnam. His results showed the southern specimens with paler wings. Some specific differences included: (1) costa with presector pale spot, 61% north, 100% south; R sector pale spot fused with accessory sector pale spot, 77% north, 100% south; Cu_1 with 2 dark spots (versus 1) distal to m-cu crossvein, 58% north, 92% south; 1A with 2 dark spots, 90% north, 100% south; and 1A without pale fringe spot, 95% north, 100% south. Toumanoff also noted that 2% of the northern *minimus* larvae had seta 4-C bifid, instead of simple. One bias found in Toumanoff's data during the present study was the probable inclusion of *pampanai* specimens among his "*minimus*" (see *pampanai* Variations section). Ho (1938) found similar variations in a series of only 14 females of *minimus* from Hainan Island. Ho was apparently the first to note that *minimus* palps can vary from

entirely pale on the distal third to like those of *fluviatilis* (this latter variation had previously been noted (Evans 1930) on one *minimus* female from Hong Kong). In fact, Edwards (1935) recorded *fluviatilis* from Hong Kong (see *fluviatilis* section). Macan (1948) found *minimus* adults from western Burma very variable and arrived at the same conclusion as Toumanoff (1936), i.e., the only constant character to differentiate *aconitus* from *minimus* is the pale proboscis on *aconitus*. An outstanding study was conducted by Liu et al. (1959) in Yunnan Province, People's Republic of China. These authors, after years of identifying adults as *varuna* based on the absence of a costa presector pale spot, but never finding *varuna* larvae, conducted an analysis of the presector spot character on progeny reared from wild females and confirmed by their associated larval skins. They determined that 81.5% (4,302/4,945) of the wild *minimus* in their study lacked a costa pale presector spot and thus, would be called *varuna*. Of the reared progeny, 89.8% (123/137) lacked the presector pale spot, and progeny from a given wild female exhibited both extremes and the intermediate state, i.e., presector pale spot on one wing, but absent on the other. Liu et al. concluded: the *varuna*-like adults were actually *minimus;* the study of progeny adults with associated immature skins was essential for solving such problems; and the same *minimus* variations found in Yunnan also occurred in Kweichow Province. Reid (1968) also has a good discussion of the variations occurring on *minimus* adults and larvae, and the status of *flavirostris* as a subspecies of *minimus*. Prior to Baisas (1974) and Knight and Stone (1977), *flavirostris* was generally considered a subspecies of *minimus*, even though Baisas (1957) suggested that it be elevated to species status. Now that *flavirostris* has been separated from *minimus*, the variations on *minimus* are more easily defined.

My search for variations on *minimus* involved the examination of wild females and progeny from wild females for 22 different characters, primarily on the wings. A total of 2,264 female *minimus* collected as adults or reared from 4th-stage larvae were examined from Thailand. These specimens originated from collections (January 1968-June 1970) in Chiang Mai, Lop Buri, Nakhon Nayok and Sara Buri provinces. An additional 449 females collected as adults or reared from 4th-stage larvae, were examined from the New Territories, Hong Kong. These specimens (mostly reared) were collected in October 1969, by the author and Mr. Prajim Boonyakanist, so that variations could be analyzed for topotypic *minimus*. Progeny examined included 854 females and 765 males reared with associated immature skins from 137 wild females collected in Sara Buri Province, Thailand. These progeny exhibited the same broad pattern of variations as seen on *aconitus* progeny. Progeny from a given female were highly variable, not having any particular set pattern, including one similar to that of the female parent. Although a wide spectrum of different wing, proboscis and/or palpal variations appeared in single broods, the average number of variations occurring per *minimus* brood was less than that occurring per *aconitus* brood. This reduction was probably a reflection of fewer *minimus* surviving to adult in each brood. *Anopheles minimus* sibling broods averaged nearly 12 adults reared, while *aconitus* broods averaged almost 21 adults. Only a few "clinal" trends as discussed under *aconitus*, were detected in the wild adults in Thailand. Furthermore, there was little evidence of the effect of temperature on characters of reared progeny. However, this could also be due to the low survival rate of *minimus* and sampling bias. Some differences between the Hong Kong and Thailand specimens may be indicative of clinal color trends.

Table 5 shows the frequencies for 12 selected characters on *minimus*.

TABLE 5. Frequency (*f*) of selected characters on feral females and progeny of feral female *An. minimus* from Thailand and Hong Kong.

Characters	Feral ♀♀				Progeny from 137 Thai ♀♀			
	Hong Kong (449)*		Thailand (2,264)		♀♀ (854)		♂♂ (765)	
	f	(No.)	*f*	(No.)	*f*	(No.)	*f*	(No.)
Proboscis with small ventral pale patch	0.013	(6)	0.061	(137)	0.057	(49)	0.0	(0)
Palpus with distal third or club pale or nearly so	0.045	(20)	0.171	(338)	0.184	(157)	0.103	(79)
fluviatilis-like palps	0.038	(17)	0.015	(35)	0.004	(3)	-	
Costa with prehumeral and/or humeral pale spot (one)**	0.009	(4)	0.023	(52)	0.025	(21)	0.013	(10)
Costa with presector pale spot (both)**	0.991	(445)	0.979	(2,218)	0.975	(833)	0.933	(714)
R sector and accessory sector pale spots separate (one)	0.229	(103)	0.130	(30)***	0.146	(125)	0.184	(141)
R_2 and/or R_3 with median pale spot (both)	0.002	(1)	0.017	(39)	0.047	(40)	0.009	(7)
R_{4+5} with basal dark spot (one)	0.991	(445)	0.965	(2,185)	0.923	(788)****	0.983	(752)****
Cu fork pale (one)	0.018	(8)	0.018	40)	0.019	(16)****	0.005	(4)****
Cu_1 with one long dark mark beyond m-cu crossvein (both)	0.125	(56)	0.029	(65)	0.032	(27)	0.302	(231)
1A with 3 dark spots (both)	0.011	(5)	0.015	(35)	0.029	(25)	0.0	(0)
1A with pale fringe spot (both)	0.0	(0)	0.013	(30)	0.015	(13)	0.0	(0)

*Total number of specimens examined.
**(One) or (both) means character on at least one wing or on both wings.
***Only 230 (not 2,264) specimens checked.
****Counted only if on both wings.

These characters have been and are still important in differentiating *minimus*. However, as with *aconitus*, there are no totally reliable characters that will identify every specimen. Thus, workers in the field should not rely on only 1, 2 characters, e.g., PSP on costa and/or dark proboscis, but should use at least 3-5 characters, e.g., proboscis PSP on costa, R_2 without median pale spot, 1A with 2 dark marks and 1A without pale fringe spot.

Examination of 449 wild Hong Kong *minimus* revealed only 16 of the 22 variations found on 2,264 wild Thailand specimens, which in part, may be a reflection of the number of specimens sampled. However, a number of the differences in character frequencies between these 2 populations were found significant, even highly significant (X^2 with df = 1), indicating factors besides sample size were involved. An increase in the hypermelanic traits (*fluviatilis*-type palps, dark proboscis, fewer pale palps, R_2 or R_3 without median pale spot, Cu_1 dark marks, 1A without pale fringe spot, R sector and accessory sector pale spots separate and R_{4+5} with prebasal dark spot) on the more northern (23° N latitude) specimens from Hong Kong, compared with Thailand specimens (14-19° N latitude) offers good evidence for a color cline in *minimus* characters as found on *aconitus*. A darkening trend in *minimus* in the more northern latitudes is also supported by Toumanoff (1936) and Liu et al. (1959). Actually, *minimus* in Hong Kong appears less variable than in Thailand, possibly suggesting the habitat in Thailand is more optimum.

The frequency of *minimus* specimens from Hong Kong exhibiting *fluviatilis*-type palpi offered good evidence for eliminating *fluviatilis* records from Hong Kong. Such specimens were infrequent, always reared from typical *minimus* larvae and pupae and always mixed in with regular *minimus* specimens as well as some specimens having palpi intermediate between *fluviatilis* and *minimus*. The absence of collections consisting of large numbers or entirely of *fluviatilis* from Hong Kong as well as Thailand indicates *fluviatilis* does not occur in these 2 countries. See *fluviatilis* section for further discussion.

Several *minimus* females from Hong Kong had a *varuna*-like habitus like those reported by Liu et al. (1959), however, the associated immature skins were used for confirmation. This situation was encountered more frequently in Thailand, and has been responsible for several false records of *varuna*.

Some additional or unusual wing variations seen on wild female *minimus* from Hong Kong (HK) and Thailand (T) include: costa with prehumeral or humeral pale spot, HK-0.007 (3/449), T-0.013 (30/2264); R_1 with accessory pale spot on preapical dark mark, HK-0.031 (14/449), T-0.018 (40/2264); R_{4+5} nearly entirely dark, HK-0.007 (3/449), T-0.003 (7/2264); M_{1+2} with pale median spot, HK-0.0 (0/449), T-0.014 (32/2264); Cu without basal dark mark, HK-0.007 (3/449), T-0.004 (8/2264); 1A entirely dark except at base, HK-0.007 (3/449), T-0.025 (56/2264); 1A without basal dark spot, HK-0.018 (8/449), T-0.003 (7/2264); costa with preapical pale spot very small or absent, HK-0.022 (10/449), T-0.009 (21/2264); R with accessory pale spot between sector and subcostal pale spots, T-(3/2264); and costa with pale spot between subcostal and preapical pale spots, T-(2/2264). Most of these variations were also seen on the Thailand progeny specimens.

Differences were found in the frequencies of several characters checked on male and female progeny. Those of most interest were: costa with prehumeral and/or humeral pale spots - ♀ - 0.025 (21/854), ♂ - 0.013 (10/765); costa with presector pale spot (Table 5); R_1 with pale spot on preapical dark mark - ♀ - 0.040 (34/854), ♂ - 0.008 (6/765); R_2 and/or R_3 with median pale spot (Table 5); Cu_1 with one long dark mark beyond the m-cu crossvein (Table 5); 1A with 3 dark spots (Table 5); and 1A with pale fringe spot (Table 5). For all

characters checked, males were darker than females, possessing fewer pale spots and larger dark marks. This trend was also found on *aconitus* males, which usually look very similar to *minimus*.

Morphologically deformed variants were found among wild females and adult progeny of *minimus*, but not as frequently as in *aconitus*. No attempt was made to isolate these traits. Five of the traits appear identical to variants seen on *aconitus* (see *aconitus* discussion for heritability status). These 5 traits and their recovery rates in *minimus* were: (1) Short palps - 1/2,264 wild females, 17/854 progeny females and 1/765 progeny males; (2) Wartoid or warted palps - 2/2,264 wild females, 6/854 progeny females and 8/765 progeny males; (3) ?Unilateral or uneven palps - 1/2,264 wild females; (4) Anal vein interruption - 5/854 progeny females and 1/765 progeny males; and (5) M_{3+4} interruption - 2/765 progeny males. An additional variant was found that appears to be identical to a trait isolated in *Aedes aegypti* (Vandehey and Craig 1962) and was also found on a single specimen of *An. quadrimaculatus* (Kitzmiller and Mason 1967). This trait, notch wing, was found on one wing of one female from Hong Kong. Eventually all of these traits will probably be found heritable and of use in cytogenetic studies.

The primary pupal variations involve setal branching (see Table 11). The color of *minimus* pupae ranges from nearly transparent to dark brown. Darker specimens are not uniformly pigmented as are *aconitus* pupae, but have a pattern of darkened areas on the cephalothorax and the metanotal plate. These specimens have a dark area dorsally in the vicinity of setae 4, 5-CT, dorsally between the trumpets and dorsally on the metanotal plate. The male genital lobes are unicolorous instead of having transverse dark bands. Strickland (1924), probably the first to describe *minimus* pupae, noted that Assam specimens had seta 1-V-VII (as submedian) long and simple or double. However, Reid (1968) stated that seta 1-V is usually branched on *minimus*, compared to simple on *fluviatilis*. This seta is usually simple on Hong Kong or Thailand *minimus*. While this seta may have up to 5 branches, it was simple in 32 of 50 setae examined from Thai *minimus* pupae.

Larvae of *minimus* were found to be more variable than anticipated. Although exceptions to the key characters were found, these characters were still valid for 99% of Thailand specimens. Some notable variations were: seta 4-C bifid (8/1,141), 3 on both sides; 1,2-P bases fused (narrowly) on approximately one-third of the specimens examined; 0-IV,V with 2-5 branches (mode 3); 0 rarely arising from the anterior tergal plates on VI, VII and one specimen on IV-VII; anterior tergal plate II concave on the caudal margin with separate posterior tergal plate with a 0-85% frequency (usually low) depending on the collection. Büttiker and Beales (1959) indicated the bases of 1,2-P were normally separate and that anterior tergal plate II was usually convex posteriorly and enclosing the posterior tergal plate on *minimus*. However, a significant proportion or even majority of larvae from given collections examined here had 1,2-P bases fused and ATP-II concave on the caudal margin. The degree of sclerotization of these characters (also including small mesothoracic submedian plates) may be influenced by some unknown environmental factor(s) (also see *aconitus* Variations discussion). Reid (1968), following Christophers (1933) suggested that *fluviatilis* averages more branches (2-5) on seta 0-III-VII than *minimus*. However, Thailand *minimus* typically have 0-IV,V with 2-5 branches (mode 3), while 0-III, VI-VII is usually simple to 3,4 branches (mode 2). I currently do not know any characters to separate the larvae of these 2 species.

A number of anomalous setal variations were seen on *minimus* larvae,

including: 2-C bifid; 2-C flattened and leaflet-like; 3-C bifid or with a lateral branch; 4-C dendritic with 6 branches like a frontal seta; 8-C bifid; and 9-C arising next to 8-C on the frontoclypeus. DeBurca and Forshaw (1947) found 182 of 357 *fluviatilis* larvae with bifid 3-C and/or 2-C during the cold winter months (30° N latitude) in Uttar Pradesh, India. Further south (18° N latitude) in Maharashtra where the temperature was much milder during the winter, they found only 10 of 250 larvae with such variations. These authors also noted hypermelanism on adult *fluviatilis* wings during the cold months and called these wing and the above larval variations, "winter variations." High frequencies of *minimus* "winter variants" have not been detected in Thailand, which only extends to about 21° N latitude.

Characters on adults and immatures of *minimus* in Thailand and Hong Kong were found highly variable during this study. These variations, like those found on *aconitus*, appear to be of a continuous nature, with numerous intermediate character states and offering no evidence of polymorphism. *Anopheles minimus* is apparently occupying a near optimum habitat in central and northern Thailand, and this is reflected in its phenetic plasticity. Previous studies in the People's Republic of China and Vietnam suggest that *minimus* becomes more melanistic with increasing northern latitude. This study provides additional data, i.e., comparisons of character frequencies between Hong Kong and Thailand specimens, supporting this trend. Despite the variations outlined above, a majority of females from any given collection in Thailand should be identifiable on the basis of the key characters. A few specimens, however, will be intermediate and best identified as Minimus Group.

TAXONOMIC DISCUSSION. *Anopheles minimus* is still a common species in many of the central and northern foothill and mountainous areas of Thailand. Wherever it is encountered certain individual adult females may be very difficult to identify due to overlapping variations with other members of the Minimus Group. During this study *minimus* females have been found in Thailand with a habitus identical or nearly identical with that described for *filipinae*, *flavirostris*, *fluviatilis*, *mangyanus* and *varuna*. In each case (except for *fluviatilis*, see p. 21), however, associated larval and pupal skins have shown these specimens to be *minimus*. In the case of *varuna*-like specimens, the adults also had typical *minimus* foretarsomere pale bands or dorsal spots. The *fluviatilis*-like adults were identified as *minimus* because they had a habitus identical with that of infrequent progeny adults reared from "typical" *minimus* mothers. In addition, *fluviatilis*-like adults are rarely collected in Thailand, and then only as individuals, never in groups. Specimens having a habitus nearly like *aconitus* are not uncommon. However, these specimens have at most a small ventral pale patch of scales on the distal half of the proboscis, rather than the extensive pale scales normally found on the proboscis of *aconitus*. On the other hand, infrequent *aconitus* may have reduced pale scaling on the proboscis and rare specimens may have this structure entirely dark. Based on these overlapping variations, at least 2 of the characters which Christophers (1933) considered most reliable for *minimus*, i.e., costa with presector pale spot and proboscis with pale patch on distoventral aspect, need to be reevaluated on a more realistic regional basis. The presence of a costa presector pale spot may be indicative of *minimus* in Hong Kong, most areas of India, southern Vietnam and Thailand, but in northern Vietnam 39% of the specimens lacked this spot (Toumanoff 1936) and in southwestern China (P. R. of China) 81% lacked this spot (Liu et al. 1959). Possibly the frequency of this spot is influenced by the temperature of the immature habitat, however, seasonal data are not available for these last 2 reported studies. Character displacement

(Brown and Wilson 1956, Mayr 1963) may also be involved, and this would help explain why the presector spot is so constant in India where *minimus* is sympatric (in part) with *fluviatilis* and *varuna*. In northern Thailand, where *fluviatilis* is absent and *varuna* rare, specimens of *minimus* having the presector pale spot absent are not uncommon, particularly in the cool season.

The status of the proboscis-pale scales character needs a total reevaluation. Christophers (1933) statement about this character was made when the Philippine species, *flavirostris*, which normally has a pale patch on the proboscis, was considered a subspecies of *minimus*. Now that this taxon *(flavirostris)* has been raised to species status, the characters of *minimus* must stand alone. Data from my study indicate that only 1.3% of the Hong Kong and 6.1% of the Thai female *minimus* possessed a pale scale patch on the venter of the proboscis. A character with such a low frequency cannot be considered characteristic of *minimus*, as claimed by Christophers (1933). This character must now be considered unusual and a hindrance to quick identification in areas where *minimus* is sympatric with *aconitus* and *varuna*. These last 2 species have variants with only a few pale scales on the proboscis. While such variants are uncommon in *aconitus*, they are more common on *varuna* (7/14 Sri Lanka females, 1/4 Thai females). In areas (e.g., Hong Kong) where *minimus* is the sole representative of the *minimus* group this character is too unusual to be of much value.

Separating adult *minimus* and *aconitus* can usually be accomplished by the key characters, but additional characters are also useful, including: the presence of absence of a presector pale spot; and R_2 with or without a median pale spot. Several other characters may also help, but they are more subjective and will become obvious only with experience. They are: pale scales (general color) - pure white to silver-white *(minimus)*, dull white to slightly yellow *(aconitus)*; scutum color - gray-buff to dark brown laterally *(minimus)*, tan to orange-brown laterally *(aconitus)*; and scutal seta-like scales - silvery-white, fairly easily seen and extending back to scutellum *(minimus)*, dull white to slightly yellow, hard to see and often extending back only to anterior margin of prescutellar bare space *(aconitus)*. These differences should not be considered reliable for colonization, hybridization studies and similar projects. Only progeny or wild reared males confirmed by associated immature skins should be used in such studies.

Infrequent Thai specimens of *minimus* (wild and progeny) had humeral as well as presector pale spots on the costa, and several females with this condition were seen from Miyako and Yaeyama, Ryukyu islands. Ho (1938), working on specimens from Hainan Island, is apparently the only other author to note this variant of *minimus*. Specimens with this extra wing spot have a habitus identical to that of *mangyanus*, which I believe is confined to the Philippines. The most logical explanation for the record of *mangyanus* in Nepal (Brydon et al. 1961) is a *minimus* with the humeral spot variation, rather than *pampanai* as suggested by Reid (1968). *Anopheles minimus* is common in Nepal, while the nearest confirmed record of *pampanai* is slightly over 1,000 km away in Lashio, Burma.

Conceivably, the record of *filipinae* (one specimen) in Nepal (Pradhan and Brydon 1960) may also be due to a *minimus* specimen having several variations, however, it is more likely the specimen was an *aconitus* variant (see *aconitus* Variations section). Seven wild females from Thailand and one from Hong Kong also possessed prehumeral pale spots on the costa. Five of these specimens had these spots in addition to humeral and presector pale spots, and 5 (including the Hong Kong specimen) were reared and confirmed as *minimus* by

their associated immature skins. This character was also found on progeny adults. Prehumeral pale costal spots were not seen on either wild or progeny *aconitus*.

Specimens of *minimus* having either prehumeral or humeral costal pale spots in conjunction with presector pale spots may be confused with *pampanai*, however, gray-black scales on the remigium apex-R base are indicative of *pampanai* and unique in the Minimus Group.

The pupa of *minimus* in Thailand is easily identified on the basis of the position and development of seta 0-III-VII. In the past, seta 1-V-VII has been used to differentiate *minimus* from *aconitus* in Thailand. This character is now known to be unreliable. There are a number of additional characters other than seta 0 that will separate these 2 species, these are discussed at length in the *aconitus* Taxonomic Discussion section.

Reid (1968) suggested that pupae of *fluviatilis* and *minimus* could be separated on the basis of seta 1-V being simple on *fluviatilis*, while usually branched on *minimus*. As discussed above (Variations section), 1-V on Thai *minimus* is usually simple like that of *fluviatilis* (India). To date, I have been unable to find reliable characters to separate the pupae of *fluviatilis* and *minimus*.

In addition to the seta 0 character, there are a number of other characters that will separate *minimus* pupae from those of *pampanai* and *varuna*. Seta 1-V-VII may be of value, although not totally reliable because of overlapping variation. These setae are usually simple on *minimus* (1-V, 1-5 branches, mode-simple; 1-VI, 1-3 branches; mode-simple; 1-VII, 1-4 branches, mode simple), while they have 2-4 branches (mode 3) on *pampanai* and 3, 4 branches (mode 3) on *varuna*. Additional characters that may help to separate *minimus* from *pampanai* include: setal branching on 3, 4-I, 3-II, III and 7-IV; 9-II located at posterolateral corner *(minimus)*, cephalad of posterolateral corner *(pampanai)*, 9-III transparent, slender and needle-like *(minimus)*, pigmented, stout and shorter *(pampanai)*; and *pampanai* paddle without fringe mesad to 1-P, which is unique in Minimus Group (see *pampanai* discussion). Other characters that may assist in the separation of *minimus* and *varuna* pupae are: setal branching on 3-I, 1-II; 9-III transparent, slender and needle-like *(minimus)*, pigmented, stout and shorter *(varuna)*; paddle refractile margin - 0.63-0.85 *(minimus)* and 0.89-0.96 *(varuna)*; paddle lateral fringe - on *minimus* short spines change rather abruptly into long filaments at 0.5-0.7 of distance from base to seta 1-P, on *varuna* short spines gradually changing to short filaments at 0.77-0.88 of distance from base to setal-P; and shape of the trumpet.

Pupae of *minimus* are easily separated from those of *culicifacies* and *jeyporiensis* by seta 7-VI, VII and the position and development of seta 0-III-VII. There are also reliable differences in the number of branches on setae 4, 9-I and 1-II-IV. The pupa of *culicifacies*, like *pampanai*, does not have a paddle fringe mesad of 1-P, while that on *minimus* extends to the mesal angle. In general, setae on *minimus* pupae have more branches than those on *culicifacies*, *jeyporiensis* and *majidi*.

The identification of *minimus* larvae in Thailand is easy. Without *fluviatilis* to cause confusion, *minimus* is the only species with large, usually branched, seta 0-III-VI arising on the integument posterolaterad of the large anterior tergal plates. Infrequent specimens may have 0 arising from the plate edge on VI, VII, but these should not cause identification problems. Several larvae from Chiang Mai Province had previously been identified as *culicifacies* because the anterior tergal plates on II-VI were smaller than normal and left the posterior tergal plate and the small submedian plates separate. These

specimens were easily identified to *minimus* by the large seta 0-IV, V, simple 2-4-C, dendroid 8-C and the shape of the median plate on the spiracular apparatus.

Larvae of *minimus* are very distinct from *aconitus* and *jeyporiensis* based on the numerous barbs on 2, 3-C on these last 2 species. Additional characters to separate *aconitus* from *minimus* larvae are listed in the *aconitus* Taxonomic Discussion section.

Actually, *minimus* larvae are most likely to be confused with *pampanai* in Thailand. Both species have simple 2-4-C, large anterior tergal plates and relatively blunt filaments on 3-T, however, there are several reliable characters other than seta 0 for differentiating these 2 species (see *pampanai* Taxonomic Discussion).

Although *varuna* is apparently rare in Thailand and normally has several fine barbs on 2-C, it is likely that occasional specimens will have 2-C simple. In such cases larvae of this species could easily be confused with *minimus* if the seta 0 differences were overlooked. Possibly the next best character for separating these 2 species is 3-T, which has leaflets with long, fine filamentous tips on *varuna*. but short relatively blunt tips on *minimus* leaflets (see Figs. 18 and 24). Other characters that may be useful in separating these 2 species are: number of setal branches on 6-C, 2, 9-I, 1-II, 9, 13-III (size also) and 5-V; 1-X length/saddle dorsum (midline) length, 1.24-1.84 on *minimus* and 1.85-2.16 on *varuna;* and development of 2-X basal branches, slender and curved on *minimus* and stout and straight on *varuna*.

Anopheles minimus is a very distinct species in Thailand, where it can usually be recognized in the adult female, pupal and larval stages. In India, however, where *fluviatilis* and *minimus* are sympatric only the adult females are phenetically differentiated. The obvious similarities of these 2 species suggest they are very closely related, however, the current lack of differences in immatures may be a reflection of the lack of comparative studies. Based on an analysis of 18 adult and immature characters used in this study, *fluviatilis* is the most closely related species to *minimus*, followed by *flavirostris*, *mangyanus*, *pampanai* and *varuna* in that order, with *aconitus* and *filipinae* showing the fewest similarities.

Unlike *aconitus*, the distribution and abundance of *minimus* in Thailand during the last 30 years has been altered considerably by pesticides, pollution and alteration of stream habitat. Due to its anthropophilic behavior *minimus* has been virtually eliminated in some areas where it originally existed on a marginal basis. In other areas under DDT regimens, selection pressure on *minimus* has favored a more zoophilic behavior. Some of the collection sites used during this study maintained large *minimus* populations without malaria. As seen in the Bionomics section, *minimus* in these areas were more readily collected from bovine baits than human baits. The effect that selection pressure toward zoophilic behavior has had on morphologic variation on *minimus* is unknown. However, since most genes are thought to be pleiotropic it would be unwise to think that morphologic variation was not involved in such a change. Accordingly, the variations and particularly their frequencies noted during this study in Thailand represent data taken from altered *minimus* populations and thus may not be comparable to *minimus* that existed in Thailand prior to 1947.

Baba (1950), while working in the Canton Delta, South China, apparently collected eggs of *minimus* which looked different from those of *minimus* sensu stricto. He designated these *minimus* subspecies X, and gave differentiating characters in a key to eggs. The adults and larvae were not separable from

those of *minimus* sensu stricto. This one letter name violates Art. 11(g)i of the ICZN and must therefore be considered an unavailable name.

BIONOMICS. Whereas *aconitus* has probably profited by association with man, *minimus* may be losing its competition with man. *Anopheles minimus* is a feral species with oviposition preferences for small to moderate sized streams of clear, cool unpolluted water that are partially shaded with grassy margins and have slow to moderate currents. Such natural streams are normally found in foothill regions or valleys in mountainous areas. Apparently artificial habitats approaching these requirements have also been created by man during irrigation projects and deforestation-land development projects. These artificial habitats are often temporary, producing large numbers of *minimus* for some years, then degradation of the habitat proceeds until *minimus* becomes uncommon. The anthropophilic tendencies of *minimus* may have developed by association with small human (or primate) groups who found the small stream environment an excellent place for hunting, and source of water for farming and temporary or permanent dwellings. Such early groups and current hill tribes in northern Thailand practice slash-and-burn farming techniques which opens up the forest and temporarily creates favorable oviposition sites for *minimus* in associated streams. The human population explosion in this century is apparently destroying this relationship. Increasing numbers of humans need more land and the forests have been altered to the extent that many of the streams become silty, sluggish and those nearest man too polluted for *minimus*. Habitat destruction and insecticides (both agricultural and for malaria control) have apparently reduced the distribution of *minimus* in Thailand considerably during recent years.

Despite claims to the contrary (Bruce-Chwatt 1970) *minimus* is still frequently encountered in central and northern Thailand. Immatures have been collected in Thailand at elevations between 45-1,000 m. Elsewhere, collections have been recorded up to 1,524 m in Assam (Christophers 1933), 1,500 m in Vietnam (Lysenko and Tang-Wang-Ngy 1965), 1,450 m in Laos (Lefebvre 1938), while Khin-Maung-Kyi (1970) noted it had not been collected at elevations over 914 m in Burma. Further west in Nepal, there are significant elevation (= ecological) differences between *minimus* and *fluviatilis*, i.e., *minimus* only up to 671 m, while *fluviatilis* occurs up to nearly 1,829 m (Pant et al. 1962).

Immatures of *minimus* have been collected in the following habitats in Thailand: stream margins (primary collection site), rock pool, sand pool next to stream, seepage pools or springs, stream pools and fallow rice fields with seepage water. Except for the rice fields these larval sites were usually associated with the fringe or edge of primary or secondary bamboo forests, secondary wet forests, secondary scrub and secondary deciduous forests. Large collections were also made from meandering streams bordered by scattered trees in cultivated areas. These streams often had marginal grass which emerged from or fell into the stream and provided the optimum habitat for *minimus* oviposition. Streams with nearly still water, large amounts of emergent or floating vegetation such as *Eichornia* spp. and *Pistia* spp. usually were not good *minimus* collection sites. Certain streams in secondary forest with heavy shade were excellent collection sites. These streams were almost always near the forest margin, near human habitations and had numerous tree roots and stones along the margin. Muirhead-Thomson (1940a, b, c) in a series of excellent studies, has shown that *minimus* females are attracted to shaded areas for oviposition, avoid unshaded and hot water habitats such as still rice fields and usually oviposit on still water among grass and vegetation

near the edge of streams. The larvae are also attracted to shade and will leave still water, crossing a substantial current to reach shade. Larvae normally attach to grass and vegetation tail first with hooked setae 2- and 3-X to resist currents. Muirhead-Thomson (1940b) found that *minimus* larvae were unable to resist a current velocity greater than 0.09 m/sec. When collections were made in unshaded or only slightly shaded habitats, such as fallow rice fields, *minimus* larvae were always located in areas with a slight current from seepage water or an irrigation stream. Muirhead-Thomson (1940c) determined that full grown *minimus* larvae were killed by a 5-minute exposure to 41°C, a temperature that was commonly reached or exceeded in rice fields in Assam during part of the year.

Immatures of *minimus* were collected from the following habitats in the New Territories, Hong Kong: stream margins (primary collection site), fallow rice fields, ditch, stream pools (large and small), seepage springs or pools, seepage marsh (slight current), small rock pool, in rice field used for raising *Eichornia* spp. for hog food (one collection where water flowed into field) and in a half-buried 38 L (10 gal) clay jar in a recently dried rice field. Observations on the optimum habitats for *minimus* larvae in Hong Kong were identical to those made in Thailand.

A number of mountainous-foothill streams were surveyed in southern Thailand (Chumphon, Krabi, Nakhon Si Thammarat, Phuket, Ranong and Trang) in 1969, but no *minimus* were collected. Prior to large scale insecticide usage for malaria control, some of the streams surveyed had large populations of *minimus*. Possibly *minimus* was existing in less than optimum conditions in southern Thailand and the DDT house-spray program caused its elimination, or reduced the foci of this species south of the Isthmus of Kra. Isolated pockets may still occur south of this area, but such areas are difficult to find and confirm. Sandosham et al. (1963) have also noted the disappearance of *minimus* from Perlis, the northernmost state in Malaysia. Anigstein (1932) collected in Songkhla, Phatthalung and Nakhon Si Thammarat provinces and reported *minimus* only in foothill areas of the 2nd province. Iyengar (1953) surveyed Nakhon Si Thammarat, Pattani, Phatthalung and Surat Thani provinces and did not record *minimus*, however, his collections were primarily made in the flat coastal plains. These data help point out a rather spotty original distribution for *minimus* in southern Thailand.

In the foothill areas of Sara Buri Province (central Thailand) *minimus* larvae were most abundant during September to January, the period coinciding with the last part of the wet monsoon season and the cool season. Some streams continued to attract ovipositing females into February-March, while others were too low and contained no *minimus* larvae after January. Adult *minimus* were collected during every month of the year in Sara Buri Province. Adult abundance coincided with peak larval abundance during September-January and reached a peak in November-December. Adults were least abundant during March-July, which usually corresponds with the latter part of the hot-dry season and the beginning of the wet season.

Adult *minimus* can be collected by various methods including: human bait; bovine baits; net traps with CO_2; CDC light trap (Ismail et al. 1978); window traps in huts (Ismail et al. 1974); nocturnal (outside) and diurnal (inside) resting collections. Light traps have been used to collect *minimus* (Causey 1937, Ismail et al. 1978), but their efficiency is still questionable. Scanlon and Sandhinand (1965) reported the collection of several *minimus* from rhesus monkey-baited net traps (ground level) during 3 trap nights. Human bait, biting-landing collections have been the most efficient collection method for

minimus in the past. However, during this study the most efficient collection method in terms of man-hours was using bovine bait, biting-landing collections. A total of 2,212 *minimus* females were collected from bovines at the rate of 5.57/man-hr, while human bait (outside) attracted 2,285 at the rate of 1.47/man-hr. This represents a 3.8:1 ratio in favor of the bovine bait. Comparative studies of the efficiency of bovine and human baits for *minimus* were conducted at 2 localities in Sara Buri Province using the same times, places and weather, but often with different numbers of collectors (Table 2). Based on mosquitoes/man-hr, *minimus* was most commonly collected from bovines at a 6.9:1 bovine:human ratio. These ratios may actually reflect a response to exposed body surface, rather than a preference for bovines over man. Regardless, bovine collections were the most efficient and productive method for collecting large numbers of *minimus* during this study. During the fall of 1967, prior to the collections included in this study, collections were made comparing human bait inside and outside huts and most specimens were attracted to the humans outside. Since large numbers of *minimus* were required, inside collections were rarely made.

From October to January most adults were collected between 1830 and 2200 h, after which levels were too low for the purposes of this study, thus very few collections were made beyond 2400 h. Resting collections on vegetation and piled wood around bovine pens at night also proved to be a good collection technique for this species.

During August 1968, *minimus* females from Sara Buri Province were dissected to determine the frequency of parous specimens. Parous individuals (not including gravid specimens) made up 29.6% (63/216) of the sample, indicating a majority of young specimens. A total of 132 wild nulliparous females were checked for the presence of sperm in the spermatheca, of these 88.4% (122) were fertilized.

The average size of a *minimus* blood meal has been estimated at least twice. Bruce-Chwatt and Göckel (1960) estimated the size at 1.0 mm^3, while Scanlon and Sandhinand (1965) gave a value of 0.55 mg. Size of blood meal plays an important role in the potential for blood parasite transfer. The size of an average *minimus* blood meal is small compared to that of *dirus* (as *balabacensis*), which is 1.53 mg (Scanlon and Sandhinand 1965).

A low level colony of *minimus* was established and maintained between 1968-70 using a forced mating technique (Ow Yang et al. 1963). The rearing techniques differed only slightly from those described by Wilkinson et al. (1974), and formed the basis for their reported colonization of *minimus*. The status of the original (1968) colony is questionable since Wilkinson et al. (1974) reported it was "allowed to die off" in 1970, while Wilkinson et al. (1972) reported the 1968 colony was "maintained at a relatively low numerical level until the numbers were increased during 1971" for experimental malaria studies. Data from 1968 show that during the initial stages of the colonization attempt the oviposition frequency for 212 females force-mated by 316 males was only 0.156 (33 females), and the hatch frequency for 2,116 eggs was 0.690 (1,461). These data are very similar to data obtained from wild females isolated for progeny studies (also noted under *aconitus*). Of 2,621 wild females isolated in oviposition vials, only 0.164 (430) oviposited, producing 28,904 eggs for a mean of 67.22 eggs per female. The eggs had a hatch frequency of 0.73 (21,093), and an average hatching time of 2.39 days for 4,744 eggs kept at ±25°C.

A number of references regarding *minimus* behavior in Thailand and Southeast Asia have characterized this species as primarily anthropophilic and

endophagic, and in some cases endophilic (Griffith 1955, Tansathit et al. 1962, Ayurakit-Kosol and Griffith 1962, Scanlon, Reid and Cheong 1968, Chow 1970). These traits were probably the primary reason for the drastic initial success against *minimus* that DDT house-spray programs had in Thailand (Griffith 1955, Ayurakit-Kosol and Griffith 1956, Griffith et al. 1957). More recently, however, reports suggesting behavioral changes in *minimus* have begun to appear. Brown (1958) mentioned a report of *minimus* resting outdoors after DDT spraying in central Thailand, in contrast to its usual behavior. Gould and Rutledge (1967) reported on collections from one locality (central Thailand) that had been sprayed for 10 years, in which outdoor biting (human) by *minimus* exceeded indoor biting. More recently (World Health Organization 1973) a possible exophagic and exophilic variant of *minimus* was reported from Thailand. This report has been supported by Ismail et al. (1974, 1975), who conducted extensive pre- and post-spraying observations in a forest fringe area in Phitsanuloke Province in north-central Thailand. Some of their pre-spray observations for *minimus* include: biting (human) densities outdoors 1.6 times that indoors (yearly average), while in the dry season it may be 3-4 times that indoors; females tend to move indoors during rains; it is an early biter during the dry season, and a late biter during the wet season; 93.2% of females in huts left before daylight, and 85% of those entering huts engorged during the stay in the hut. Based on these and other data these authors suggest that 2 biological variants of *minimus* possibly exist, and that the domestic variant has become scarce due to DDT spraying, while the more exophilic-exophagic variant has been maintained in its feral environment. Considering the genetic plasticity of this species based on phenetic variants, a more logical explanation would allow for a potentially large number of behavioral (= biological) variants. Selection pressure exerted by DDT spraying will obviously have favored the survival of that portion of the population feeding outdoors and not coming into contact with DDT. Ismail et al. (1975) also made the following post-spray observations on *minimus*: the excito-repellency of DDT led to an even larger decrease in indoor contact with man, with outside contact 3.5 times as high as inside; the excito-repellency of DDT also stimulated *minimus* to bite earlier with less pre-biting resting time; fair numbers of females were observed around water buffalo before and after spraying; the highest malaria vectorial capacity coincided with the beginning of the wet season, when *minimus* had the highest longevity. Other biological observations from Ismail et al. (1975) include: an average of 2 days for ovarian development during the wet season based on one blood meal and up to 4 days in the cool season; and a feeding rhythm for *minimus* of 5 days during the cool season and approximately 3 days during the rest of the year. A more recent study (Ismail et al. 1978) in a village in Sara Buri Province that was also one collection site for this study, revealed even more pronounced exophagic behavior in *minimus*, and supported most of the other observations noted in the above 1974-75 studies. This study also showed that *minimus* was more or less equally attracted to man and cattle outdoors, and deviated more to man when cattle were scarce or absent. Khin-Maung-Kyi and Winn (1976) found essentially the same exophilic-exophagic behavior, seasonal occurrence and hourly biting behavior in *minimus* in Burma as found in the above Thailand studies. Taylor (1975) has noted similar changes in the feeding behavior of *An. farauti* Laveran, following the use of DDT spray in houses in the British Solomon Islands Protectorate.

To date, *minimus* remains susceptible to DDT, but behavioral patterns other than the typical anthropophilic and endophagic pattern have been observed (above) in the field. The explanations for the above behavioral changes attri-

buted to DDT, and the actual significance of the changes, are still conjectural (Elliott and de Zulueta 1975, Molineaux et al. 1979). Actually *minimus* has been shown to be one of the most susceptible anophelines to DDT, with a LC_{50} of DDT as low as 0.05% in Nepal (Brown and Pal 1971). Khin-Maung-Kyi (1971) gives LC_{50} of DDT values between 0.24-0.30% for *minimus* in Burma. Apparently the first tests on Thai *minimus* were on larvae (Yasuno and Kerdpibule 1967), which showed a LC_{50} value of DDT at 0.0035 ppm. Moussa and Nawarat (1969) tested adults and larvae from Thailand. Adult *minimus* had a LC50 of DDT value of 0.31%, while larvae had a value of 0.016%. Based on a steep mortality regression line with a slope value of 6.4, the last authors felt the *minimus* adults (Sara Buri Province) were homogeneous with respect to the response to DDT. More recently Ismail et al. (1978) tested adult *minimus* (Sara Buri Province) for DDT susceptibility and found LC_{50} values for years 1972-73, 1973-74, and 1974-75 calculated as 0.33%, 0.40% and 0.48%, respectively. These figures show *minimus* is still highly susceptible to DDT in Thailand.

Beside human malarial and filarial parasites, the only other parasites recorded from *minimus* were encysted metacercariae of trematodes found in 4/251 dissected larvae from Amoy, South China (Feng 1933). Jenkins (1964) cited Feng (1933) as also finding *Blastocrithidia culicis* in *minimus*, but this citation is not correct. Jenkins (1964) did not actually see Feng (1933) but used the Review of Applied Entomology, Series B, which he also cited incorrectly. The correct Rev. Appl. Entomol. B reference for Feng (1933) is 1933, vol. 21: 218, not 1934, vol. 22: 103. To further complicate matters the review article wrongly says Feng found *Herpetomonas culicis* in *minimus*. Wirth and Hubert (1959) discussed the record of *Culicoides (T.) anophelis* feeding on *minimus* in Hong Kong. In 1969, I found several specimens of a *Culicoides*, probably *anophelis*, on blood engorged *minimus* in Sai Kung District, New Territories, Hong Kong.

A complete discussion of crossing experiments between *aconitus* and *minimus* is found in the Hybridization Experiments section.

ANOPHELES (CELLIA) PAMPANAI BÜTTIKER AND BEALES
(Figures 3-6, 19-21; Tables 12, 18)

Anopheles (Myzomyia) pampanae Büttiker and Beales 1959: 63 (♂*, ♀*, L*, distr.); Anonymous 1959: 288 (name emended to *pampanai*).

Anopheles (Cellia) pampanai Büttiker and Beales, Stone, Knight and Starcke 1959: 51; Büttiker and Beales 1965: 197 (keys); Peyton and Scanlon 1966: 1 (♀*, key, distr.); Reid 1968: 313 (♀, L, holotype designation); Rattanarithikul and Harrison 1973: 2 (L*, key); Reid 1976: 111 (lectotype designation); Knight and Stone 1977: 49 (tax.); Klein 1977: 117 (biol.).

All known stages of this species are easy to identify. Adults (both sexes) can be recognized by the costa base having both humeral and presector pale spots and the remigium apex - R base having gray-black scales. The pupa differs from the other species by the paddle fringe and the branching of the abdominal setae. The larva can be recognized by the large tergal plates, the simple seta 2-C and the position and development of abdominal seta 0. This species is similar to *aconitus* except for:

FEMALE (Figs. 3-6, 19). *Head.* Antennal flagellomere 1 with gray-white scales on mesal surface, flagellomeres 2,3 without pale scales; proboscis with

black decumbent scales, without pale scales distally, labellum bare and noticeably paler than labium; forefemur/proboscis ratio 0.82-0.90, 0.86 mean (11 females); palpus with black erect scales at base and on segment 2, with decumbent scales on remainder; palpus color pattern fairly stable, with silver-white scales in 3 bands; small basal pale band at segmental joint 2,3; median pale band on apex of segment 3 and base of segment 4 most variable, usually shorter than preapical dark band or apical pale band; apical pale band on distal 0.15-0.20 of segment 4 and entire segment 5. *Thorax.* Integument brown, central portion of scutum usually nearly solid ash-gray, may have faint dark longitudinal lines in acrostichal and dorsocentral setal rows; fossa, scutal angles and supraalar areas dark brown; scutum with curved, slightly flattened, white seta-like scales back to scutellum, scales more obvious than those on *aconitus* and less dense than those on *minimus;* pleural setae: 1 propleural, 1,2 spiracular, 2,3 prealar, 3,4 upper and 3-6 lower sternopleural, 3,4 upper and 0 lower mesepimeral. *Wing.* Pale markings white, dark markings usually black, common pattern follows. Costa with humeral, presector, sector, subcostal and preapical pale spots; remigium with basal 0.85 pale scaled, apex with gray-brown scales; vein R base adjacent to remigium with gray-brown to black scales; R sector pale spot and accessory pale sector spot usually separated by dark spot; R_1 without accessory pale spot on preapical dark mark; R_S-R_{2+3} with separate pale spots at origin, adjacent to R_{4+5} origin, at R_{2+3} fork; R_2 and R_3 dark except origin and apex; R_{4+5} with prebasal and preapical dark spots, base, apex and middle pale, median pale area usually long; M_{1+2} dark except origin and tip; Cu with large prebasal dark spot, fork dark-scaled; Cu_1 usually with 3 dark and 3 pale spots, pale spots at m-cu crossvein, between 2 most apical dark spots, at tip, infrequently median pale spot absent and vein primarily dark; Cu_2 dark at origin; 1A primarily dark, with base pale, small prebasal dark spot followed by pale area, distal 0.5-0.6 dark-scaled; wing apex usually with 2 broad pale fringe spots, uppermost beginning just above or at R_1 tip and extending down to just below R_2 tip, lowermost beginning at R_3 and extending down to include R_{4+5} tip; dark fringe spot between R_2 and R_3 tips often very small; 1A tip without pale fringe spot; hind margin of wing basal to 1A tip often with wide pale fringe spot. *Legs.* Upper midcoxa with 3-5 setae; forefemur slightly thicker than other femora; hindfemur with dorsal and lateral pale scales on apex; tibiae with small lateral patch of pale scales on apex; tarsomeres generally as described for *aconitus,* except apical pale scales on tarsomeres often in narrow bands instead of dorsal patches. *Abdomen.* Unicolorous light to dark brown, covered with numerous light tan setae, setae darker on distal segments.

MALE (Fig. 19). *Head.* Palpus pale areas silver-white instead of light yellow as on *aconitus,* color pattern variable and similar to *minimus.* *Thorax.* Scutal integument centrally gray, laterally brown; pale white seta-like scales extending back onto scutellum, more prominent than on female. *Wing.* Costa with humeral and presector pale spots; apex of remigium and base of R with gray-brown scales; R with sector pale and accessory pale sector spots often separated by dark spot; R_2; R_3, M_{1+2}, M_{3+4} usually without median pale spots; Cu_1 infrequently dark distal to m-cu crossvein; tip of 1A without pale fringe spot. *Genitalia.* Basimere with dark scales; claspette usually with 1,2 short setae ventromesad of long apical seta; basal tubercle of long apical seta with prominent spine; lateral club fused from approximately 3 basal stems; aedeagus with 4,5 leaflets on each side, largest 2,3 with serrate edge on at least one side; proctiger membranous, with nearly parallel longitudinal wrinkles, presence of absence of minute spicules unknown.

PUPA (Fig. 20, Table 12). Integument clear to tan, with wing cases, cephalothorax between trumpets and metanotal plate more darkly pigmented, paddles clear. *Cephalothorax.* Wing case on dark specimens with lines on veins. *Trumpet.* Generally same color as darker areas on cephalothorax, meatus 0.19-0.32 length of trumpet. *Metanotal Plate.* Seta 10-MP with 2-5 branches. *Abdomen.* Seta 0-II-VII small, simple or bifid, mesad and cephalad 2-II-VII; 9-V-VII dark, flattened, often curved; 9-I with 3-6 branches; 1-II with 16-33 branches; 2-II with 5-10 branches; 6-II very long, 1-3 branches; 9-II small, simple, slightly cephalad of posterolateral corner; 1-III with 13-27 branches; 2-III with 7-12 branches; 4-III with 4-9 branches; 5-III with 7-15 branches; 7-III with 5-9 branches; 8-III with 3-6 branches; 9-III small, pigmented, 0.25-0.36 length of 9-IV; 4-IV with 4-6 branches; 7-IV with 5, 6 branches; 9-IV, 0.26-0.47 length of segment V, 0.6-0.8 length of 9-V; 1-V with 2-4 branches; 4-V with 2-4 branches; 9-V, 0.43-0.67 length of segment V; 2-VI with 5, 6 branches; 4-VI with 2-4 branches; 5-VI with 4-7 branches; 7-VI simple or bifid, very long, 0.96-1.38 length of segment VI; 9-VI, 0.84 to 1.00 length of 9-VII, 0.64-0.67 length of segment VI; 2-VII with 3, 4 branches; 4-VII with 2, 3 branches; 5-VII with 5-7 branches; 6-VII small, just mesad of 9-VII, with 2-5 branches; 7-VII simple or bifid, very long, 0.96-1.20 length of segment VII; 9-VII, 0.60-0.67 length of segment VII; 9-VIII dark, flattened, with 11-24 closely set short branches arising from broad central stem. *Genital Lobe.* Male with 2 dark bands across lobe, basal and on distal half, separated by pale band, lobe apex pale. *Paddle.* Refractile margin shorter, 0.66-0.76 of distance from base to seta 1-P; paddle 1.53-1.66 as long as wide; lateral fringe changing from short spines to long filaments abruptly at 0.5-0.6 of distance from base to seta 1-P; paddle fringe not extending mesad of seta 1-P; 1-P, 0.33-0.45 length of paddle.

LARVA (Fig. 21, Table 18). Dark brown without discernible color pattern. *Head.* Dark brown, may have dark pattern similar to *aconitus* except anterior transverse dark line usually absent; antenna very dark brown, 5.00-6.67 as long as wide, with stout spicules except at base and on dorsal surface; seta 1-A short, simple; inserted on outer dorsal aspect, 0.20-0.28 from base; 2-C long, simple; 3-C simple, slightly over 0.5 length of 2-C; 4-C simple, reaching cephalad to bases of 2-C; 8-C with 3-6 branches; from central stem, not dendroid; 12-C with 6-10 branches; 15-C with 8-10 branches. *Thorax.* With up to 8 very small sclerotized plates arranged in central transverse rows on the dorsum of the pro- and/or mesothorax; sclerotized bases of setae 1, 2-P fused, rarely separate; 3-P often arising from lateral edge of 1, 2-P sclerotized base; 1-P with 16-27 branches; 2-P with 14-20 branches; 9-P with 7-12 branches; 10, 12-P long, simple; 11-P short, with 2-4 branches; 1-M with 24-30 branches; 4-M long, with 2 branches (rarely 3) arising from near base; 3, 5-M simple, long (5-M longest), bases often sclerotized and infrequently joined; 9, 10-M long, simple; 12-M simple; 3-T with 13-20 lanceolate leaflets, with blunt tips; 9-T with 3-7 branches; 10-T long, simple. *Abdomen.* Posterior margin of anterior tergal plate II usually concave, not enclosing posterior tergal plate, anterior and posterior plates on II rarely fused; segment II without pair of small oval submedian plates; segments III-VII with or without small submedian plates, if present, separate from anterior tergal plates; seta 0-II small, simple, arising just on or off of posterolateral margin of anterior tergal plate; 0-III-VII small, simple, rarely bifid, arising on anterior tergal plate 0.21-0.38 of distance from lateral margin to midline; 1-I-VII with well developed leaflets, leaflets with well developed shoulders and fine filaments; 1-I with 12-18 leaflets; 1-II with 16-21 leaflets; 7-III with 3-6 branches; 13-III small with 6-12 branches; 6-IV with 3

branches; 13-IV with 4-6 branches; 6-V with 2,3 branches; 13-V with 4,5 branches; 2-VII with 2-4 branches; 2-VIII with 10-13 branches; small sclerotized plate may occur adjacent to 14-VIII; pecten plate with 3,4 long teeth, 8-10 short teeth; seta 1-X simple, long, 1.85-2.05 dorsal length of saddle; 2-X with most basal branches long, usually curved or sinuous, with gradually tapering filamentous tips.

EGG. Undescribed.

TYPE-DATA. The lectotype ♀ is deposited, with associated larval and pupal skins mounted on separate glass slides, in the BMNH and bears the following labels: (1st label) - "Preke Chi Meang, Cambodia, Snoul region, Kratié Province. 17.V.58. Legs. W. Büttiker, P. F. Beales;" (2nd label) - *"Anopheles (C.) pampanai* Büttiker & Beales 1959, Type ♀(X) X;" (3rd label) "A. species Büttiker & Beales (X);" and (4th label) - "SEAMP Acc. No. 124." One ♂ and 2♀ paralectotypes with associated larval and pupal skins mounted on separate glass slides are also deposited in the BMNH. These are designated by letters, i.e., ♂ (CC), ♀ (A) and ♀ (Z) and have nearly the same data as the lectotype. An additional paralectotype exists as the 4th-stage larval skin and pupal skin on separate glass slides, of a ♂ specimen (missing) with essentially the same label data and designated by the numeral "K." There are an additional 2♀ and 3♂ paralectotypes in the BMNH with essentially the same label data as the above specimens, but without associated immature skins. These are labeled: ♂ Syntype 1, ♀ Syntype 2, ♀ Syntype 3, ♂ Syntype 4, ♂ Syntype 5. Additional information on the lectotype and paralectotypes in the BMNH can be found in Reid (1976).

The specimens of *pampanai* originally sent to the BMNH by Büttiker and Beales were labeled either "Type" or "Syntype," while specimens (2♂, 6♀, 8 larval skins and 2 whole larvae) labeled "Co-types" were supposedly deposited in the Public Health Laboratories, Division of Malaria, Manila, Philippines. The status of the latter specimens is unknown. According to the ICZN rules all of the above specimens deposited in the BMNH and Manila are to be considered syntypes. Reid (1968: 313, footnote) mistakenly labeled specimen "Z" in the BMNH as the holotype, but recently (1976) corrected this and designated specimen "X" as the lectotype.

An examination of the lectotype and its associated immature skins revealed the following. The left palpus (right broken off) does not agree with the palpus illustrated in the original description showing a long preapical dark band, but has the preapical dark band narrower than the subapical pale band, and the apical pale band. The right wing of the lectotype was illustrated in the original description, but did not show a pale fringe spot on the hind margin halfway between the wing base and the apex of vein 1A. The left wing differs from the right by having the preapical pale and dark spots on the costa equal length, and by Cu_1 having 2 dark spots distal to the m-cu crossvein instead of one long dark spot. Both the 4th-stage larval skin and the pupal skin (mounted on its side) of the lectotype will soon be destroyed, as the mounting medium (Berlese's fluid) on both slides is crystallizing and is already adjacent to the head of the larval skin.

DISTRIBUTION (Fig. 20). Büttiker and Beales (1959) described *pampanai* based on specimens from northeastern Burma (Lashio) and Cambodia. Subsequent collections in Cambodia (J. M. Klein collections - ORSTOM) have produced additional specimens of this species, however, no specimens from Burma were located during this study. In fact, Khin-Maung-Kyi (1971) apparently overlooked the record of this species in Burma when he reviewed the Myzomyia Group (= Series) in Burma.

Peyton and Scanlon (1966) were the first to record *pampanai* in Thailand, from specimens collected by personnel of the SEATO Medical Research Laboratory and the National Malaria Eradication Project. These specimens consisted of larvae from Chanthaburi, Phayao (then Chiang Rai) and Nan provinces and a single female from Prachin Buri Province. Scanlon, Peyton and Gould (1968) stated that the Chiang Rai record came from a specimen labeled "Payao" (actually "Payao, 8-11 Mar 60, Prasert") which was presumed to be "Phayao" in Chiang Rai Province. This presumption was correct, as specimens of *An. insulaeflorum* (Swellengrebel and Swellengrebel-de Graff) with this label were found during this study. These included one slide labeled "Chiengrai, Payao, 8-11 Mar 60, Prasert, Coll 3.", with the same handwriting and ink as on the *pampanai* slide. Since then, Chiang Rai has been split into Chiang Rai and Phayao provinces. During this study a number of additional specimens of *pampanai* from Thailand were either found in museum collections or collected in the field. These include: 6 females from Chiang Mai Province, 6 females and 8 whole larvae from Chanthaburi Province, 8 females from Buriram Province, one female from Prachin Buri Province and 2 whole larvae, found in the Thurman Collection in the USNM, that were collected in 1952 in Lampang Province. Unfortunately, the distribution of *pampanai* in Thailand is still poorly known. Apparently this species is widely, but sparsely distributed from Cambodia across the Korat Plateau and its fringe areas into the large northern valleys in Thailand. The habitat requirements are poorly understood, but seem to coincide with large stream-small river systems, during the dry season, on or adjacent to the plateau or in large broad valleys. One possible explanation for the very infrequent collection of *pampanai* in Thailand is the very limited amount of collecting that has been done in this habitat and particularly on the Korat Plateau.

The type-series of this species came from 10 km north of Snoul in eastern Cambodia, and just across the border from Loc Ninh, Binh Long Province, Vietnam. This close proximity to Vietnam led Do-Van-Quy (1968) to include *pampanai* in keys for Vietnamese anophelines, and in 1971, Do-Van-Quy (unpublished interim report, Institute Pasteur, Vietnam) listed a single female of *pampanai* collected in Dak Pek, Kontum Province, near the border with Laos. A single female of *pampanai* was found during this study in the USNM from Plei Djereng, Pleiku Province, Vietnam. This specimen definitely establishes *pampanai* as occurring in Vietnam. It is interesting that 3 of Toumanoff's (1936) figured wing variations for Vietnamese *minimus* (p. 154), i.e., VII, IX and XI, show a dark spot on the base of vein R, as would appear on *pampanai*. Whether these 3 figures are artist errors or imply that Toumanoff actually had *pampanai* specimens among his *minimus*, is conjecture.

The confirmed distribution for *pampanai* now ranges from northeastern Burma, down through Thailand and Cambodia into Vietnam. Since this species has been reported from an area adjacent to Laos, it probably also occurs there. Reid (1968) suggested that the record of *mangyanus* from Nepal (Brydon et al. 1961) might actually refer to *pampanai*, however, no specimens are available for confirmation. As discussed earlier (p. 24) the record of *mangyanus* in Nepal is not considered valid, and probably was based on a *minimus* variant (see *minimus* Variations section).

Material examined includes 86 specimens: 8♂, 47♀, 18 L, 6 individual rearings (6 p, 7 l).

CAMBODIA. Kratié: Prek Chi Meang (Ksim 2), 8♂, 11♀, 2 L, 5 p, 6 1 (includes lectotype) - BMNH; Ksim, 1♀ - USNM. Kampot: Po Phnom Twea, 3♀ - USNM. Kompong Speu: Pichnil, Stung Chral, 9♀ - ORSTOM.

THAILAND. Buriram: Krasang District, Tambol Lamduan, 8♀ - USNM. Chanthaburi: Pong Namron, 5 L - USNM, 6♀, 8 L - BMNH. Chiang Mai: Nong Quai #2, 1♀, 1 p, 1 l - BMNH; Muang, Huey Kaeo, 5♀ - METC. Lampang: Ngao District, km 114, 2 L - USNM. Phayao: Payao (= Phayao), 1 L - USNM. Prachin Buri: Ban Bu Phram, 1♀ - USNM; Amphur Kabinburi, Ban Wang Mued #5, 1♀ - USNM.

VIETNAM. Pleiku: Plei Djereng, 1♀ - USNM.

VARIATIONS (Fig. 6, Tables 12, 18). Variations were noted primarily on female and larval specimens. All adults checked during this study were consistent in having a humeral pale spot on the costa and gray-black scales on the remigium apex - R base. The 15 females in the USNM were also checked for other variations. Ten specimens had the R sector and accessory sector pale spots separate. Vein 1A was dark scaled except at the base on 2 specimens, and 1A lacked a prebasal dark spot on 3 specimens. Only 3 specimens had vein Cu_1 with one long dark spot beyond the m-cu crossvein as depicted for the lectotype in the original description. The other 12 specimens had the long dark spot interrupted in the middle by a pale spot. The length of the preapical dark band on the female palpus was also found variable. The original description shows this band wider than the subapical pale band, however, 5 (5/14) had this dark band equal to and 4 (4/14) had the dark band narrower than the subapical pale band.

Only 4 pupae were available for study and setal branching differences noted below and in Table 12 were the primary variations noted.

Twenty-four larvae and larval skins were checked and besides setal branching differences the following variations were found. The sclerotized bases of setae 1, 2-P were separated (not fused) on 2 specimens. The 3-T leaflets on 4 specimens were tapered like those of *aconitus*, rather than blunt. The small median posterior tergal plate on segment II was fused with the anterior tergal plate on 3 specimens. The number of small dorsal thoracic plates varied from 0 to 8, and when 8 occurred, several appeared to be on the prothorax rather than the mesothorax. Several larvae were observed with a small ventral bilobed plate just cephalad of seta 14-VIII. The setae 1, 2-P and tergal plate characters discussed above were used in the original description of *pampanai* as primary characters in differentiating this species from *minimus*. The frequencies of the above variations in these 2 characters, in addition to those on *minimus* (see *minimus* Variation section) suggest that they are not as reliable as originally supposed, and should not be used as primary characters for separating these 2 species.

TAXONOMIC DISCUSSION. Although this is one of the easiest members of the series for taxonomists to identify, in field situations specimens are identified while alive or immediately prior to dissection for parasites and the small humeral pale spots on the costa and the gray-black scales on the remigium apex-R base may be overlooked. In such cases, *pampanai* specimens will probably be identified as *minimus*, as reported for Burmese specimens (Büttiker and Beales 1959). Persons identifying specimens of the Myzomyia Series under such conditions should concentrate on the extra pale spot (humeral) at the base of the costa. Occasional specimens of *aconitus* and *minimus* have humeral pale spots. The gray-black scales on the remigium apex-R base are difficult to see and should be checked only after the humeral pale spot has been found.

Certain other characters are also useful in identifying *pampanai* adults. The pale scales on *pampanai* are white or silver-white, while those of *aconitus* are usually creamy-white or very pale yellow. The tarsomeres on *pampanai* have small apical pale bands or dorsal patches, while *varuna* tarsomeres are

entirely dark. No specimens of *pampanai* were found with either 3 pale spots on vein 1A or a pale fringe spot at the apex of 1A, while at least one of these 2 characters is almost always present on *aconitus* and *jeyporiensis* specimens. The proboscis of *pampanai* was found invariably dark-scaled, while the proboscis of *aconitus* normally has pale scales, and *varuna* frequently has a small distoventral patch of pale scales on the proboscis. Only 6% of *minimus* examined from Thailand had a distoventral patch of pale scales on the proboscis. The scutal pale scales on *pampanai* are long, slender, seta-like and usually less obvious than those on *minimus*. There are a number of similarities between *jeyporiensis* and *pampanai*, including a humeral pale spot on the costa and gray scales on the remigium apex-R base. However, *jeyporiensis* has a wide pale band on foretarsomere 1, short white scales on the scutum and either 3 pale spots on vein 1A or a pale fringe spot at 1A apex. As discussed under *aconitus*, the palpal banding patterns on *aconitus*, *minimus*, *pampanai* and *varuna* are highly variable and should not be used for differentiating these species. Reid (1968) noted an additional difference from those in the original description between *mangyanus* and *pampanai* females. The basal dark mark on Cu reaches or overlaps the base of the R presector dark mark on *pampanai*, while that on *mangyanus* is shorter and does not reach the R presector dark mark. An examination of 13 *pampanai* and 16 *mangyanus* confirms this character. Reid also said that the basal Cu dark mark on *pampanai* is usually twice as long as the costa humeral dark mark. Only 9 of 13 *pampanai* conformed to this character. These characters are additional evidence of the distinctness of *pampanai*.

Pupae of *pampanai* generally have more branches on their setae than the other members of the Oriental Myzomyia Series, and consequently are easily identified. The color pattern on *pampanai* pupae may also be helpful in identification. The metanotum and cephalothorax between the trumpets are very dark, a pattern also found on some specimens of *jeyporiensis*, *minimus* and *varuna*. However, *pampanai* was the only species found with 2 dark transverse bands on the male genital lobes. Seta 9-II is often located cephalad of the posterolateral corner instead of at the corner, and 9-III while at the corner is usually darkly pigmented and stout instead of slender and needle-like. The paddle offers the best characters for identifying *pampanai* pupae. The short refractile margin is very similar to those found on *flavirostris* and *mangyanus* in the Philippines. *Anopheles pampanai* appears unique in the Minimus Group in having the paddle fringe not extending mesad of seta 1-P, while *culicifacies* is the only other members of the series in the Orient with this character.

The 4th-stage larva is probably the easiest stage to use for identifying *pampanai*. In Thailand, only *minimus* and *pampanai* in the subgenus *Cellia* and *palmatus* (Rodenwaldt) in the subgenus *Anopheles* have seta 2-C simple and very large anterior tergal plates on the abdominal segments. *Anopheles palmatus* can be identified immediately by the 2-C bases being very close together. Separating *pampanai* from *minimus* is equally easy using the key characters. Infrequent specimens of *varuna* in Sri Lanka have 2-C simple and 2 of 9 specimens from Thailand had only one fine barb on 2-C, thus it seems likely that occasional Thai specimens of *varuna* will be found with 2-C simple. The development and location of seta 0 on the abdominal segments of *pampanai* and *varuna* are nearly identical. However, the long fine filaments on *varuna* 3-T leaflets are very distinct from the relatively short blunt 3-T leaflets on *pampanai*.

A number of other characters may be of use in identifying *pampanai* larvae. All specimens examined to date have either a dark brown pattern without an

anterior transverse bar on the frontoclypeus or the frontoclypeus nearly entirely dark brown. The antennae were invariably dark brown. Seta 8-C never appeared dendroid as is common on *minimus*. The heavily sclerotized bases of 1,2-P, although not always fused, are of secondary value in separating *pampanai* from many specimens of *aconitus* and *minimus*. The development of 4-M is an excellent character for separating *pampanai* from *minimus* and also *fluviatilis*. Besides differences in the number of 4-M branches, these branches on *pampanai* are longer than those on *minimus*. Slight overlap occurs when using the 4-M branch summation method for separating *pampanai* (4-6) from *aconitus* (6-9) and *varuna* (6-10). The sclerotized, often fused, bases on 3,5-M, is a *pampanai* character shared with *minimus* and *varuna*, however, the bases of 3,5-M on *aconitus* are not sclerotized. The anterior tergal plate on segment II is usually, i.e. 87.5% (21/24), concave on the posterior margin with the posterior tergal plate separate, and this can be used as a good secondary character for separating *pampanai* from *aconitus* and *varuna*. However, this character should not be used to differentiate *pampanai* from *minimus*, because it occurs on *minimus* throughout Thailand, and has a high frequency in some populations. The mesal position of seta 0 on the abdominal tergal plates of *pampanai* is fairly distinct, with *varuna* the only other mainland Southeast Asian species besides *palmatus* that has 0 in a similar position. The small oval submedian abdominal plates are less constant on *pampanai* than on the other Minimus Group species. These plates are usually present on segmens I-VII on *minimus* and *varuna* and on II-VII on *aconitus*, but only on III-VII on *pampanai* (when they are present). Seta 1-I on *pampanai* always has well developed leaflets with shoulders and filaments, while those on *aconitus* usually lack shoulders and filaments. Seta 1-X on *pampanai*, like that on *varuna*, is apparently slightly longer in proportion to the dorsal margin of the saddle than those of the other 4 members of the series in Thailand.

Based on the diagnostic characters used in this study, *pampanai* is most similar to *mangyanus* in the Philippines, then *flavirostris*, *minimus*, *varuna* and *filipinae* in that order. The many similarities between *pampanai* and *mangyanus* partially isolate these 2 species from the remaining species in the Minimus Group. *Anopheles pampanai* shows the least similarity to *aconitus*. Whether the above similarities imply relationship or simply reflect fortuitous convergence-divergence is unknown.

BIONOMICS. Most of the biological information known about this species was published in the original description. Subsequent collections of *pampanai* have been limited and often not accompanied by detailed collection records. According to Büttiker and Beales (1959), adult and immature *pampanai* were found with *minimus*. Oviposition sites were slow flowing foothill streams with sandy or rocky bottoms, shaded edges and steep river banks covered with dense vegetation. Larvae were most abundant and predominant over *minimus* toward the end of the dry season along river margins under dense root cover, however, after the rains returned *minimus* became the dominant species. These authors speculated that *pampanai* could tolerate a higher level of pollution than *minimus*. Adult males and females were found resting in hollowed river banks, on exposed roots under banks or on overhanging roots. Adults in Burma were found resting in houses during the daytime. All *pampanai* collected on water buffaloes in Cambodia were taken before 2400 h.

Thailand records indicate that all larvae were collected in "streams," with the last specimen taken in 1965. Adult females were collected in Thailand in 1966 and 1969. Specimens (4) were collected from buffaloes in outside pens between 1900-2159 h and 5 were taken biting man (outside) between 1915-2215 h.

These 9 females were taken in rural isolated villages near a large stream or a small river. Concentrated efforts to find *pampanai* larvae in those streams were fruitless.

ANOPHELES (CELLIA) VARUNA IYENGAR

(Figures 3, 4, 6, 22-24; Tables 6, 7, 13, 19)

Anopheles fluviatilis of Cogill 1903: 327 (L, biol.); Edwards 1922: 90 (tax., as *minimus* Theobald); Iyengar 1924: 27 (= *varuna* Iyengar).

Anopheles varuna Iyengar 1924: 24 (♀*, tax., biol., distr.); Christophers and Puri 1931: 489 (♀*, L, tax., distr.); Menon 1938: 121 (E*); Roy 1938: 269 (L*, tax.); Rao and Ramakrishna 1940: 509 (L, tax.); Russell and Rao 1940: 160 (L, biol.); Rao 1961: 103 (review, biol., distr., med. signif.).

Anopheles (Myzomyia) minimus var. *varuna* Iyengar, Christophers 1924a: 51 (tax.); Puri 1928b: 522 (L, tax.): Edwards 1932: 52 (tax.).

Anopheles minimus var. *varuna* Iyengar, Christophers 1924b: 298 (tax., distr.); Evans 1930: 588 (L*, tax.).

Anopheles (Myzomyia) funestus var. *listoni* of Carter 1924: 71 (♂, ♀*, L*, tax.).

Anopheles (Myzomyia) varuna Iyengar, Puri 1931: 155 (L*, tax.); Christophers 1933: 214 (♂*, ♀*, L*, tax., biol., distr.); D'Abrera 1944: 348 (E*, tax.); Carter 1950: 87 (distr.); Thurman 1959: 121 (distr.); Khin-Maung-Kyi 1971: 478 (biol., distr.).

Anopheles (Cellia) varuna Iyengar, Stone, Knight and Starke 1959: 58 (tax.); Peyton and Scanlon 1966: 2 (♀*, ? distr.); Scanlon, Peyton and Gould 1968: 30 (checklist, ? distr.); Reid 1968: 313 (♂*, ♀*, L*, tax.); Rattanarithikul and Harrison 1973: 3 (? distr.); Knight and Stone 1977: 57 (tax., distr.).

All adults identified as *varuna* should be confirmed on the basis of associated immature skins. Adults of *aconitus*, *minimus* and *varuna* can have the same general habitus, particularly in northern Thailand. Consequently, the usual adult *varuna* characters (i.e., 2 broad apical pale bands on palpus, hind margin of wing without pale fringe spot at 1A, basal third of costa entirely dark and proboscis dark or with distal pale scales) are often of little taxonomic value. The only characters that appear significant on *varuna* females are the entirely dark tarsomeres and Cu_1 with one long dark mark beyond the m-cu crossvein. However, since these characters are not totally reliable because of overlap from the other species, adults should be confirmed by immature skins. The pupa of *varuna* looks very similar to that of *aconitus*, but can be readily identified by the key characters. The 4th-stage larva of *varuna* is distinct and is the best life stage to use for identifying this species. Seta 2-C on *varuna* almost always had one to several weak barbs, 4-C is normally simple, the 3-T leaflets have long tapering filamentous tips and seta 0, when present, is always on the large abdominal anterior tergal plates. Other reliable characters are presented in the Taxonomic Discussion section. This species is like *aconitus* except for:

FEMALE (Figs. 3-4, 6, 22, Tables 6, 7). *Head.* Vertex with pale erect scales above interocular space, erect creamy-brown scales laterally, erect black scales on occiput; pedicel integument dark gray or brown; flagellomere 1 with pale gray scales on dorsal and mesal surface, remaining flagellomeres

without scales; proboscis entirely dark with small blue-black decumbent scales, or with subapical flavescent area on venter and usually dorsum; labellum nearly bare, paler than labium; forefemur/proboscis ratio 0.77-0.87, 0.83 mean (18 females); palpus slender, slightly shorter than proboscis, with decumbent scales; palpus with 3 pale bands, narrow bands at segmental joints 2,3, and 3,4, variable apical band on apex of segment 4 and entire segment 5. *Thorax.* Scutal integument centrally ash-gray, laterally dark brown; anterior promontory with long, slender, erect pale scales medially, shorter pale scales laterally; scutum with short very fine seta-like pale scales between dorsocentral setal rows back to cephalic end of prescutellar area; prescutellar space bare except large dark lateral setae; scutellum with anterior row of short tan or brown setae, posterior row of long dark setae; pleural integument dark gray or brown, without scales; pleural setae: 1 propleural, 1,2 spiracular, 3,4 prealar, 2,3 upper and 3-6 lower sternopleural, 4-6 upper and 0 lower mesepimeral. *Wing.* Color pattern variable (see Variations section), primarily dark with small pale areas, common pattern follows. Costa primarily dark with sector, subcostal and preapical pale spots; remigium pale-scaled; vein R with large basal and sector pale areas separated by equal sized dark area; R_1 dark except subcostal, preapical pale spots and tip; R_S-R_{2+3} dark except small pale spots at origin, crossvein R_{2+3}-R_{4+5} and R_{2+3} fork; R_2 and R_3 dark except small pale spots at base and apex; R_{4+5} with prebasal and preapical dark spots, small pale spots at origin and apex, variable median pale spot; M dark except pale scales at base, small pale spot at m-cu crossvein and pale M fork; M_{1+2} and M_{3+4} dark except small pale spots at base and apex; Cu with white scales at origin, variable prebasal dark spot, pale spot then dark to include fork; Cu_1 dark-scaled with 2-3 pale spots, pale spots constant at m-cu crossvein and apex, 3rd pale spot when present, intermediate between other 2; Cu_2 mostly dark, with or without basal pale spot, with small apical pale spot; 1A with origin pale-scaled, usually with dark spot on basal half, with distal half dark scaled; apical pale fringe spot starting at or just above apex of R_1, extending down to R_2; additional small pale fringe spots at apices of R_3 (may be absent), R_{4+5}, M_{1+2}, M_{3+4}, Cu_1, and Cu_2, 1A without pale fringe spot; hind margin of wing usually without pale fringe spot basal to 1A apex. Integument dark, upper midcoxa with 3-6 setae; forefemur slightly swollen on basal half, otherwise femora, tibiae and tarsomeres long, slender with blue-black scales; tarsomeres without pale bands or patches. *Abdomen.* Unicolorous dark brown or gray with brown setae.

MALE (Fig. 22). *Head.* Antennal flagellomere 1 with few gray scales on mesal surface; forefemur/proboscis ratio 0.66-0.69, 0.68 mean (5 males); palpus with pale scales at apices of segments 3-5, without pale band at segmental joint 2,3. *Wing.* (See Variations section.) More slender than female wing, with fewer, darker scales. *Genitalia.* Basimere with dark scales laterally and ventrally, with 4,5 parabasal spines; claspette with 1,2 small ventromesal setae, long, large apical seta, stout lateral club and shorter seta between long apical seta and stout club; lateral club on claspette fused from 2-4 basal stems, shorter than long apical seta; aedeagus with 4 or more leaflets on each side of tip; largest aedeagus leaflets with serrate edge on one side; proctiger cone-shaped, membranes with parallel wrinkles, extending half distance to basimere apex, without spicules.

PUPA (Fig. 23, Table 13). Integument light tan to light brown, with darker areas between trumpets and on metanotal plate, paddles light tan. *Cephalothorax.* Wing cases usually without dark lines on veins. *Trumpet.* On light specimens darker than cephalothorax; meatus 0.20-0.31 length of

trumpet; pinna expanded distally, flattened by longitudinal ridge making venter or trumpet apex concave. *Abdomen.* Seta 0-II-VII simple, rarely bifid, mesad and cephalad of 2-II-VII; 9-IV-VII dark brown, usually flattened, may have 1,2 small distal branches; 2-I with 6-8 branches; 4-I with 4-10 branches; 9-I with 2-5 branches; 1-II with 12-19 branches; 2-II with 4-7 branches; 3-II with 3-5 branches; 4-II with 3-6 branches; 5-II with 5-7 branches; 6-II long, with 1-3 branches; 9-II small, simple; 1-III with 15-21 branches; 2-III with 7-14 branches; 4-III with 3-5 branches; 5-III with 10-19 branches; 6-III with 4-10 branches; 7-III with 2-5 branches; 9-III dark, broad, with less acute tip, small, 0.27-0.45 length of 9-IV; 1-IV with 8-15 branches; 2-IV with 4-13 branches; 4-IV with 1-3 branches; 5-IV with 6-10 branches; 6-IV with 4-7 branches; 7-IV with 2-5 branches; 9-IV, 0.28-0.43 length of segment V, 0.73-0.90 length of 9-V; 1-V with 3,4 branches; 2-V with 3-9 branches; 4-V with 2-5 branches; 9-V simple, rarely with minute distal branch, 0.38-0.55 length of segment V, 0.68-1.00 length of 9-VII; 1-VI with 3,4 branches; 2-VI with 3-6 branches; 4-VI simple to bifid; 5-VI with 3-5 branches; 7-VI, with 1-3 branches, long, 0.84-1.19 length of segment VI; 9-VI, 0.88-1.00 length of 9-VII, 0.45-0.57 length of segment VI; 1-VII with 3-4 branches; 2-VII with 2-5 branches; 4-VII simple or bifid; 5-VII with 2-5 branches; 7-VII simple to bifid distally, long, 0.86-1.22 length of segment VII; 9-VII, 0.42-0.56 length of segment VII; 9-VIII flattened, with 12-17 closely set branches arising from broad central stem. *Genital Lobe.* Unicolorous, without bands of pigment. *Paddle.* Light tan pigmentation; refractile margin very long, 0.89-0.96 of distance from base to seta 1-P; paddle 1.42-1.62 as long as wide; lateral fringe changing gradually from fairly stout spines to filaments at 0.77-0.88 of distance from base to seta 1-P; paddle fringe extending mesad of seta 1-P to mesal angle; 1-P, 0.28-0.42 length of paddle.

LARVA (Fig. 24, Table 19). Brown to nearly black, without distinct color pattern. *Head.* With variable brown color pattern on frontoclypeus, usually similar to that described for *minimus*, i.e., like a musician's tuning fork, without an anterior transverse brown band; antenna usually dark brown, may be paler on basomesal 0.33, 5.97-6.67 as long as widest point; seta 1A inserted on outer dorsal aspect, 0.26-0.32 from base; 4-A with 6-9 branches; 2-C long, with 1-4 short lateral barbs (rarely without barbs), most basal barbs often more stout; 3-C, 0.50-0.67 length of 2-C, usually simple, infrequently with one small lateral barb; 4-C simple, extending cephalad approximately to base of 2-C; 8-C with 3-9 branches; 15-C with 7-11 branches. *Thorax.* Often with 1,2 pairs of small submedian sclerotized plates on dorsum of mesothorax; sclerotized bases of setae 1,2-P broadly fused; 1-P with 21-29 branches; 2-P with 16-21 branches; 9-P with 10-15 branches; 10, 12-P long, simple; 11-P with 3-5 branches; 1-M with 23-33 branches; 3,5-M simple, bases usually partially sclerotized and infrequently fused; 4-M with 3-5 branches; 9; 10-M long, simple; 3-T with very short thick stalk, 15-23 light brown lanceolate leaflets, with long, very finely tapered filamentous tips; 9-T with 6-9 branches; 10-T long, simple. *Abdomen.* Anterior tergal plates on II-VII very large with broadly rounded lateral margins, 0.60-0.85 width of segment, posterior margins convex, enclosing small posterior tergal plates; segments 1-VII usually with small oval submedian plates separate from anterior tergal plate, occasionally fused with anterior tergal plate on several segments; seta 0-II-VII simple or bifid (rarely trifid), small, arising on anterior tergal plate 0.22-0.38 of distance from lateral margin to midline; 1-I-VII leaflets light brown, with shoulders and very long slender filaments, often pale in region of shoulders; 1-I with 13-21 leaflets; 4-I with 5-8 branches; 1-II with 17-23 leaf-

lets; 5-II small, weak, with 4-6 branches from near base; 13-III large like 13-IV, with 3-5 branches; 1-IV with 19-26 leaflets; 6-IV with 3 branches; 9-IV with 3-5 branches; 13-IV with 4-6 branches; 6-V with 3 branches; 13-V with 3-5 branches; 2-VII with 2-4 branches; 0-VIII small, simple, posterolaterad of tergal plate; 2-VIII with 11-14 branches; pecten plate with 4, 5 long and 7-11 short teeth; seta 2-S with 7-12 branches; 8-S with 5-8 branches; 1-X simple, long, 1.85-2.16 dorsal length of saddle; 2-X basal branches with long tapering filamentous tips.

EGG. The egg of *varuna* was first described "with fairly stable characteristics" from India (Kerala) by Menon (1938). However, D'Abrera (1944) found considerable variation in *varuna* eggs from Ceylon. In view of these wide variations and the lack of eggs for study, no description is attempted here, and readers are urged to consult the 2 above references.

TYPE-DATA. In the original description Iyengar (1924) indicated the type of *varuna* was in the Bengal Malaria Research Laboratory, Calcutta, and co-types were in the Indian Museum, Calcutta and the BMNH. Christophers (1933) repeated this information, except for the BMNH location. Stone et al. (1959) indicated the type was in the Zoological Survey of India, Indian Museum, Calcutta, India. In 1963, Dr. John E. Scanlon (personal communication) visited Calcutta and searched for the type-material of *varuna*. The Bengal Malaria Research Laboratory has now been incorporated into the School of Tropical Medicine. Personnel at the latter site did not know the location of the type of *varuna*. Dr. Scanlon also searched for the co-types (= paratypes) supposedly deposited at the Indian Museum in the Zoological Survey of India collection, but was unable to find these specimens. In 1972, I was unable to find specimens which could be part of the type-series for *varuna* in the BMNH. Knight and Stone (1977) list the type-location for *varuna* as "Location unknown." It is hoped that future searches in India will uncover these specimens.

DISTRIBUTION (Fig. 23). The adult female of *varuna* is so similar in habitus to variations of *aconitus*, *minimus* and possibly *fluviatilis* that its distribution in some areas is still uncertain. In addition, early descriptions of the larva (Christophers and Puri 1931, Puri 1931, Christophers 1933) wrongly described the inner and outer clypeal setae as always simple, while the majority of larvae have weak barbs at least on 2-C. This is primarily an Indian species, but even there, many early records of *fluviatilis* (or *listonii*) and *minimus* possibly refer to this species, particularly in southern India. Based on the literature and specimens examined this species has the following distribution: BANGLADESH; BURMA; INDIA (Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu and Uttar Pradesh); NEPAL; SRI LANKA; and THAILAND. I have not seen confirmed specimens (with associated immature skins) from a number of the Indian states, Bangladesh, Burma and Nepal, however, *varuna* probably occurs in all the areas listed above. I consider the records of *varuna* from Indonesia (Swellengrebel and Rodenwaldt 1932, Brug and Bonne-Wepster 1947, Van Hell 1952) to apply to *flavirostris*. Since *varuna* is not known south of approximately 17°N latitude in Burma and Thailand, I do not believe it occurs on the equator or south of the equator in Indonesia. Covell (1944) and Rao (1961) list *varuna* from southern China, however, I have not seen other references listing this distribution. Furthermore, Feng (1938) and Chow (1949) did not list this species in their reviews of the literature and records of anopheline mosquitoes in China. Liu et al. (1959) referred to Chinese records of *varuna* based on adults in Kweichow and Yunnan provinces. However, these authors very ably demonstrated by progeny rearings that those records were

false and actually applied to dark winged *minimus* (see under *minimus*). The record of *varuna* from Vietnam (Reisen et al. 1971) was based on light trap specimens and should not be considered valid without confirmation.

Thurman (1959) recorded *varuna* from Thailand for the first time, but did not retain specimens for examination. Between 1961-77, thousands of collection man-hours were expended and thousands of anopheline specimens were collected and/or reared and identified by personnel at the SEATO Medical Research Laboratory, Bangkok, without finding a single specimen confirmed by immature skins to verify Thurman's record. Adults taken in biting collections that keyed to and matched the general habitus of *varuna* were not uncommon in central and particularly northern Thailand. However, each time these females were allowed to oviposit, the offspring (reared adults with associated skins) invariably showed the wild parent to be either *aconitus* or *minimus*. During the peak anopheline months of October-December 1969, numerous *aconitus* and a few *minimus* variants were collected in the Chiang Mai Valley that would key to *varuna*. In central Thailand (Sara Buri) *minimus* variants were more likely to look like *varuna* than *aconitus* variants. This lack of proof prompted Peyton and Scanlon (1966), Scanlon, Peyton and Gould (1968) and Rattanarithikul and Harrison (1973) to question the validity of the Thailand record.

In March 1977, I examined 9 adults with associated immature skins and 3 whole larvae, kindly sent by Dr. Peter F. Beales, WHO Malariologist, Bangkok. These specimens were collected in Lampang Province, Amphur Thoen during July 1976, and definitely confirm the existence of *varuna* in Thailand. Only minor variations were found between these specimens and a larger group of specimens from Sri Lanka. In July 1978, 2 additional collections of *varuna* were made in Thailand by the author and personnel of the Armed Forces Research Institute of Medical Sciences (AFRIMS), Bangkok. These collections were made in Ban Nam Phrae Nai #1, Amphur Hang Dong, Chiang Mai Province, and consisted of 4 adults reared with associated immature skins, one whole pupa and 3 whole larvae.

A total of 136 *varuna* specimens were examined during this study (19♂, 36♀, 40 larvae, 18 larval and 20 pupal skins). Specimens examined from Thailand (Chiang Mai and Lampang) include 5♂, 8♀, 6 larvae, 13 larval and 14 pupal skins. Additional specimens (14♂, 31♀, 34 larvae, 5 larval and 6 pupal skins) were examined from the following countries: BANGLADESH; BURMA; INDIA; and SRI LANKA.

VARIATIONS (Figs. 3, 6; Tables 6, 7, 13, 19). Most of the past and present confusion in Asia regarding the identification of *varuna* is due to overlapping adult variations on the part of *aconitus*, *minimus* and possibly *fluviatilis*. An example of this confusion is the illustration (Fig. 7) for *varuna* in Bhatia and Kalra (1961). The specimen figured is almost certainly *aconitus* without pale vein 1A fringe spots. Other wing characters, i.e., 3 dark spots on 1A, pale median spots on R_2 and R_3, and 2 dark spots on Cu_1 beyond the m-cu crossvein, are all *aconitus* characters. I have not seen the first 2 characters on *varuna*, and the last character occurs on less than 50% of *varuna* specimens. Based on the specimens I have seen, *varuna* adult and larval characters seem slightly more stable than those of *aconitus* and *minimus*, but, this opinion may be biased by the lower number of specimens examined. There are, however, several adult and larval variations that have played very important roles in the confusion surrounding this species.

In a discussion section just prior to the original description of *varuna*, Iyengar (1924) states, "The proboscis is not pale in its apical half above or

below." However, several months later, Christophers (1924b) noted "The rather frequent presence of some paling of the proboscis in the apical half, . . ." on *varuna*. Christophers used this character to suggest *varuna* was closely related to *minimus*, which also can have pale scales on the distal half of the proboscis. Although the pale scales on the proboscis of *varuna* were described as not always present, several subsequent authors (e.g., Bhatia and Kalra 1961, Wattal 1963, Bonne-Wepster 1963, Stojanovich and Scott 1966) have used a pale proboscis as a primary means of identifying the species. This character occurred on only 44% (8/18) of females examined in this study. The other 10 specimens had the proboscis entirely dark-scaled. Furthermore, the flavescent scales were very difficult to see on a portion of the females possessing them. Flavescent scales also occur on the proboscis of *aconitus* and less frequently on *minimus*.

Another variable adult character causing confusion is the number of dark spots on Cu_1 distal to the m-cu crossvein. *Anopheles varuna* is usually described as having only one long dark mark on this area of vein Cu_1, but this occurred on only 53% (10/19) of the females and 75% (6/8) of the males examined during this study. *Anopheles aconitus* rarely has only one dark mark on Cu_1 beyond the m-cu crossvein (Table 1), while this character is only slightly more common (Table 5) on *minimus*. The following wing characters were found constant on 8 male and 19 female *varuna*: (1) costa without presector pale spot (one male with spot on left wing); (2) R without separate accessory sector pale spot; (3) R_2 and R_3 without median pale spot; (4) R_{4+5} with basal spot; (5) M_{1+2} without median pale spot; (6) Cu fork dark; (7) 1A with one long dark spot on distal half; and (8) hind margin of wing without pale fringe spot at tip of 1A. One female had Cu_2 entirely dark except at the apex and 1A entirely dark except at the base.

Adults of *varuna* were invariably dark, with the pleural sclerites, scutum and the abdomen dark brown-black. There was no trace of banding or pale dorsal spots on the tarsomeres. Pale specimens like *aconitus*, were not seen. The palpus of male *varuna* typically has a narrow pale band at the apices of 3, 4 and the distal 0.33-0.50 of 5 pale. These bands were variable, with that on 4 often not extending across the segment, but none of the males had the club almost entirely pale as frequently occurs on *aconitus* and *minimus*. Wattal et al. (1960) noted one morphologically deformed female of *varuna* with unilateral or uneven palps (see *aconitus* Variations section). No deformed specimens were seen during this study.

In previous publications several morphological characters have been used consistently for separating the adult females of *aconitus*, *minimus* and *varuna* (Table 6).

TABLE 6. Previously published primary key characters to differentiate the adult females of *An. aconitus*, *varuna* and *minimus*.

Character	Species		
	aconitus	*varuna*	*minimus*
Proboscis	distal 0.5 pale	dark or with mostly ventral pale area	dark or with small ventral pale area
Wing presector pale spot	present or absent	absent	present
Vein Cu_1 distal dark spots	2 short	1 long	2 short
Vein 1A dark spots	3 short	2 (1 short + 1 long)	2 (1 short + 1 long)
Vein 1A fringe	pale	dark	dark

The occurrence of the characters listed in Table 6 on specimens of these 3 species (Table 7) illustrates the variability of several of the characters in Thailand and highlights the problem of identifying certain females of these species.

Only one additional adult character was found during this study that will definitely assist in the identification of *varuna*. This character, the absence of apical pale banding or apical dorsal spots on the tarsomeres of *varuna*, will be of particular help in separating adults of *varuna* from *aconitus*, which has fairly conspicuous pale tarsal bands, particularly on the foretarsomeres. This character will also separate *varuna* from *minimus*, however, the small dorsoapical pale patches on the foretarsomeres of *minimus* are more difficult to see than those on *aconitus*.

Variations in pupal setal branching are presented in Table 13. The ranges for branching in the table were taken from Thailand specimens. Pupae from Sri Lanka exhibited fewer branches on most setae, and these data were not included in the table. The peculiar shape of the trumpet was originally thought to be due to slide mounting-coverslip pressure. However, an examination of all available pupae revealed this character is stable, even on slides in which the trumpet is free-floating in thicker mounts.

Variations in larval setal branching are presented in Table 19. The ranges given were taken from Thai specimens. Sri Lanka larvae like the pupae, usually had fewer branches on most setae. As for the pupae, I consider these differences probably due to geographical variation.

One variation on *varuna* larvae has been responsible for considerable taxonomic confusion, i.e., the presence or absence of lateral barbs on seta 2-C. Cogill (1903) originally noted the fine barbs or "filaments" on 2-C on *varuna* (as *fluviatilis*) larvae. In 1972, I found one larval skin (#292 tube 22) and 4 whole larval slides in the BMNH from Cogill's collection. The 4 whole larvae were ruined but the one skin is clearly *varuna* and has 2 short barbs on the remaining seta 2-C. Carter (1925) thinking he was discussing *fluviatilis* (as *listoni*), not only described, but inadvertently illustrated the larva of *varuna* for the first time. Carter discussed 2 types of *"listoni"* (= *varuna*) larvae from Ceylon; (A) with clypeal setae simple and (B) the most common form on Ceylon, with the clypeals having a few "short branches" (= barbs) at intervals along the stem. These 2 references to *varuna* larvae have not been recognized by most authors as applying to *varuna*. Consequently, Evans (1930), Christophers and Puri (1931) and Puri (1931) were usually given credit for the first accurate larval descriptions and illustrations of *varuna* larvae. In the last 2 references southern Indian larvae were used and the clypeal setae were described as "simple, unfrayed." Christophers (1933) followed this by implying *varuna* clypeal setae were like those on *minimus*. Since then most of the major mosquito publications with keys have depicted *varuna* larvae as having 2-C simple (e.g., Russell et al. 1943, Puri 1949, Foote and Cook 1959, Wattal 1963, Bonne-Wepster 1963, Reid 1968). Roy (1938) found the predominant form of *varuna* in Bengal had 2-C barbed and Rao and Ramakrishna (1940) found the same in Orissa and Madras. D'Abrera (1944) reconfirmed Carter's (1925) contention (as *listoni*) that the most abundant form of *varuna* on Ceylon had 2-C barbed. These last 3 publications were, unfortunately, not considered in the major publications listed above. Consequently, I believe that most *varuna* larvae have not been correctly identified since 1931. Based on Roy (1938), 93% of the *varuna* larvae from Bengal had 2-C barbed, while Rao and Ramakrishna (1940) found 98% (286/291) from Madras and 98% (394/402) from Orissa with 2-C barbed. During the present study, all 13 Thai larval

TABLE 7. Frequency (*f*) of published key characters on adult females of *An. aconitus*, *varuna* and *minimus**.

Characters	*aconitus*				*varuna*		*minimus*			
	Feral (1,302)*		Progeny (1,165)		Feral** (22)		Feral (2,264)		Progeny (854)	
	f	(No.)	*f*	(No.)	*f*	(No.)	*f*	(No.)	*f*	(No.)
Proboscis entirely dark	0.0	(0)	0.002	(2)	0.476	(10/21)	0.939	(2,126)	0.943	(805)
Proboscis partially pale on distal 0.3, often ventral only	0.015	(20)	0.025	(29)	0.524	(11/21)	0.061	(138)	0.057	(49)
Proboscis entirely pale on distal 0.3-0.5	0.985	(1,282)	0.973	(1,134)	0.0	(0)	0.0	(0)	0.0	(0)
Presector pale spots absent (both)***	0.756	(984)	0.871	(1,015)	1.0	(22)	0.020	(45)	0.025	(21)
Presector pale spot present (one)***	0.244	(318)	0.129	(150)	0.0	(0)	0.980	(2,219)	0.975	(833)
Presector pale spots present (both)	0.183	(238)	0.083	(97)	0.0	(0)	0.962	(2,178)	0.974	(832)
Vein Cu_1 with 1 long distal dark spot (both)	0.006	(8)	0.0	(0)	0.50	(11)	0.029	(66)	0.032	(27)
Vein 1A with 3 dark spots (both)	no count		0.744	(867)	0.0	(0)	0.012	(27)	0.032	(27)
Vein 1A with 2 dark spots (one)	no count		0.256	(298)	0.0	(0)	0.988	(2,237)	0.968	(827)
Vein 1A with 2 dark spots (both)	0.107	(139)	0.196	(228)	1.0	(22)	0.985	(2,230)	0.967	(826)
Vein 1A with pale fringe (both)	no count		0.694	(809)	0.0	(0)	0.013	(29)	0.012	(10)
Vein 1A with dark fringe (one)	no count		0.301	(351)	0.0	(0)	0.987	(2,235)	0.988	(844)
Vein 1A with dark fringe (both)	0.123	(160)	0.251	(292)	1.0	(22)	0.976	(2,210)	0.981	(838)

*Total number of specimens examined.

**All from Thailand except 14 *varuna* from Sri Lanka, which exhibited the same frequency of variations as Thai *varuna*.

***(One or (both) = character on at least one wing or on both wings.

skins of *varuna* had at least one barb on one 2-C and 88.5% (23/26) of Sri Lanka larvae of *varuna* had at least one barb on one 2-C. These data confirm that seta 2-C on *varuna* occurs with one to several small barbs or is simple, and suggest that the barbed 2-C variation is by far the most common in most areas. Consequently, I think the simple 2-C variation of *varuna* as described by Christophers and Puri (1931) and Puri (1931) does not represent typical *varuna*, but a less common variation that may possibly have a slightly higher frequency in southern India and Sri Lanka (11.5% this study).

By recognizing only those *varuna* larvae with 2-C simple and only those females with pale scales on the proboscis, less than half of the total *varuna* specimens were being identified by published keys. Thus, it is not unexpected that this species has long remained a taxonomic enigma.

Several other variable larval characters were noted. Seta 3-C on *varuna* can also have weak barbs as found on 2-C, however, the frequency of barbs on 3-C is much lower. Rao and Ramakrishna (1940) found barbs on *varuna* 3-C on none of 291 larvae from Madras and 56% (225/402) of larvae from Orissa. Only 7.7% (1/13) of Thai larval skins had one barb on one 3-C and 14.8% (4/27) of Sri Lanka larvae had one barb on one 3-C. None of the specimens examined had more than one barb on 3-C and none had both setae 3-C with a barb. Typically, 4-C is described as simple on *varuna*, however, Rao and Ramakrishna (1940) noted none of 291 larvae from Madras and 0.7% (3/402) of larvae from Orissa with this seta bifid. This seta was simple on all (13) Thai larval skins examined and was bifid on only 3.8% (1/26) of larvae from Sri Lanka. The one specimen with 4-C bifid had both 4-C forked at approximately 0.33 from the base. The occasional specimens of *varuna* with 4-C bifid might possibly be confused with *aconitus* larvae. Larvae of *varuna* often exhibited 1, 2 pairs of small dorsal submedian plates on the mesothorax as previously described for *minimus* (Reid 1968). Two small dorsal submedian plates were usually found on abdominal segments I-VII, however, occasionally these plates were incorporated into or fused with the anterior tergal plate on several segments. Only one anomalous variation was found on a *varuna* larva. This specimen lacked the right 4-C, without even a trace of its alveolus.

The adult variations discussed above definitely make specimens of *varuna* among the most difficult in the series to identify. This is particularly true where *varuna* is also sympatric with *aconitus* and *minimus* (see Thailand key). Fortunately, the pupal and 4th larval stage are more readily identified. Although the barbs on larval 2-C are not present 100% of the time, they are probably present on 90-95% of *varuna* larvae. When they are present, they are diagnostic because of the few barbs present in comparison with those on *aconitus* and *jeyporiensis*.

TAXONOMIC DISCUSSION. As outlined in the Variations section, there are several reasons why *varuna* has remained so poorly known for so long. However, the primary reason has been the reliance on a stable (100%) character concept and an unwillingness to accept a variable character concept. This was compounded by a lack of revisionary studies (Scanlon, Reid and Cheong 1968, Reid 1970) in Southeast Asia and the Indian subregion since the 1930's, and a lack of adequate reared material in collections outside of India.

In Thailand, *varuna* is obviously an uncommon species. The systematic collections made all over Thailand by SEATO Medical Research Laboratory personnel since the early 1960's have been very thorough and have revealed many cryptic mosquito species and their habitat associations. Despite this thoroughness, *varuna* was not detected and confirmed in Thailand until personnel of the Thai National Malaria Eradication Project collected it in Lam-

pang Province in July 1976. This particular region of Thailand is the logical area an "Indian" species such as *varuna* would be expected to occur. Several other "Indian" species are known from northwest Thailand, they are *culicifacies*, *jeyporiensis*, *stephensi*, and several species of *Aedes (Stegomyia)* (Huang 1972, 1977).

In much of peninsular India and Sri Lanka where *minimus* does not occur and *aconitus* is not very abundant, *varuna* females should be relatively easy to identify. In more eastern and northern areas such as Nepal, Assam, West Bengal, Bangladesh, Burma and Thailand, however, where *minimus* and *aconitus* are common and often exhibit melanic variations during the cool season, *varuna* females may be impossible to identify with any degree of reliability without associated immature skins. In the Chiang Mai area of Thailand, *varuna*-like melanic adult variants of *aconitus* are quite common, particularly during the cool months (November-January). During these months infrequent melanic specimens of *minimus* also occur in the Chiang Mai area that may resemble *varuna* or in some cases *fluviatilis* (usually the former). Further south in central Thailand (e.g., Sara Buri), where *varuna* probably does not occur, *varuna*-like variants of *minimus* are more common than similar variants of *aconitus*. This is apparently due to clinal changes in the color pattern of *aconitus*, causing this species to be paler in the southern and central areas of Thailand.

Usually, *varuna* adults should be distinct from those of *aconitus* on the basis of many characters: color--*aconitus* pale yellow to light brown, *varuna* dark brown to black; antennal integument--*aconitus* pale white to light tan, *varuna* dark gray to brown; vein R_2--*aconitus* usually with median pale spot, *varuna* with only basal and apical pale spots; R_{4+5}--*aconitus* usually with small basal dark spot or without basal dark spot, *varuna* usually with large basal dark spot; M_{1+2}--*aconitus* often with median pale spot, *varuna* without median pale spot; Cu_1--*aconitus* usually with 2 dark spots distal to m-cu crossvein, *varuna* often with only one long dark spot distal to m-cu crossvein; 1A--*aconitus* usually with 2 dark spots on distal half, *varuna* with only one long dark spot on distal half; 1A pale fringe spot--*aconitus* usually present, *varuna* absent; and foretarsomeres--*aconitus* with distinct apical pale bands or dorsal pale spots, *varuna* entirely dark.

There are not as many characters for separating *varuna* and *minimus* adults: antennal integument--*minimus* pale white to light tan, *varuna* dark gray to brown; presector pale spot on costa--*minimus* usually present, *varuna* rarely present; R accessory sector pale spot--*minimus* often present, *varuna* absent; Cu_1--*minimus* usually with 2 dark spots distal to m-cu crossvein, *varuna* often with only one long dark spot distal to m-cu crossvein; and foretarsomeres--*minimus* usually with dorsoapical pale spots or narrow bands, *varuna* entirely dark.

Adult female *varuna* are easily separated from *culicifacies* by differences in the following characters: resting posture, palpal banding, basal costal pale spots, color of scales on the remigium-R base, color of scales usually on R_{4+5}, color of scales on Cu base and the pale fringe spots on the wing margin.

The separation of *jeyporiensis* and *pampanai* adults from those of *varuna* is also easy. Adults of *varuna* and *jeyporiensis* can be separated by differences in the following characters: scutal scales, foretarsomere pale bands or dorsoapical spots, basal costal pale spots, R_1 accessory pale spot on preapical dark mark, R_2 with median pale spot, Cu_1 dark spots distal to m-cu crossvein and 1A pale fringe spot. Adults of *varuna* and *pampanai* can be

separated by differences in the following characters: foretarsomere pale bands or dorsoapical spots, basal costal spots, color of scales on the remigium-R base and presence or absence of a separate R accessory sector pale spot.

The pupal stage of *varuna* is very similar to those of *aconitus* and *pampanai*, but has a number of distinct characters. Differences separating the pupae of *aconitus* from *varuna* were listed in the *aconitus* Taxonomic Discussion section. Characters to differentiate the pupae of *pampanai* and *varuna* are: shape of the trumpet; seta 4-C branches--*pampanai* (5-7), *varuna* (2-5); 4-II branches --*pampanai* (6-10), *varuna* (3-6); 7-III branches--*pampanai* (5-9), *varuna* (1-5); 4-IV branches--*pampanai* (4-6), *varuna* (1-4); 7-IV branches--*pampanai* (5, 6), *varuna* (1-5); paddle refractile margin--*pampanai* (0.66-0.76), *varuna* (0.89-0.96); paddle fringe--*pampanai* (not mesad of 1-P), *varuna* (extending mesad of 1-P to mesal angle); and male genital lobe--*pampanai* (with 2 transverse dark bands), *varuna* (unicolorous).

The pupae of *minimus* and *varuna* are most easily separated by the development and position of seta 0-III-VII (*minimus* usually 2-5 long branches and lateral, *varuna* small, simple or bifid and mesal). Other characters to differentiate the pupae of these 2 species are listed in the *minimus* Taxonomic Discussion section.

The pupa of *varuna* is best separated from those of *culicifacies* and *jeyporiensis* by the key characters. In addition, *varuna* pupae can be separated from those of *culicifacies* by differences in the following characters: trumpet shape; branches of setae 2, 4, 9-I (length also), 5-II, 1, 5-III, 5, 6-IV and 1-V-VII; and the paddle fringe. Pupae of *varuna* can be separated from those of *jeyporiensis* by: trumpet shape, and branches of setae 2, 3, 5-C, 2, 4, 9-I (length also), 1, 3, 5-II, 1, 2, 5, 6-III, 1, 2-IV, 6-IV, 2-V, 2-VI and 9-VIII.

The 4th-stage larva of *varuna* is the best stage for identifying the species. The larval characters are much easier to see than those on the pupa and although several characters are variable, the total combination is highly reliable. The following combination of characters should identify 99-100% of the *varuna* larvae encountered: seta 2-C with 1-4 fine lateral barbs, 4-C simple, 8-C branched, 4-M with 3-6 branches, 3-T leaflets with long, tapering filamentous tips, anterior tergal plates on abdominal segments very large and wide (0.60-0.85 width of segment), anterior tergal plate II convex on caudal margin and enclosing median posterior tergal plate, seta 0-II-VII arising on anterior tergal plates 0.22-0.38 of distance from lateral margin to midline, 13-III with 3-5 branches and large like 13-IV and median plate on spiracular apparatus with lateral arms.

Besides the key characters, other characters for differentiating the larvae of *varuna* from those of *aconitus* and *minimus* are listed in the Taxonomic Discussion sections of those 2 species. Characters exhibiting differences between the larvae of *culicifacies* and *varuna* are: barbs or branches on setae 2, 8-C, 2-P, 4-I, 13-III, 9-IV, 2-VII, VIII; sclerotized bases of 1, 2-P; leaflets on 3-T and 1-I; size of the abdominal anterior tergal plates; location of abdominal seta 0; and shape of the median plate on the spiracular apparatus. Of these, the differences in 2, 8-C, 3-T, size of anterior tergal plates, location of seta 0 and shape of the median plate are the most diagnostic. Characters to separate the larvae of *varuna* and *jeyporiensis* are: barbs or branches on setae 2-4-C, 2-P, 1-M, 9-T, IV, 8-S and 1-X; leaflets on 3-T and 1-II; size of abdominal anterior tergal plates; location of abdominal seta 0; and development of tips of basal branches on 2-X. Of these, the differences in 2-4-C, 1-X, 3-T, anterior tergal plates, location of seta 0 and 2-X basal branches are the most distinct.

If larvae of *varuna* in Thailand occur without barbs on 2-C, or if these barbs are overlooked, these larvae could be incorrectly identified as *pampanai* since both species have large abdominal tergal plates with seta 0 arising on the plates some distance from the edge. There are several other characters, however, that will separate the larvae of these 2 species under these circumstances, they are: 9-P branches--*pampanai* (7-12), *varuna* (10-15); 4-M branches and their length--*pampanai* (2, 3 long, summation both sides 4-6), *varuna* (3-6 short, summation both sides 6-10); tips of 3-T leaflets--*pampanai* nearly always with abruptly tapering, blunt tips), *varuna* (with long gradually tapering, filamentous tips); 13-III branches and development--*pampanai* (6-12, weakly developed, smaller than 13-IV), *varuna* (3-5 large stout branches, equal size of 13-IV); and anterior tergal plate II--*pampanai* (concave on caudal margin with posterior tergal plate separate), *varuna* (convex on caudal margin, enclosing posterior tergal plate).

Taxonomically, *varuna* represents a distinct specific taxon that is an obvious member of the Minimus Species Group. This species possesses fairly variable adult characters, and may appear very similar to several other species in the Minimus Group. In addition, highly variable characters on *aconitus*, *minimus* and possibly *fluviatilis*, often overlap and obscure the diagnostic characters on *varuna*. When possible, every effort should be made to confirm suspected adults of *varuna* by rearing additional specimens with associated immature skins. This is the only basis on which additional records of *varuna* in Thailand or Southeast Asia should be accepted.

In the past (Christophers 1924a, Christophers and Puri 1931, Christophers 1933), this species was thought to have its closest affinities with *minimus*. Based on 18 character states (adult, pupal and larval) examined during this study, *varuna* has the most similarities with *mangyanus*, *pampanai*, *aconitus*, *fluviatilis*, *flavirostris*, *minimus* and *filipinae*, in decreasing order. Accordingly, I consider *varuna* quite distantly rather than closely related to *minimus*.

BIONOMICS. The habitat and biology of *varuna* in Thailand are poorly known, and most of the biological information here is based on Indian and Burmese studies. Larvae of *varuna* are typically found in stagnant, but fresh water in ponds, ditches, irrigation canals, roadside pools and particularly man-made earthen or brick-lined wells in the flat plains areas of India (Christophers 1933, Russell and Rao 1940). In Tamil Nadu, India, larvae of this species were extremely abundant in wells, with irrigation canals a poor 2nd and rare in tanks (ponds), ditches and pools in any type of ricefield (Russell and Rao 1940). Rao (1961) reported larvae of this species as most common in slowly running water including seepage water sources in hill tract areas of India and Khin-Maung-Kyi (1971) in Burma, found larvae most common in slow running, grass-edged streams and seepages and ricefields with seepage water in hilly areas where the water source is exposed to sunlight. Rao (1961) also noted that larvae have been found in habitats with dense vegetation, but they are more abundant when the vegetation is cleaned up, and in some collections larvae seem to prefer shade under overhanging vegetation. Larval collections of *varuna* in Thailand have come from still seepage water, still water along a stream margin or from a large isolated stream pool. The last 2 habitats had abundant emergent grass and other vegetation and the larvae were collected by pressing the vegetation down or moving it aside.

Very few publications have mentioned the elevation requirements of *varuna*. Recently, Prakash and Husainy (1974a) collected this species between 152 m to over 761 m in Madhya Pradesh, India, with the peak density between 457-609 m. Rahman et al. (1975) in Tamil Nadu, India, found larvae of *varuna* only in a

forested area between 300-450 m. The collection from Lampang Province, Thailand was made at 200 m or above, while the 1978 collections from Chiang Mai Province were made at approximately 400 m.

Reports on the adult behavior of *varuna* have been contradictory and confusing, causing Covell (1944) and Rao (1961) to discuss the possibility of 2 different biological races of *varuna* in India. Generally, early references (e.g., Covell 1944) note that in the flat plains areas of India the species is zoophilic, feeding primarily on bovines, and found resting much more commonly in cattle sheds than human habitations. Khin-Maung-Kyi (1971) reported the same behavior for Burmese specimens. Rao (1961) summarizes reports from the hilly areas of east central India, where *varuna* adults were often captured in human habitations and were decidedly anthropophilic. More recently, Prakash and Husainy (1974a) working in the hills of east central India, found *varuna* purely zoophilic and exophilic, with a distribution restricted to forested areas. Precipitin tests showed contradictory primate-bovine frequencies for different samples from India, Nepal and Pakistan (probably = Bangladesh) (Bruce-Chwatt et al. 1966).

Apparently adult *varuna* are basically exophilic and very prone to seek and use outside resting shelter if it is available. Muirhead-Thomson (1951) found numerous *varuna* adults resting on the steep shaded banks over small streams. Of the over 2,000 adults he captured, 47% were blood-fed. Muirhead-Thomson also reported that development of eggs in the ovaries required about 48 h during the warmer part of the year. Rao (1961) reported on previous studies indicating that repeated feeding may be necessary for *varuna* eggs to mature. This physiological behavior was also mentioned in the *culicifacies* Bionomics section and is known as "gonotrophic discordance."

Adults of *varuna* (probably females) have been reported to have a flight range up to slightly less than 1 km (Rao 1961). Adults in southern India were usually most prevalent during the monsoon season, however, in Burma, Khin-Maung-Kyi (1971) described a seasonal prevalence with 2 peaks, one during the early part of the monsoon and a higher peak just after the wet monsoon ends. Khin-Maung-Kyi also gave the only reference to hourly biting preferences, i.e., on cattle between 1800-2400 h. No reports are available on the susceptibility of this species to insecticides.

Several parasites other than *Plasmodium* spp. have been reported from *varuna*, these are: *Coelomomyces anophelesicus* Iyengar and *C. indicus* found in Indian specimens (Iyengar 1935, 1962); *Thelohania legeri* Hesse, and *T. obscura* Kudo, from Indian larvae; and a *Mermis* sp. in Indian larvae. These last 2 reports were summarized by Jenkins (1964). Recently, Hazard and Anthony (1974) placed the species of *Thelohania* parasitizing mosquitoes in the genus *Parathelohania* Codreanu.

HYBRIDIZATION EXPERIMENTS

One of the primary objectives of this study was the experimental hybridization of as many of the species in the series as possible. It was hoped that these experiments would determine to what degree the test species were genetically compatible, and if hybrids in nature could be responsible (in part) for the wide variation found in adult characters. However, colonization of the respective species by the forced mating technique (Ow Yang et al. 1963) was considered necessary to produce adequate numbers for hybridization attempts. Most members of this series had not been colonized, and previous attempts had

shown that *aconitus* and *minimus* would not mate in the laboratory. Once colonies of the test species were successfully maintained by the forced mating technique, then the technique was considered sufficiently reliable for the colonies to serve as controls for the crossing experiments. Unfortunately, time limitations and the low density and sparse distribution of most of the series members in Thailand made colonization and subsequent hybridization experiments possible only with *aconitus* and *minimus*.

By 1969-early 1970 successful colonies of *aconitus* and *minimus* were being maintained in Thailand by the forced mating technique, and hybridization experiments were initiated. Handling requirements used during the experiments were as follows:

(1) The specimens used were progeny raised from eggs oviposited by wild females in the laboratory, because they appeared stronger than colony specimens.
(2) All specimens were individually isolated when they reached the 4th larval stage and assigned a rearing number at that time.
(3) Adults were individually isolated in small cup containers upon emergence and provided with a dilute sugar source and skins of immature stages were mounted on slides to confirm identification.
(4) Females were allowed one blood meal and were at least 48 h old before mating, while males were at least 24 h old before mating.
(5) Identities of the adults were confirmed again by the associated immature skins just before actual forced mating.
(6) Forced-mated females were placed in individual cup containers with a dilute solution of a locally produced multivitamin syrup and placed in a separate room from the males.
(7) Gravid females were maintained in isolation and allowed to oviposit.
(8) Eggs from a given female were placed in a small hatching container, then transferred to a larger pan of water with a screen covering.
(9) Hybrid larvae reared to 4th instar were individually isolated and skins were collected and mounted on slides when the adults emerged.

This strict regimen was maintained throughout the experiments and the chance of accidental mating was considered eliminated.

A total of 122 crosses were made between *aconitus* and *minimus*, of which 46 were *aconitus* ♀ x *minimus* ♂ and 76 were *minimus* ♀ x *aconitus* ♂. In the former category one *aconitus* oviposited 29 eggs and these failed to hatch. In the alternate cross 8 *minimus* oviposited 535 eggs, but only 153 eggs from 4 different females hatched. All larvae died before reaching 3rd instar, except 3 from one female. These 3 produced 2 adult males and one dead female pupa. Both males were morphologically more like *minimus*, with distinct scales on the scutum. One male died within 6 h, while the 2nd male was backcrossed to a *minimus* female after 30 h. Although this female remained alive 7 days after mating and was given a blood meal, she did not oviposit. None of the females involved were dissected to determine if they were fertilized, eggs were not checked for embryonation and the 2 hybrid males were not checked for testes development.

Although certain questions remain unanswered, the results of these crosses appear very similar to several crosses conducted between members of the Maculipennis Species Group (Kitzmiller et al. 1967), between *stephensi* and *maculatus* Theobald (Narang et al. 1972) and several crosses discussed in Kitzmiller (1976). These crosses are characterized by the oviposition of only a few eggs, of which most do not hatch, and those larvae that do hatch are usually unable to develop beyond the early larval stages. According to

Coluzzi and Kitzmiller (1975) these characteristics are indicative of considerable genetic incompatibility.

Based on the results of these experiments I feel very confident that hybrids of *aconitus* x *minimus*, if they exist in nature, are extremely rare and not a significant factor in the study of variations of these 2 species. Accordingly, based on these hybridization experiments and the accompanying progeny morphological studies, I consider *aconitus* and *minimus* distinct species that are not only morphologically distinct in nearly every life stage, but also genetically incompatible. These finding imply that these 2 species are phylogenetically distantly related members of the Minimus Group.

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LITERATURE CITED

AINSLEY, R. W.
1976. Laboratory colonization of the malaria vector, *Anopheles culicifacies*. Mosq. News 36: 256-8.

ANIGSTEIN, L.
1932. Malaria and anophelines in Siam. Q. Bull. Hlth. Org. League of Nations 1: 233-308.

ANONYMOUS
1959. Corrigendum [*pampanae* emended to *pampanai* according to Article 14, International Rules of Zoological Nomenclature]. Acta Trop. 16: 288.

ASLAMKHAN, M., M. AAQIL and M. HAFEEZ
1972. Genetical and morphological variations in a naturel population of the malaria mosquito, *Anopheles stephensi* from Karachi, Pakistan. Biologia 18: 29-41.

ASLAMKHAN, M. and R. H. BAKER
1969. Karyotypes of some *Anopheles*, *Ficalbia* and *Culex* mosquitoes of Asia. Pak. J. Zool. 1: 1-7.

ATMOSOEDJONO, S. and D. T. DENNIS
1977. *Anopheles aconitus* and *An. subpictus* naturally infected with *Wuchereria bancrofti* in Flores, Indonesia. Mosq. News 37: 529.

AYURAKIT-KOSOL, L. and M. E. GRIFFITH
1956. The developing antimalaria vigilance programme in Thailand. Bull. W.H.O. 15: 799-805.

1962. Progress toward malaria eradication in Thailand. Proc. 9th Pac. Sci. Congr. (1957 Bangkok). 17: 122-36.

BABA, K.
1950. A study of anopheline mosquitoes in relation to the epidemiology of malaria in Canton Delta, South China. Trans. Kansai Entomol. Soc. 15(2): 1-11.

BAISAS, F. E.
1936. Notes on Philippine mosquitoes, VI: the pupal characters of anophelines of the subgenus *Myzomyia*. Philipp. J. Sci. 6: 205-20.

1957. Notes on Philippine mosquitoes, XVIII. The malaria vector, *flavirostris:* summary of recent findings. Mon. Bull. Bur. Health Philipp. 29: 68-74.

1974. The mosquito fauna of Subic Bay Naval Reservation, Republic of the Philippines. 1st Med. Serv. Wing (PACAF) Tech. Rep. 72-2: 1-170.

BAISAS, F. E., A. U. PAGAYON, B. CRISOSTOMO and F. DIGMA
1950. Malaria inquiry in Baguio and vicinity (August 1946). Mon. Bull. Bur. Health Philipp. 26: 43-61.

BANKS, C. S.
1906. A list of Philippine Culicidae with descriptions of some new species. Philipp. J. Sci. 1: 977-1005.

1914. A new Philippine malaria mosquito. Philipp. J. Sci. (D) 9: 405-7.

BARNES, M. E.
1923a. Notes on the anopheline mosquitoes of Siam. Am. J. Hyg. 3: 121-6.

1923b. Anopheline mosquitoes with special reference to the species found in Siam. J. Nat. Hist. Soc. Siam 6: 65-79.

BARRAUD, P. J. and S. R. CHRISTOPHERS
1931. On a collection of anopheline and culicine mosquitoes from Siam. Rec. Malar. Surv. India 2: 269-85.

BASIO, R. G.
1971. The mosquito fauna of the Philippines (Diptera: Culicidae). Natl. Mus. Philipp. Monogr. 4: 1-198.

BELKIN, J. N.
1962. The mosquitoes of the South Pacific (Diptera: Culicidae). Univ. Calif. Press, Berkeley and Los Angeles, 2 vols. 608 and 412 p.

BENNETT, G. F., M. WARREN and W. H. CHEONG
1966. Biology of the simian malarias of Southeast Asia. II. The susceptibility of some Malayan mosquitoes to infection with five strains of *Plasmodium cynomolgi*. J. Parasitol. 52: 625-31.

BHATIA, M. L. and N. L. KALRA
1961. Chapter 1. Pictorial account of malaria vectors in India. pp. 1-12, *in* Vectors of malaria in India. (2nd edit.). Natl. Soc. India Malar. Mosq.-Borne Dis., Delhi. 242 p.

BHATIA, M. L. and K. S. KRISHNAN
1961. Chapter 11. *A. culicifacies* Giles, 1901, pp. 147-86, *in* Vectors of malaria in India. (2nd edit.). Natl. Soc. India Malar. Mosq.-Borne Dis., Delhi. 242 p.

BINGHAM, E.
1968. Environmental conditions relating to harmful insects of mainland Southeast Asia. U. S. Army Natick Lab. Tech. Rep. 69-28-ES-40: 1-61.

BONNE-WEPSTER, J.
1963. Appendix 7. The Malayan region, p. 701-12, *in* Russell, P. F., L. S. West, R. D. Manwell and G. Macdonald. 1963. Practical malariology. Oxford Univ. Press, London. 750 p.

BONNE-WEPSTER, J. and N. H. SWELLENGREBEL
1953. The anopheline mosquitoes of the Indo-Australian Region. J. H. De Bussy, Amsterdam. 504 p.

BRAHMACHARI, U. N.
1911. On an anopheline allied to *Myzomyia listoni*. Indian Med. Gaz. 46: 268.

BRAM, R. A., M. D. DELFINADO, B. A. HARRISON, E. L. PEYTON, R. RATTANARITHIKUL and J. E. SCANLON
1968. Mosquito fauna of Thailand, p. 341-3, *in* 1967-68 Annu. Prog. Rep., SEATO Med. Res. Lab., Bangkok. 474 p.

BROWN, A. W. A.
1958. Insecticide resistance in arthropods. W.H.O. Monogr. Ser. 38: 1-240.

BROWN, A. W. A. and R. PAL
1971. Insecticide resistance in arthropods. (2nd edit.). W.H.O. Monogr. Ser. 38: 1-491.

BROWN, W. L. and E. O. WILSON
1956. Character displacement. Syst. Zool. 5: 49-64.

BRUCE-CHWATT, L. J.
1970. Global review of malaria control and eradication by attack on the vector. Misc. Publ. Entomol. Soc. Am. 7: 7-23.

BRUCE-CHWATT, L. J., C. GARRETT-JONES and B. WEITZ
1966. Ten years' study (1955-64) of host selection of anopheline mosquitoes. Bull. W.H.O. 35: 405-39.

BRUCE-CHWATT, L. J. and C. W. GÖCKEL
1960. A study of the blood-feeding patterns of *Anopheles* mosquitoes through precipitin tests. Results of collaborative work for the period 1955-59 and their application to malaria eradication programmes. Bull. W.H.O. 22: 685-720.

BRUG, S. L.
1938. *Filaria bancrofti* - overbrengers op Kabaena. Meded. Dienst Volksgezond. Med.-Ind. 27: 88-97.

BRUG, S. L. and J. BONNE-WEPSTER
1947. The geographical distribution of the mosquitoes of the Malay Archipelago. Chron. Natura 103: 179-97.

BRYDON, H. W., G. JOSHI and S. PRADHAN
1961. *Anopheles* distribution and its relation to the malaria eradication program in central Nepal. Mosq. News 21: 102-5.

BUNNAG, T.
1977. Nidal delineation of Thailand: an approach to disease ecology in major nidal base regions. Southeast Asian J. Trop. Med. Public Health 8: 236-48.

BÜTTIKER, W. W.
1958a. Observations on the physiology of adult anophelines in Asia. Bull. W.H.O. 19: 1063-71.

1958b. Notes on exophily in anophelines in South-East Asia. Bull. W.H.O. 19: 1118-23.

BÜTTIKER, W. W. and P. F. BEALES
1959. *Anopheles pampanae*, a new species of mosquito from Cambodia. Acta Trop. 16: 63-9.

1965. Keys to the anopheline mosquitoes of Cambodia with reference to species occurring in some neighboring territories. Bull. Soc. Entomol. Suisse 37: 191-214.

CABRERA, B. D. and P. V. ARAMBULO
1977. Malaria in the Republic of the Philippines. Acta Trop. 34: 265-79.

CAGAMPANG-RAMOS, A. and R. F. DARSIE
1970. Illustrated keys to the *Anopheles* mosquitoes of the Philippine Islands. USAF Fifth Epidemiol. Flight, PACAF Tech. Rep. 70-1: 1-49.

CARTER, H. F.
1925. The anopheline mosquitoes of Ceylon. Part I. The differential characters of the adults and larvae. Ceylon J. Sci. (D) 1: 57-97.

1950. Ceylon mosquitoes: Lists of species and names of mosquitoes recorded from Ceylon. Ceylon J. Sci. (B) 24: 85-115.

CAUSEY, O. R.
1937. Some anopheline and culicine mosquitoes of Siam with remarks on malaria control in Bangkok. Am. J. Hyg. 25: 400-20.

CHOW, C. Y.
1949. The identification and distribution of Chinese anopheline mosquitoes. J. Natl. Malariol. Soc. 8: 121-31.

1970. Bionomics of malaria vectors in the Western Pacific Region. Southeast Asian J. Trop. Med. Public Health 1: 40-57.

CHOW, C. Y., R. M. IBNOE and S. T. JOSOPOERO
1960. Bionomics of anopheline mosquitoes in inland areas of Java, with special reference to *Anopheles aconitus* Dön. Bull. Entomol. Res. 50: 647-60.

CHRISTOPHERS, S. R.
1912a. [Paper read on duties of central committee - record of the 2nd meeting of the general malaria committee, held in Bombay on 16-17 November 1911.]. Paludism (Simla) 4: 25-7.

1912b. [Paper read on work in the Andamans - record of the 2nd meeting of the general malaria committee, held in Bombay on 16-17 November, 1911.] Paludism (Simla) 4: 42-4.

1912c. Malaria in the Andamans. Sci. Mem. Gov. India 56: 1-48.

1915. The male genitalia of *Anopheles*. Indian J. Med. Res. 3: 371-94.

1916. A revision of the nomenclature of Indian Anophelini. Indian J. Med. Res. 3: 454-88.

1924a. Provisional list and reference catalogue of the Anophelini. Indian Med. Res. Mem. 3: 1-105.

1924b. Some further varieties of Indian species of *Anopheles* with notes on the species *A. pallidus* Theobald and *A. philippinensis* Ludlow. Indian J. Med. Res. 12: 295-301.

1933. The fauna of British India, including Ceylon and Burma. Diptera. Vol. IV. Family Culicidae. Tribe Anophelini. Taylor and Francis, London. 371 p.

CHRISTOPHERS, S. R. and P. J. BARRAUD
1931. The eggs of Indian *Anopheles*, with descriptions of the hitherto undescribed eggs of a number of species. Rec. Malar. Surv. India 2: 161-92.

CHRISTOPHERS, S. R. and K. CHAND
1915. Notes on some anophelines from Arabia and Mesopotamia. Indian J. Med. Res. 3: 180-200.

CHRISTOPHERS, S. R. and I. M. PURI
1931. Species and varieties of the *funestus* series of *Anopheles*. Rec. Malar. Surv. India 2: 481-93.

CLARKE, J. L, P. R. J. HERATH and M. B. WICKRAMASINGHE
1974. Studies on DDT resistance in *Anopheles culicifacies* in Sri Lanka. WHO/MAL/74.826, 11 p.

COGILL, H.
1903. The *Anopheles* of Karwar (North Kanara). J. Bombay Nat. Hist. Soc. 15: 327-36.

COLBOURNE, M. J. and S. A. SMITH
1964. Problems of malaria in the Aden Protectorate (report on a visit). WHO/MAL/442, 70 p.

COLUZZI, M. and J. B. KITZMILLER
1975. Anopheline mosquitoes, p. 285-309, *in* King, R. C. (ed.). Handbook of genetics. Vol. 3. Invertebrates of genetic interest. Plenum Publ. Co., New York. 874 p.

COVELL, G.
1944. Notes on the distribution, breeding places, adult habits and relation to malaria of the anopheline mosquitoes of India and the Far East. J. Malar. Inst. India 5: 399-434.

CRAWFORD, R.
1938. Some anopheline pupae of Malaya with a note on pupal structure. Federated Malay States, Singapore. 110 p.

D'ABRERA, V. ST. E.
1944. The eggs of the Ceylon anopheline mosquitoes. J. Malar. Inst. India 5: 337-59.

DAS GUPTA, S. K.
1964. *Culicoides (Trithecoides) anophelis* Edwards [Insecta: Diptera: Ceratopogonidae] as an ectoparasite of insect vectors. Proc. Zool. Soc. (Calcutta) 17: 1-20.

DAVIS, N. C.
1928. A consideration of variability in the *Nyssorhynchus* group of the genus *Anopheles*. Am. J. Hyg. 8: 539-63.

DE BURCA, B. and H. W. FORSHAW
1947. Winter variations of the larva of *A. fluviatilis* from northern India and Bombay Presidency. Indian J. Malariol. 1: 417-8.

DE FLUITER, H. J.
1948. Malaria en malaria-overbrengers in de krijgsgevangenkampen Chungkai en Tamuang (W. Thailand). Entomol. Ber. (Amst.) 12: 270-5.

DE MEILLON, B.
1947. The anophelini of the Ethiopian geographical region. Publ. S. Afr. Inst. Med. Res. 10: 1-272.

DÖNITZ, W.
1902. Beitrage zur Kenntniss der *Anopheles*. Z. Hyg. Infektionskr. 41: 15-88.

1903. Beitrage zur Kenntniss der *Anopheles*. II. Mittheilung. Z. Hyg. Infektionskr. 43: 215-38.

DO-VAN-QUY
1968. Second revision of "Keys to *Anopheles* adult females and larvae of Vietnam," p. 150-60, *in* 1967-68 Annu. Prog. Rep., U. S. Army Med. Res. Team (WRAIR). Vietnam and Inst. Pasteur Vietnam, Saigon. 428 p.

DO-VAN-QUY and TRAN-VAN-MAU
1971. Mosquito fauna of South Vietnam. (An interim report of the Institut Pasteur, Saigon). [Unpublished]. 33 p.

EDWARDS, F. W.
1913. New synonymy in Oriental Culicidae. Bull. Entomol. Res. 4: 221-42.

1915. [Footnote], p. 156, *in* Ludlow, C. S. 1915. The synonymy of *Anopheles christophersi*, Theo., and *A. indefinita*, Ludl. Bull. Entomol. Res. 6: 155-7.

1922. Mosquito notes.--III. Bull. Entomol. Res. 13: 75-102.

1932. Genera Insectorum Diptera, Fam. Culicidae. Fasc. 194. Desmet-Verteneuil, Brussels. 258 p.

1935. Mosquito notes.--XII. Bull. Entomol. Res. 26: 127-36.

ELLIOTT, R. and J. DE ZULUETA
1975. Ethological resistance in malaria vectors. Behavioural response to intradomestic residual insecticides. WHO/MAL/75.855, 15 p.

EVANS, A. M.
1930. On certain distinguishing characters observed in *Anopheles funestus* Giles. Ann. Trop. Med. Parasitol. 24: 587-92.

1938. Mosquitoes of the Ethiopian region. II. Anophelini adults and early stages. Br. Mus. Nat. Hist., London. 404 p.

EVANS, A. M. and C. B. SYMES
1937. *Anopheles funestus* and its allies in Kenya. Ann. Trop. Med. Parasitol. 31: 105-12.

FENG, L. G.
1933. Some parasites of mosquitoes and flies found in China. Lingnan Sci. J. 12: 23-32.

1938. A critical review of literature regarding the records of mosquitoes in China. Part I. Subfamily Culicinae, Tribe Anophelini. Peking Nat. Hist. Bull. 12: 169-81.

FLOORE, T. G., B. A. HARRISON and B. F. ELDRIDGE
1976. The *Anopheles (Anopheles) crucians* subgroup in the United States (Diptera: Culicidae). Mosq. Syst. 8: 1-109.

FOOTE, R. H. and D. R. COOK
1959. Mosquitoes of medical importance. U. S. Dept. Agric. Handb. 152: 1-158.

GARRETT-JONES, C.
1964. The human blood index ofmalaria vectors in relation to epidemiological assessment. Bull. W.H.O. 30: 241-61.

GATER, B. A. R.
1935. Aids to the identification of anopheline imagines in Malaya. Malar. Advis. Bd., Federated Malay States, Singapore. 242 p.

GATER, B. A. R. and P. D. RAJAMONEY
1929. A summary of records of anopheline breeding - places in Malaya. Bull. Inst. Med. Res., Federated Malay States 1929 No. 2: 1-33.

GILES, G. M.
1901. Description of four new species of *Anopheles* from India. Entomol. Mon. Mag. 37: 196-8.

1902. A handbook of gnats or mosquitoes. 2nd ed. John Bale, Sons and Danielsson Ltd., London. 530 p.

1904. A revision of the Anophelinae, being a first supplement to the second edition of "A handbook of the gnats or mosquitoes." London. 47 p.

GILLIES, M. T.
1963. A note on the identification of *Anopheles rivulorum* Leeson (Diptera: Culicidae). Proc. R. Entomol. Soc. Lond. (B) 32: 86-8.

GILLIES, M. T. and B. DE MEILLON
1968. The Anophelinae of Africa south of the Sahara (Ethiopian zoogeographical region), 2nd ed. Publ. S. Afr. Inst. Med. Res. 54: 1-343.

GOULD, D. J., S. ESAH and U. PRANITH
1967. Relation of *Anopheles aconitus* to malaria transmission in the central plain of Thailand. Trans. R. Soc. Trop. Med. Hyg. 61: 441-2.

GOULD, D. J. and L. C. RUTLEDGE
1967. *Anopheles* and malaria, p. 384-90, *in* 1966-67 Annu. Prog. Rep., SEATO Med. Res. Lab., Bangkok. 518 p.

GRIFFITH, M. E.
1955. A note on *Anopheles minimus* Theobald as a malaria vector in Thailand. Atti. VI Int. Congr. Microbiol. (1953 Rome) 5: 565-7.

GRIFFITH, M. E., E. B. THURMAN and J. M. BUTLER, JR.
1957. The status of malaria control in Thailand. Mosq. News 17: 90-2.

GROTHAUS, R. H., T. G. FLOORE, R. S. STASIAK and W. F. MINER
1971. A partial list of the mosquitoes of I Corps, Republic of Vietnam, with notes on bionomics. U. S. Nav. Med. Fld. Res. Lab. 21(16): 1-31.

HARA, J.
1959. Taxonomical notes on the female terminalia of some anopheline mosquitoes of Japan and Formosa. (With the key to the species and 13 plates). Taxonomical and ecological studies on mosquitoes of Japan. (Part 12). Jap. J. Exp. Med. 29: 107-19.

HARBACH, R. E. and K. L. KNIGHT
1978a. A mosquito taxonomic glossary XIV. The larval body (except chaetotaxy). Mosq. Syst. 10: 53-105.

1978b. A mosquito taxonomic glossary XVI. Vestiture. Mosq. Syst. 10: 540-64.

HARINASUTA, T., H. M. GILLES and A. A. SANDOSHAM (ED.)
1976. SEAMEO-TROPMED scientific group meeting: Malaria in Southeast Asia. Southeast Asian J. Trop. Med. Public Health 7: 641-78.

HARINASUTA, C., S. SUCHARIT, T. DEESIN, K. SURATHIN and S. VUTIKES
1970. Bancroftian filariasis in Thailand, a new endemic area. Southeast Asian J. Trop. Med. Public Health 1: 233-45.

HARRISON, B. A.
1973. *Anopheles (An.) reidi*, a new species of the *barbirostris* species complex from Sri Lanka (Diptera: Culicidae). Proc. Entomol. Soc. Wash. 75: 365-71.

HARRISON, B. A. and J. M. KLEIN.
1975. A revised list of the *Anopheles* of Cambodia. Mosq. Syst. 7: 9-12.

HARRISON, B. A., J. F. REINERT, S. SIRIVANAKARN, Y.-M. HUANG, E. L. PEYTON and B. DE MEILLON
1974. Distributional and biological notes on mosquitoes from Sri Lanka (Ceylon) (Diptera: Culicidae). Mosq. Syst. 6: 142-62.

HARRISON, B. A. and J. E. SCANLON
1975. Medical entomology studies--II. The subgenus *Anopheles* in Thailand (Diptera: Culicidae). Contrib. Am. Entomol. Inst. (Ann Arbor). 12(1): 1-307.

HAWKING, F.
1973. The distribution of human filariasis throughout the world. Part two: Asia. WHO/FIL/73.114, 55 p.

HAZARD, E. I. and D. W. ANTHONY
1974. A redescription of the genus *Parathelohania* Codreanu 1966 (Microsporida: Protozoa) with a reexamination of previously described species of *Thelohania* Henneguy 1892 and descriptions of two new species of *Parathelohania* from anopheline mosquitoes. U. S. Dept. Agric. Tech. Bull. 1505: 1-26.

HO, CH'I.
1938. On a collection of anopheline mosquitoes from the island of Hainan. Ann. Trop. Med. Parasitol. 32: 387-411.

HORSFALL, W. R.
1955. Mosquitoes - their bionomics and relation to disease. The Ronald Press Co., New York. 723 p.

HUANG, Y.-M.
1972. Contributions to the mosquito fauna of Southeast Asia. XIV. The subgenus *Stegomyia* of *Aedes* in Southeast Asia. I - The *scutellaris* group of species. Contrib. Am. Entomol. Inst. (Ann Arbor) 9(1): 1-109.

1977. Medical Entomology Studies -VII. The subgenus *Stegomyia* of *Aedes* in Southeast Asia. II - The *edwardsi* group of species. III-The *w-albus* group of species (Diptera: Culicidae). Contrib. Am. Entomol. Inst. (Ann Arbor) 14(1): 1-111.

ISMAIL, I. A. H., V. NOTANANDA and J. SCHEPENS
1974. Studies on malaria and responses of *Anopheles balabacensis balabacensis* and *Anopheles minimus* to DDT residual spraying in Thailand. Part I. Pre-spraying observations. Acta Trop. 31: 129-64.

1975. Studies on malaria and responses of *Anopheles balabacensis balabacensis* and *Anopheles minimus* to DDT residual spraying in Thailand. Part II. Post-spraying observations. Acta Trop. 32: 206-31.

ISMAIL, I. A. H., S. PHINICHPONGSE and P. BOORASRI
1978. Responses of *Anopheles minimus* to DDT residual spraying in a cleared forested foothill area in central Thailand. Acta Trop. 35: 69-82.

IYENGAR, M. O. T.
1924. On the Indian anophelines of the *funestus* group and the description of a new species (Diptera, Culicidae). Indian J. Med. Res. 12: 23-9.

1935. Two new fungi of the genus *Coelomomyces* parasitic in larvae of *Anopheles*. Parasitology 27: 440-9.

IYENGAR, M. O. T.
1938. Studies on the epidemiology of filariasis in Travancore, Calcutta. Indian Med. Res. Mem. 30: 1-179.

1953. Filariasis in Thailand. Bull. W.H.O. 9: 731-66.

1962. Validation of two species of *Coelomomyces* described from India. J. Elisha Mitchell Sci. Soc. 78: 133-4.

JACKSON, R. B.
1936a. Investigations into the habits and pathogenicity of the anophelines met within two localities in Hong Kong during 1931-1935. Chin. Med. J. 50: 1098-113.

1936b. Some observations on the occurrence of filarial infection in mosquito and man in Hong Kong. Chin. Med. J. 50: 1767-72.

1951. A review of investigations of the habits and pathogenicities of the common anophelines of Hong Kong. Trans. R. Soc. Trop. Med. Hyg. 45: 91-101.

JAMES, S. P.
1902. Malaria in India. Sci. Mem. Med. Sanit. Dept. India. (New series) 2: 1-106.

1911a. *M. culicifacies* variety *punjabensis*, p. 72, *in* James, S. P. and W. G. Liston. 1911. A monograph of the *Anopheles* mosquitoes of India. 2nd ed. Thacker, Spink and Co., Calcutta. 125 p.

1911b. Notes on mosquitoes. I. - The Indian Anophelinae. Paludism (Simla) 2: 52-63.

JENKINS, D. W.
1964. Pathogens, parasites and predators of medically important arthropods. Bull. W.H.O. 30 (Suppl.): 1-150.

JONES, T. W. T.
1950. Anopheline larvae as intermediate hosts for larval trematodes. Parasitology 40: 144-8.

KHIN-MAUNG-KYI
1970. Malaria vectors in Burma I. *Anopheles minimus* Theobald, 1901. Union Burma J. Life Sci. 3: 205-16.

1971. The anopheline mosquitoes of Burma 3. Subgenus *Myzomyia* Blanchard group *Myzomyia* Christophers. Union Burma J. Life Sci. 4: 473-83.

KHIN-MAUNG-KYI and S. M. WINN
1976. Studies on malaria and *Anopheles balabacensis balabacensis* and *Anopheles minimus* in Burma. WHO/MAL/76.875, 23 p.

KING, W. V.
1932. Three Philippine *Anopheles* of the *funestus-minimus* subgroup. Philipp. J. Sci. 48: 485-523.

KITZMILLER, J. B.
1976. Genetics, cytogenetics, and evolution of mosquitoes. Adv. Genet. 18: 315-433.

KITZMILLER, J. B., G. FRIZZI and R. BAKER
1967. Evolution and speciation within the *maculipennis* complex of the genus *Anopheles*, p. 151-210, *in* Wright, J. W. and R. Pal (ed.). 1967. Genetics of insect vectors of disease. Elsevier Publ. Co., New York. 794 p.

KITZMILLER, J. B. and G. F. MASON
1967. Formal genetics of anophelines, p. 3-15, *in* Wright, J. W. and R. Pal (ed.). 1967. Genetics of insect vectors of disease. Elsevier Publ. Co., New York. 794 p.

KLEIN, J.-M.
1977. La fauna des moustiques du Cambodge I. - Anophelinae (Diptera, Culicidae). Cah. O.R.S.T.O.M. Ser. Entomol. Parasitol. 15: 107-22.

KLOSS, C. B.
1915. Zoogeographical divisions for Siam. J. Nat. Hist. Soc. Siam 1: 250-1.

KNIGHT, K. L.
1953. The mosquitoes of the Yemen (Diptera, Culicidae). Proc. Entomol. Soc. Wash. 55: 212-34.

1978a. Supplement to a catalog of the mosquitoes of the world (Diptera: Culicidae). Thomas Say Found., Entomol. Soc. Am. 6 (Suppl.): 1-107.

1978b. A new *Aedes (Finlaya)* mosquito from Thailand. Mosq. Syst. 10: 106-16.

KNIGHT, K. L. and R. E. HARBACH
1977. Maxillae of fourth stage mosquito larvae (Diptera: Culicidae). Mosq. Syst. 9: 455-77.

KNIGHT, K. L. and A. STONE
1977. A catalog of the mosquitoes of the world (Diptera: Culicidae). 2nd Edition. Thomas Say Found., Entomol. Soc. Am. 6: 1-611.

KOIDZUMI, M
1924. The anophelines of Formosa. Trans. Far-East Assoc. Trop. Med. (5th Congr., Singapore) 5: 96-101.

KRISHNASWAMI, A. K.
1961. Chapter 7. *A. minimus* Theobald, 1901, p. 91-101, *in* Vectors of malaria in India. (2nd Edit.) Natl. Soc. India Malar. Mosq.-Borne Dis., Delhi. 242 p.

LAMBORN, W. A.
1922. The bionomics of some Malayan anophelines. Bull. Entomol. Res. 13: 129-49.

LAVERAN, M. A.
1901. Sur des culicides provenant du Haut-Tonkin. C. R. Soc. Biol., Paris 53: 993-4.

LEESON, H. S.
1930. Variations in the wing ornamentation of *Anopheles funestus* Giles. Bull. Entomol. Res. 21: 421-8.

1940. On the wing forms of *Anopheles funestus* Giles. Bull. Entomol. Res. 31: 57-8.

1948. Anopheline larvae collected in Arabia. Ann. Trop. Med. Parasitol. 42: 253-5.

LEESON, H. S. and O. THEODOR
1948. Mosquitos of Socotra. Bull. Entomol. Res. 39: 221-9.

LEFEBVRE, M.
1938. *A. minimus*, vecteur principal du paludisme au Laos. Bull. Soc. Pathol. Exot. 31: 387-90.

LEICESTER, G. F.
1908. The Culicidae of Malaya. Stud. Inst. Med. Res., Federated Malay States. 3(3): 18-261.

LEKAGUL, B. and J. A. Mc NEELY
1977. Mammals of Thailand. Assoc. Conserv. Wildl., Bangkok. 758 p.

LISTON, W. G.
1901. A years' experience of the habits of *Anopheles* in Ellichpur. Indian Med. Gaz. 36: 361-6, 441-3.

LIU, L. C., C. C. FANG and M. H. HU
1959. Study on the forms of *Anopheles minimus* Theobald, 1901. Acta Entomol. Sin. 9: 154-60.

LUDLOW, C. S.
1914. Philippine mosquitoes. Psyche 21: 30-2.

1915. The synonymy of *An. christophersi* Theo. and *A. indefinita* Ludl. Bull. Entomol. Res. 6: 155-7.

LYSENKO, A. YA. and TANG-WANG-NGY
1965. Studies on the epidemiology of malaria in North Vietnam. 4. Division of North Vietnam into malariological zones. Med. Parasitol. Parizit. Bolezn. 34: 189-94.

MC KENDRICK, A. G. and S. R. CHRISTOPHERS
1912a. Editorial. Paludism (Simla) 5: 1-2.

1912b. Current Literature. - Brahmachari. Paludism (Simla) 5: 11.

MACAN, T. T.
1948. Mosquitoes and malaria in the Kabaw and Kale valleys, Burma. Bull. Entomol. Res. 39: 237-68.

MACKINNON, J. R. and K. MACKINNON
1974. Animals of Asia the ecology of the Oriental region. Holt, Rinehart and Winston, New York. 172 p.

MAFFI, M.
1971. On some larvae of the *Myzomyia* series collected in the Yemen. Parassitologia (Rome) 13: 449-54.

MANALANG, C.
1930. Morphology and classification of the Philippine variety of *Anopheles aconitus* Dönitz, 1902, and *Anopheles minimus* Theobald, 1901. Philipp. J. Sci. 43: 247-60.

MANGKOEWINOTO, R. M. M.
1919. Anophelines of West-Java. Meded. Burgerl. Geneesk. Dienst Ned.-Ind. 8: 41-82.

MARKS, E. N.
1954. A review of the *Aedes scutellaris* subgroup with a study of variation in *Aedes pseudoscutellaris* (Theobald) (Diptera: Culicidae). Bull. Br. Mus. (Nat. Hist.) Entomol. 3: 349-414.

MATTINGLY, P. F. and K. L. KNIGHT
1956. The mosquitoes of Arabia I. Bull. Br. Mus. (Nat. Hist.) Entomol. 4: 91-141.

MAYR, E.
1963. Animal species and evolution. The Belknap Press, Harvard Univ. Press, Cambridge. 797 p.

1969. Principles of systematic zoology. McGraw-Hill Book Co., New York. 428 p.

MENON, M. A. U.
1938. A note on the eggs of *Anopheles varuna* Iyengar and *Anopheles fluviatilis* James. J. Malar. Inst. India 1: 121-2.

MENON, M. A. U. and A. GEORGE
1950. On the variation of female palpal bands in *Anopheles jeyporiensis* James 1902 (A statistical study). Bull. Cent. Res. Inst. Univ. Travancore, India 1: 59-76.

MOLINEAUX, L., G. R. SHIDRAWI, J. L. CLARKE, J. R. BOULZAGUET and T. S. ASHKAR
1979. Assessment of insecticidal impact on the malaria mosquito's vectorial capacity, from data on the man-biting rate and age-composition. Bull. W.H.O. 57: 265-74.

MORISHITA, K.
1932. The eggs of the Formosan anophelines. J. Med. Assoc. Formosa 31: 331-40.

MOUSSA, M. A. and P. NAWARAT
1969. Susceptibility of six anopheline species from Thailand to insecticides. Mosq. News 29: 210-6.

MUIRHEAD-THOMSON, R. C.
1940a. Studies on the behaviour of *Anopheles minimus*. Part I. The selection of the breeding place and the influence of light and shade. J. Malar. Inst. India 3: 265-94.

1940b. Studies on the behaviour of *Anopheles minimus*. Part II. The influence of water movement on the selection of the breeding place. J. Malar. Inst. India 3: 295-322.

1940c. Studies on the behaviour of *Anopheles minimus*. Part III. The influence of water temperature on the choice and suitability of the breeding place. J. Malar. Inst. India 3: 323-48.

1951. Mosquito behaviour in relation to malaria transmission and control in the tropics. Edward Arnold and Co., London. 219 p.

NARANG, N., S. NARANG and J. B. KITZMILLER
1972. Lack of gene flow among three species of anopheline mosquitoes. Syst. Zool. 21: 1-6.

NGUYEN-THUONG-HIEN
1968. The genus *Anopheles* in the Republic of Vietnam. Bur. Entomol., Ministry Health, Saigon. 205 p.

OW YANG, C. K., F. L. STA MARIA and R. H. WHARTON
1963. Maintenance of a laboratory colony of *Anopheles maculatus* Theobald by artificial mating. Mosq. News 23: 34-5.

PAL, R.
1964. Ecology of Indian anopheline mosquitoes in relation to malaria eradication. WHO/MAL/440, 10 p.

PANT, C. P., G. D. PRADHAN, Y. SHOGAKI and S. L. SHRESHTA
1962. Distribution of anophelines in relation to altitude in Nepal. WHO/MAL/343, 12 p.

PARSONS, R. E., T. J. DONDERO, JR. and C. W. HOOI
1974. Comparison of CDC minature light traps and human biting collections for mosquito catches during malaria vector surveys in Peninsular Malaysia. Mosq. News 34: 211-3.

PAYUNG-VEJJASASTRA, L.
1935. Malaria survey at Tung Song, Nakhon Si Thammarat. Dept. Health (Thailand), Public Health Bull. 11: 658-66.

PENDLETON, R. L. and R. C. KINGSBURY
1962. Thailand: Aspects of landscape and life. Am. Geogr. Handb., Duell, Sloan and Pearce, New York. 321 p.

PEYTON, E. L. and B. A. HARRISON
1979. *Anopheles (Cellia) dirus*, a new species of the Leucosphyrus Group from Thailand (Diptera: Culicidae). Mosq. Syst. 11: 40-52.

PEYTON, E. L. and J. E. SCANLON
1966. Illustrated key to the female *Anopheles* mosquitoes of Thailand. U. S. Army Med. Comp., South East Asia Treaty Organ., Bangkok. 47 p.

PRADHAN, S. P. and H. W. BRYDON
1960. A record of *Anopheles filipinae* in Nepal. Mosq. News 20: 319-20.

PRAKASH, R. and Z. H. HUSAINY
1974a. Studies on the anopheline mosquitoes of the Bastar district (Madhya Pradesh). Part I. Distributional pattern of adults. Ann. Zool. (Agra) 10: 13-52.

1974b. Studies on the anopheline mosquitoes of the Bastar district (Madhya Pradesh). Part II. A note on the record of *Anopheles (Cellia) majidi* McCombie Young & Majid, 1928. Ann. Zool. (Agra) 10: 53-6.

PURI, I. M.
1928a. On two species of Indian anopheline mosquitoes, *A. jeyporiensis* James and *A. moghulensis* Christophers. Indian J. Med. Res. 16: 513-8.

1928b. The relationship of certain morphological characters of anopheline larvae to the classification of Indian anopheline mosquitoes. Indian J. Med. Res. 16: 519-28.

1931. Larvae of anopheline mosquitoes, with full description of those of the Indian species. Indian Med. Res. Mem. 21: 1-227.

PURI, I. M.
1949. Anophelines of the Oriental region, p. 483-505, *in* Boyd, M. F. (ed.). 1949. Malariology, Vol. 1. W. B. Saunders Co., Philadelphia. 787 p.

RAHMAN, J., M. V. SINGH and N. N. SINGH
1960. A note on the study of morphology, prevalence and host preference of an ecocline of *A. fluviatilis* in Nainital Tarai (U. P.). Bull. Natl. Soc. Indian Malar. Mosq. Dis. 8: 137-42.

RAHMAN, S. J., B. L. WATTAL and M. I. D. SHARMA
1975. Ecology of mosquitoes of Nilgiri hills (Tamil Nadu) with particular reference to vectors of human diseases. Indian J. Entomol. 35: 228-46.

RAJENDRAM, S., M. H. M. ABDUL CADER and T. VISVALINGAM
1950. Malaria eradication in Ceylon. Nature (Lond.) 166: 486.

RAMAKRISHNA, V.
1954. Variation in palpal banding in *A. fluviatilis* James, 1902. Bull. Natl. Soc. Indian Malar. Mosq. Dis. 2: 210.

RAMALINGAM, S.
1975. Vectors of *Wuchereria bancrofti* and *Brugia malayi* in the South and Southeast Asian Regions: Their distribution, biology and control. Ceylon J. Med. Sci. 24: 1-27.

RAO, V. V.
1961. Chapter 8. *A. varuna* Iyengar, 1924, p. 103-18, *in* Vectors of malaria in India. (2nd ed.). Natl. Soc. India Malar. Mosq.-Borne Dis., Delhi. 242 p.

RAO, V. V. and V. RAMAKRISHNA
1940. A note on the larva of *A. varuna* (Iyengar). J. Malar. Inst. India 3: 509-12.

RATANAWORABHAN, N.
1975. An illustrated key to the female *Culicoides* of Chiangmai Valley, Thailand. U. S. Army Med. Comp., South East Asia Treaty Organ., Bangkok. 49 p.

RATTANARITHIKUL, R. and B. A. HARRISON
1973. An illustrated key to the *Anopheles* larvae of Thailand. U. S. Army Med. Comp., South East Asia Treaty Organ., Bangkok. 14 p.

REID, J. A.
1947. Type specimens of Culicidae described by Laveran (Diptera: Culicidae). Proc. R. Entomol. Soc. Lond. (B) 16: 86-91.

1950a. The *Anopheles umbrosus* group (Diptera: Culicidae). Part I: Systematics, with descriptions of two new species. Trans. R. Entomol. Soc. Lond. 101: 281-318.

REID, J. A.
1950b. Some new records of anopheline mosquitoes from the Malay Peninsula with remarks on geographic distribution. Bull. Raffles Mus. 21: 48-58.

1953. The *Anopheles hyrcanus* group in South-east Asia (Diptera, Culicidae). Bull. Entomol. Res. 44: 5-76.

1962. The *Anopheles barbirostris* group (Diptera, Culicidae). Bull. Entomol. Res. 53: 1-57.

1965. A revision of the *Anopheles aitkenii* group in Malaya and Borneo. Ann. Trop. Med. Parasitol. 59: 106-25.

1968. Anopheline mosquitoes of Malaya and Borneo. Stud. Inst. Med. Res. Malaya 31: 1-520.

1970. Systematics of malaria vectors. Anopheline systematics and malaria control, with special reference to Southeast Asia. Misc. Publ. Entomol. Soc. Am. 7: 56-62.

1976. A lectotype for *Anopheles (Cellia) pampanai* Büttiker & Beales, 1959. Mosq. Syst. 8: 111-3.

REID, J. A. and K. L. KNIGHT
1961. Classification within the subgenus *Anopheles* (Diptera, Culicidae). Ann. Trop. Med. Parasitol. 55: 474-88.

REID, J. A., B. L. WATTAL and W. PETERS
1966. Notes on *Anopheles maculatus* and some related species. Bull. Indian Soc. Malar. Commun. Dis. 3: 185-97.

REISEN, W. K. and M. ASLAMKHAN
1976. Observations on the swarming and mating behaviour of *Anopheles culicifacies* Giles in Nature. Bull. W.H.O. 54: 155-8.

REISEN, W. K., J. P. BURNS and R. B. BASIO
1971. The distribution and abundance of mosquitoes on USAF installations in Asia for 1970. 1st Med. Serv. Wing (PACAF) Tech. Rep. 71-2: 1-40.

REUBEN, R.
1971. Studies on the mosquitoes of North Arcot District, Madras State, India Part 1. Seasonal densities. J. Med. Entomol. 8: 119-26.

ROBERTSON, R. C.
1941. A malaria survey on the China-Burma highway. Trans. R. Soc. Trop. Med. Hyg. 34: 311-32.

ROY, D. N.
1938. A note on the larva of *A. varuna* Iyengar. J. Malar. Inst. India 1: 269-72.

ROZEBOOM, L. E. and B. D. CABRERA
1964. Filariasis in Mountain Province, Luzon, Republic of the Philippines. J. Med. Entomol. 1: 18-28.

1965. Filariasis caused by *Wuchereria bancrofti* in Palawan, Republic of the Philippines. Am. J. Epidemiol. 81: 216-21.

RUSSELL, P. F. and F. E. BAISAS
1934. A practical illustrated key to larvae of Philippine *Anopheles*. Philipp. J. Sci. 55: 307-36.

1936. A practical illustrated key to adults of Philippine *Anopheles*. Philipp. J. Sci. 59: 15-64.

RUSSELL, P. F. and T. R. RAO
1940. On habitat and association of species of anopheline larvae in South-eastern Madras. J. Malar. Inst. India 3: 153-78.

1942a. On the swarming, mating, and ovipositing behavior of *Anopheles culicifacies*. Am. J. Trop. Med. 22: 417-27.

1942b. A study of density of *Anopheles culicifacies* in relation to malaria endemicity. Am. J. Trop. Med. 22: 535-58.

RUSSELL, P. F., L. E. ROZEBOOM and A. STONE
1943. Keys to the anopheline mosquitoes of the world. Am. Entomol. Soc., Philadelphia. 152 p.

SAIFUDDIN, U. T., R. H. BAKER and R. K. SAKAI
1978. The chromosomes of *Anopheles culicifacies*. Mosq. News 38: 233-9.

SANDHINAND, U.
1951. Anophelines of Chieng Mai Province, Thailand. J. Med. Assoc. Thailand 34: 33-8.

SANDOSHAM, A. A., R. H. WHARTON, D. E. EYLES, M. WARREN and W. H. CHEONG
1963. Malaria in Perlis. Med. J. Malay 18: 46-51.

SCANLON, J. E. and S. ESAH
1965. Distribution in altitude of mosquitoes in northern Thailand. Mosq. News 25: 137-44.

SCANLON, J. E., E. L. PEYTON and D. J. GOULD
1968. An annotated checklist of the *Anopheles* of Thailand. Thai Natl. Sci. Pap., Fauna Ser. 2: 1-35.

SCANLON, J. E., J. A. REID and W. H. CHEONG
1968. Ecology of *Anopheles* vectors of malaria in the Oriental Region. Cah. O.R.S.T. O.M. Ser. Entomol. Med. 6: 237-46.

SCANLON, J. E. and U. SANDHINAND
1965. The distribution and biology of *Anopheles balabacensis* in Thailand (Diptera: Culicidae). J. Med. Entomol. 2: 61-9.

SENEVET, G.
1931. Contribution à l'étude des nymphes d'anophelinés (2 mémoire). Arch. Inst. Pasteur Alger. 9: 17-112.

1947. *Anopheles tonkinensis* synonyme de *A. alongensis*. Arch. Inst. Pasteur Alger. 25: 214-7.

SERVICE, M. W.
1960. A taxonomic study of *Anopheles funestus funestus* Giles (Diptera: Culicidae) from southern and northern Nigeria, with notes on its varieties and synonyms. Proc. R. Entomol. Soc. Lond. (B) 29: 77-84.

1964. An analysis of individual and seasonal variations occurring in the wing ornamentation of *Anopheles (Cellia) funestus* Giles (Diptera: Culicidae). Proc. R. Entomol. Soc. Lond. (B) 33: 139-43.

SHALABY, A. M.
1965. Studies on the age composition of *Anopheles culicifacies* populations in India at different phases of development of resistance to DDT. Ann. Entomol. Soc. Am. 58: 918-23.

1969. Host-preference observations on *Anopheles culicifacies* (Diptera: Culicidae) in Gujarat State, India. Ann. Entomol. Soc. Am. 62: 1270-3.

SHARMA, M. I. D.
1961. Chapter 6. *A. fluviatilis* James, 1902, p. 77-90, *in* Vectors of malaria in India. (2nd ed.). Natl. Soc. India Malar. Mosq.-Borne Dis., Delhi. 242 p.

SIMMONS, J. S., T. F. WHAYNE, G. W. ANDERSON and H. M. HORACK
1944. Global epidemiology. A geography of disease and sanitation. Vol. 1. J. B. Lippincott Co., Philadelphia. 504 p.

SINGH, S.
1974. XVI. Some aspects of the ecology and geography of Diptera, p. 500-16, *in* Mani, M. S. (ed.). 1974. Ecology and biogeography in India. Monogr. Biol., W. Junk, The Hague 23: 1-773.

SINTON, J. A.
1917. A trematode parasite of anopheline mosquitoes. Indian J. Med. Res. 5: 192-4.

1932. Helminthic infections in Indian anopheline mosquitoes. Rec. Malar. Surv. India 3: 347-51.

SINTON, J. A. and G. COVELL
1927. The relation of the morphology of the buccal cavity to the classification of anopheline mosquitoes. Indian J. Med. Res. 15: 301-9.

SOERONO, M., G. DAVIDSON and D. A. MUIR
1965. The development and trend of insecticide-resistance in *Anopheles aconitus* Dönitz and *Anopheles sundiacus* Rodenwaldt. Bull. W.H.O. 32: 161-8.

SOPER, F. L. and D. B. WILSON
1943. *Anopheles gambiae* in Brazil 1930 to 1940. The Rockefeller Found., New York. 262 p.

STAGE, H. H.
1958. Malaria-control problems in Vietnam. Proc. 10th Int. Congr. Entomol. 3: 615-22.

STANTON, A. T.
1912. On the changes which occur in certain characters of *Anopheles* larvae in the course of their growth. Bull. Entomol. Res. 3: 387-91.

1915a. The larvae of Malayan *Anopheles*. Bull. Entomol. Res. 6: 159-72.

1915b. Notes on Sumatran Culicidae. Indian J. Med. Res. 3: 251-8.

1922. [Description of *aconitus* egg], p. 135, *in* Lamborn, W. A. 1922. The bionomics of some Malayan anophelines. Bull Entomol. Res. 13: 129-49.

STOJANOVICH, C. J. and H. G. SCOTT
1966. Illustrated key to *Anopheles* mosquitoes of Thailand. U. S. Dept. H.E.W., Public Health Serv. (CDC). 44 p.

STOLL, N. R., R. PH. DOLLFUS, J. FOREST, N. D. RILEY, C. W. SABROSKY, C. W. WRIGHT and R. V. MELVILLE (ED.)
1964. International code of zoological nomenclature adopted by the XV International Congress of Zoology. Int. Trust Zool. Nomencl., London. 176 p.

STONE, A., K. L. KNIGHT and H. STARCKE
1959. A synoptic catalog of the mosquitoes of the world (Diptera, Culicidae). Thomas Say Found., Entomol. Soc. Am. 6: 1-358.

STRICKLAND, C.
1924. The anophelines *funestus*, *minimus* and *aconitus*, including a description of the larva of *minimus*. Indian J. Med. Res. 12: 145-52.

SWEET, W. C., L. C. FENG, C. Y. CHOW and S. C. HSU
1942. Anophelines of southwestern Yunnan and their relation to malaria. J. Natl. Malariol. Soc. 1: 25-32.

SWEET, W. C. and B. A. RAO
1938. Measurements of *A. culicifacies* ova. J. Malar. Inst. India 1: 33-5.

SWELLENGREBEL, N. H. and E. RODENWALDT
1932. Die Anophelen von Niederländisch-Ostindien (3rd ed.). Gustav Fischer, Jena. 242 p.

SWELLENGREBEL, N. H. and J. M. H. SWELLENGREBEL-DE GRAAF
1920. List of the anophelines of the Malay Archipelago with special reference to adults and larvae of new or incompletely described species or varieties. Bull. Entomol. Res. 11: 77-92.

TANSATHIT, P., B. THAVARAMARA, S. CHALAWYOO and C. KAMPANARDSAENYAKARA
1962. Malaria in Sattahib Naval Base, Thailand. Proc. 9th Pac. Sci. Congr. (1957 Bangkok) 17: 137-43.

TAYLOR, B.
1975. Changes in the feeding behaviour of a mosquito vector, *Anopheles farauti* Lav., following use of DDT as a residual spray in houses in the British Solomon Islands Protectorate. Trans. R. Entomol. Soc. Lond. 127: 277-92.

THEOBALD, F. V.
1901. A monograph of the Culicidae or mosquitoes. Vol. 1, Br. Mus. (Nat. Hist.), London. 424 p.

1902a. The classification of the anophelina. J. Trop. Med. 5: 181-3.

1902b. A short description of the Culicidae of India, with descriptions of new species of *Anopheles*. Proc. R. Soc. Lond. Ser. (B) 69: 367-94.

1903. A monograph of the Culicidae or mosquitoes. Vol. 3. Br. Mus. (Nat. Hist.), London. 359 p.

1907. A monograph of the Culicidae or mosquitoes. Vol. 4, Br. Mus. (Nat. Hist.), London. 639 p.

1910. A monograph of the Culicidae or mosquitoes. Vol. 5, Br. Mus. (Nat. Hist.), London. 646 p.

THURMAN, D. C., JR. and E. B. THURMAN
1955. Report of the initial operation of a mosquito light trap in northern Thailand. Mosq. News 15: 218-24.

THURMAN, E. B.
1954. The establishment of a malaria control training center in Chiengmai, Thailand, with American cooperation. Proc. N. J. Mosq. Exterm. Assoc. 41: 163-6.

1959. A contribution to a revision of the Culicidae of northern Thailand. Univ. Md. Agric. Exp. Sta. Bull. A-100: 1-177.

TOUMANOFF, C.
1931a. Sur la prèsence d'une variéte d'*Anopheles jeyporiensis* James au Tonkin et son ròle dans la transmission locale du paludisme. Bull. Soc. Pathol. Exot. 24: 958-67.

1931b. Sur une variéte nouvelle d'*Anopheles aconitus* Dönitz observee au Tonkin. C. R. Soc. Biol, Paris 107: 575-6.

1936. L'Anophelisme en Extreme-Orient. Coll. Soc. Pathol. Exot. Mongr. 4: 1-434.

TOUMANOFF, C. and HOANG-TICH-TRY
1937. Nouvelle contribution à le connaissance de la faune anophelienne de la haute altitude du Tonkin (Chapa). Bull. Soc. Med. Chirung, Indochine 15: 980-91.

TREILLARD, M.
1934. *Myzomyia minima* Theobald, doit-elle etre appelée *Myzomyia vincenti* Laveran? Bull. Soc. Pathol. Exot. 27: 750-1.

TSUZUKI, J.
1902. Report on an investigation on malaria in Taiwan, with appendix (in Japanese). Saikingaku Zasshi No. 75: 25-51 (1902: 90-117). (publ. in Feb.).

URBINO, C. M.
1947. *Anopheles mangyanus* Banks, 1907 recently discovered malaria vector and its control in the Philippines. Mon. Bull. Bur. Health Philipp. 23: 229-50.

VANDEHEY, R. C. and G. B. CRAIG
1962. Genetic variability in *Aedes aegypti* (Diptera: Culicidae) II. Mutations causing structural modifications. Ann. Entomol. Soc. Am. 55: 58-69.

VAN HELL, J. C.
1933. *A. minimus* var. *flavirostris* Ludlow. Geneesk. Tijdschr. Ned.-Ind. 73: 20-30.

1952. The anopheline fauna and malaria vectors in south Celebes. Doc. Med. Geogr. Trop. 4: 45-56.

VAN THIEL, P. H.
1922. Aanteekeningen over *Agamadistomum anophelis*. Tijdschr. Vergelijk. Geneesk., Leyden 7: 305-21.

WALCH, E. W. and G. B. WALCH-SORGDRAGER
1934. The eggs of some Netherlands-Indian anophelines. Trans. Far-East Assoc. Trop. Med. (9th Congr., Nanking). 2: 65-81.

WATTAL, B. L.
1961. Chapter 9. *Anopheles jeyporiensis* var. *candidiensis* Koidzumi, 1924, p. 119-35, *in* Vectors of malaria in India. (2nd ed.). Natl. Soc. India Malar. Mosq.-Borne Dis., Delhi. 242 p.

1963. Appendix 5. Southern and northern Asia, p. 680-96, *in* Russell, P. F., L. S. West, R. D. Manwell and G. MacDonald. 1963. Practical malariology. Oxford Univ. Press, London. 750 p.

WATTAL, B. L., N. L. KALRA and M. L. MAMMEN
1960. Observations on certain morphological abnormalities in 20 species of Indian *Anopheles*. Indian J. Malariol. 14: 291-310.

WHARTON, R. H.
1950. Daytime resting places of *Anopheles maculatus* and other anophelines in Malaya, with results of precipitin tests. Med. J. Malaya 4: 260-71.

1953. The habits of adult mosquitoes in Malaya. III. - Feeding preferences of anophelines. Ann. Trop. Med. Parasitol. 47: 272-84.

WHITE, G. B.
1974. *Anopheles gambiae* complex and disease transmission in Africa. Trans. R. Soc. Trop. Med. Hyg. 68: 278-98.

1975. Notes on a catalogue of Culicidae of the Ethiopian region. Mosq. Syst. 7: 303-44.

1977. The place of morphological studies in the investigation of *Anopheles* species complexes. Mosq. Syst. 9: 1-24.

WILKINSON, R. N., D. J. GOULD and A. BOONYAKANIST
1972. Comparative susceptibility of *Anopheles balabacensis* and *Anopheles minimus* to naturally occurring *Plasmodium falciparum* in central Thailand. Proc. Helminthol. Soc. Wash. 39 (Special Issue): 423-7.

1974. Laboratory colonization of *Anopheles minimus* Theobald. Mosq. News 34: 29-32.

WILKINSON, R. N., S. NEOYPATIMANONDH and D. J. GOULD
1976. Infectivity of *falciparum* malaria patients for anopheline mosquitoes before and after chloroquine treatment. Trans R. Soc. Trop. Med. Hyg. 70: 306-7.

WILSON, T. and J. A. REID
1949. Malaria among prisoners of war in Siam ("F" Force). Trans. R. Soc. Trop. Med. Hyg. 43: 257-72.

WIRTH, W. W. and A. A. HUBERT
1959. *Trithecoides*, a new subgenus of *Culicoides* (Diptera, Ceratopogonidae). Pac. Insects 1: 1-38.

WORLD HEALTH ORGANIZATION
1973. Malaria eradication and other antimalaria activities in 1972. W.H.O. Chron. 27: 516-24.

WU, S. C.
1936. The eggs of some Chinese anopheline mosquitoes. Entomol. Phytopathol., Hangchow 4: 261-73.

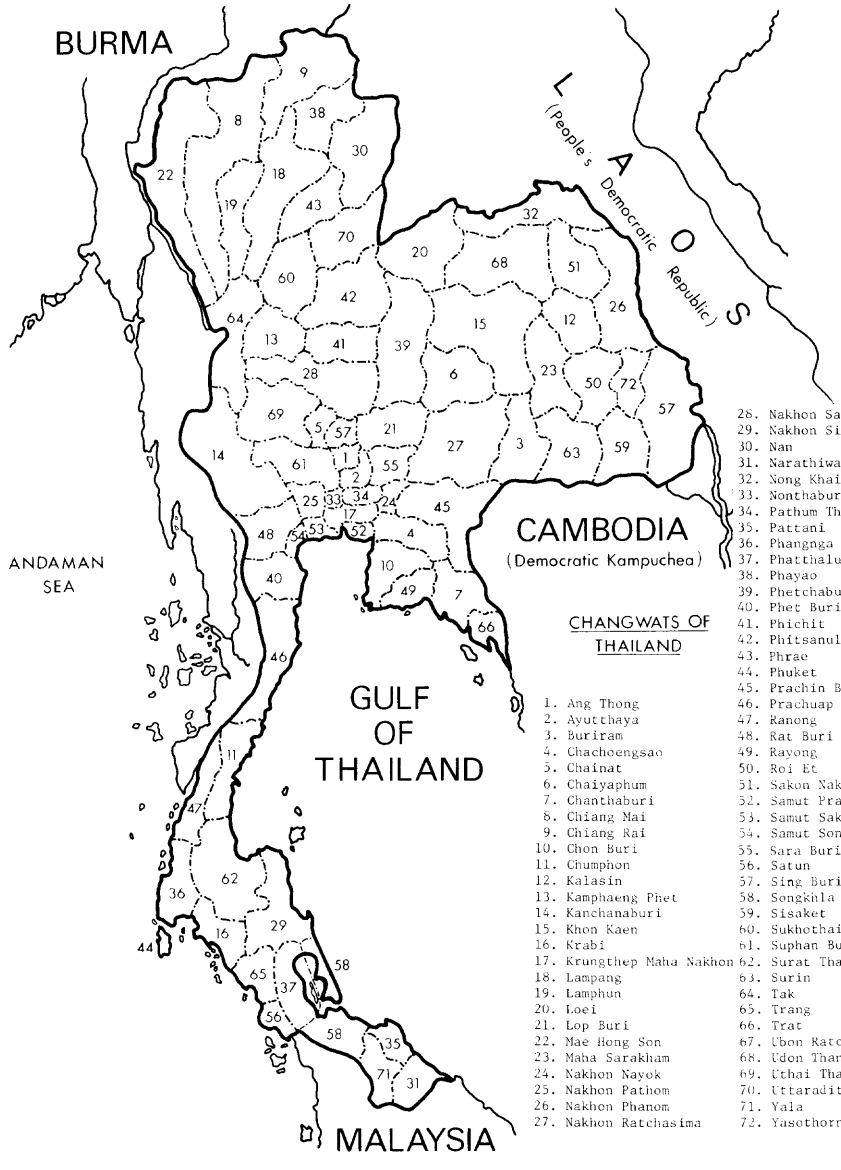
YAMADA, S.
1925. A revision of the adult anopheline mosquitoes of Japan: Systematic descriptions, their habits, and their relations to human diseases (Part II.) Sci. Rep. Gov. Inst. Infect. Dis. (Tokyo) 4: 447-93.

YASUNO, M. and V. KERDPIBULE
1967. The susceptibility of various species of mosquitoes to DDT and dieldrin in Thailand. Jap. J. Exp. Med. 37: 563-79.

YOUNG, T. C. M. and S. A. MAJID
1928. A variety of *Anopheles karwari* collected in Coorg, S. India. Indian J. Med. Res. 16: 469-71.

LIST OF FIGURES

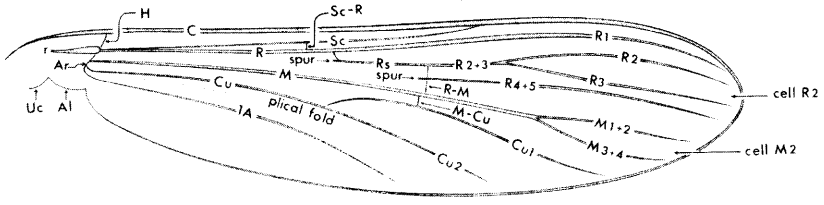
Fig.1



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. Krungthep Maha Nakhon
18. Lampang
19. Lamphun
20. Loei
21. Lop Buri
22. Mae Hong Son
23. Maha Sarakham
24. Nakhon Nayok
25. Nakhon Pathom
26. Nakhon Phanom
27. Nakhon Ratchasima
28. Nakhon Sawan
29. Nakhon Si Thammarat
30. Nan
31. Narathiwat
32. Nong Khai
33. Nonthaburi
34. Pathum Thani
35. Pattani
36. Phangnga
37. Phatthalung
38. Phayao
39. Phetchabun
40. Phet Buri
41. Phichit
42. Phitsanulok
43. Phrae
44. Phuket
45. Prachin Buri
46. Prachuap Khiri Khan
47. Ranong
48. Rat Buri
49. Rayong
50. Roi Et
51. Sakon Nakhon
52. Samut Prakan
53. Samut Sakhon
54. Samut Songkhram
55. Sara Buri
56. Satun
57. Sing Buri
58. Songkhla
59. Sisaket
60. Sukhothai
61. Suphan Buri
62. Surat Thani
63. Surin
64. Tak
65. Trang
66. Trat
67. Ubon Ratchathani
68. Udon Thani
69. Uthai Thani
70. Uttaradit
71. Yala
72. Yasothorn

Fig. 2



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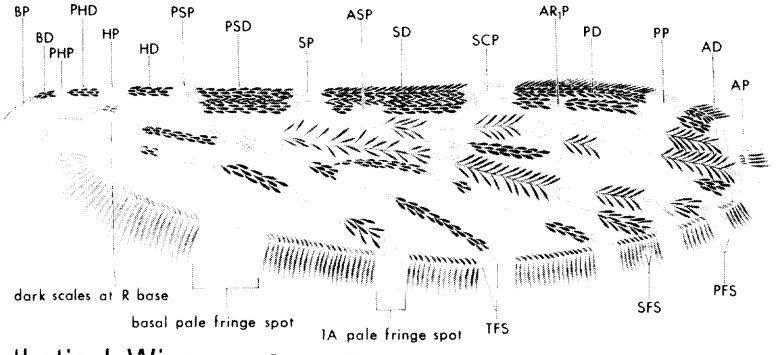

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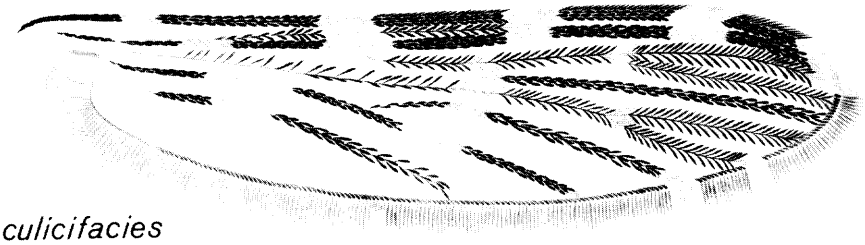


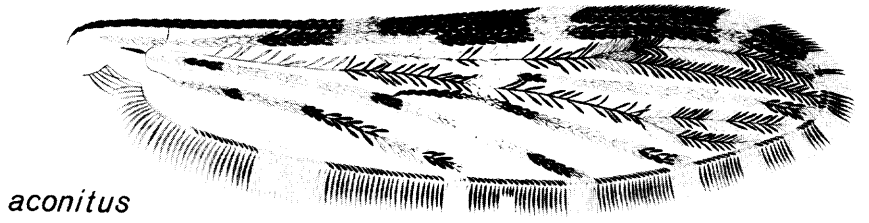
culicifacies

culicifacies costa variations

jeyporiensis

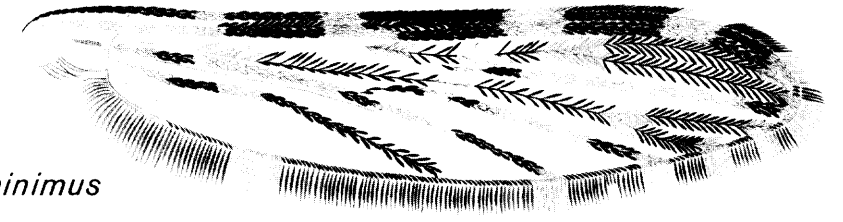
jeyporiensis costa variations

Fig. 3

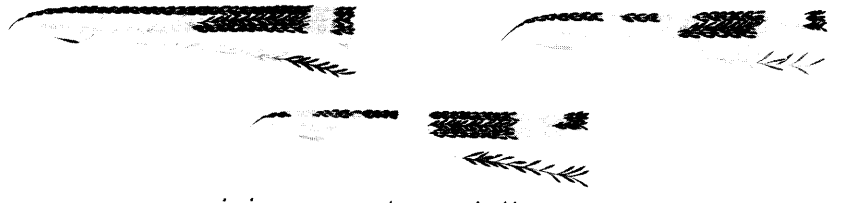


aconitus

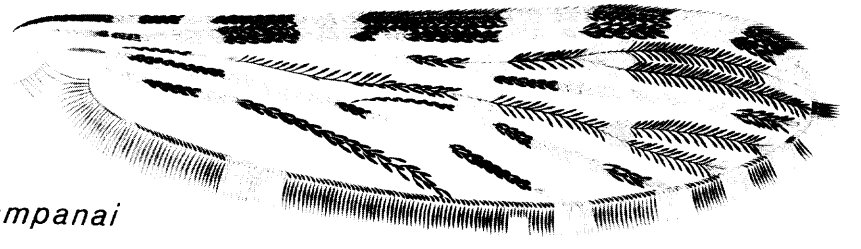
aconitus costa variations



minimus



minimus costa variations



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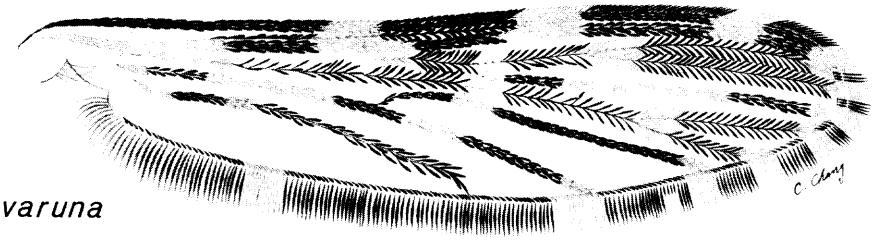

varuna

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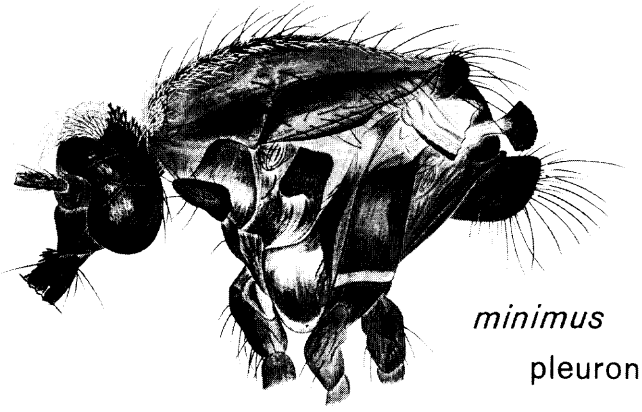
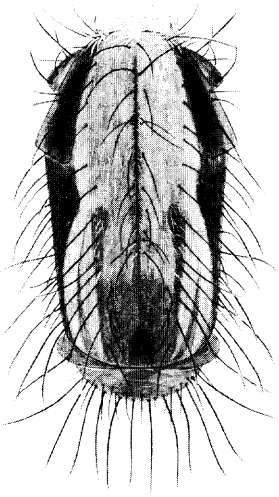
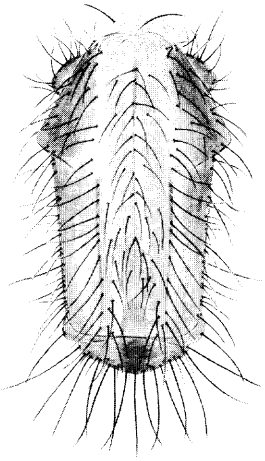


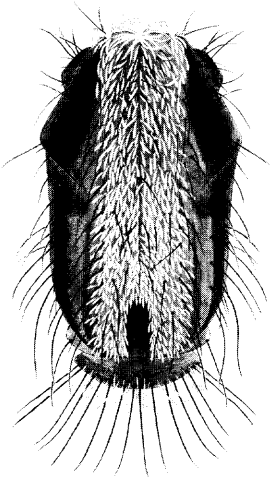
minimus
pleuron



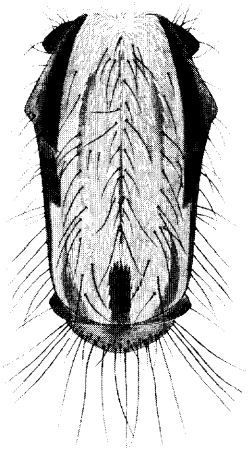
aconitus



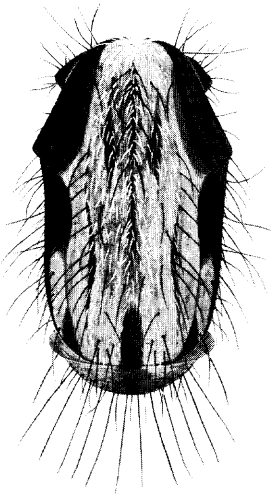
culicifacies
Dorsal view of scutum



jeyporiensis



minimus



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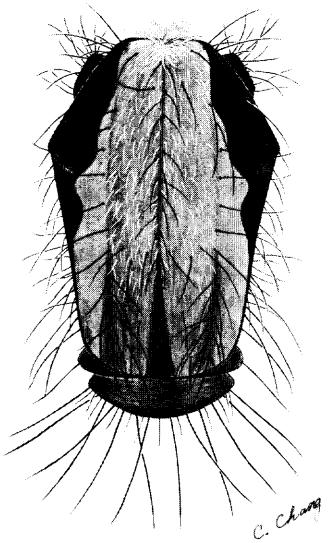
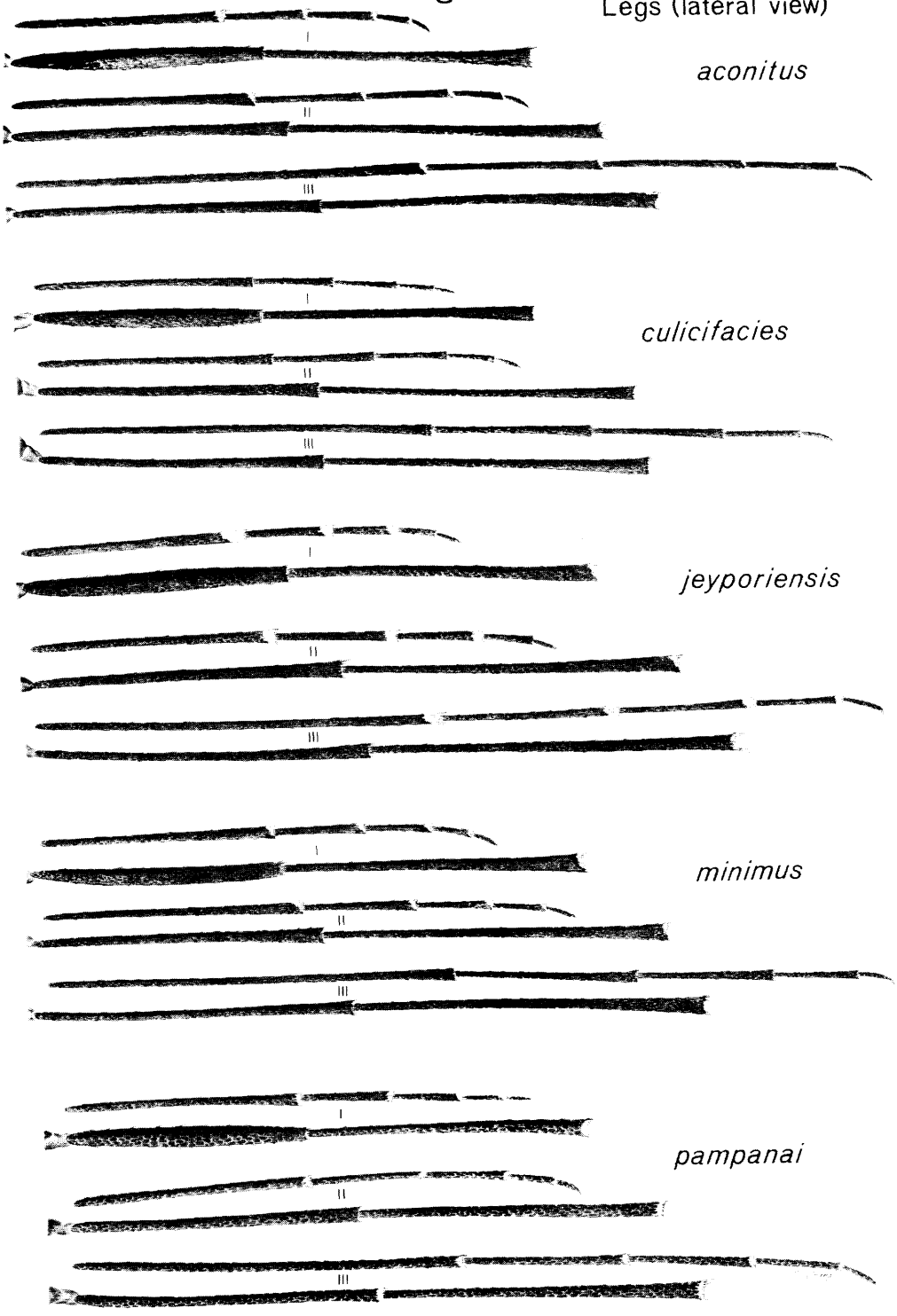


varuna

Fig. 5

Legs (lateral view)



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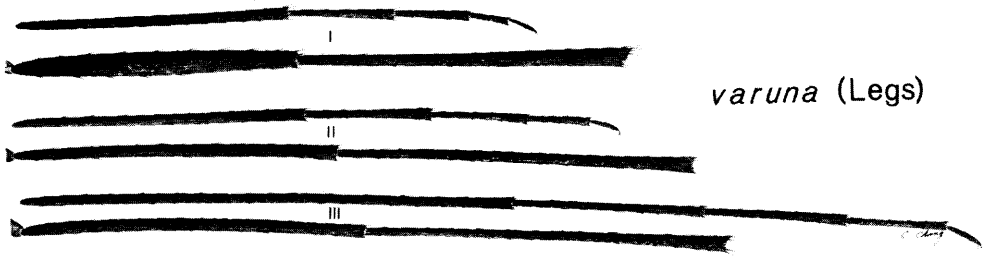
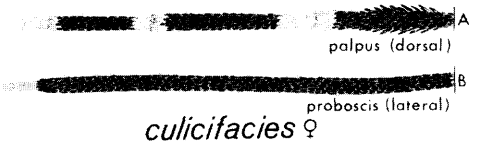
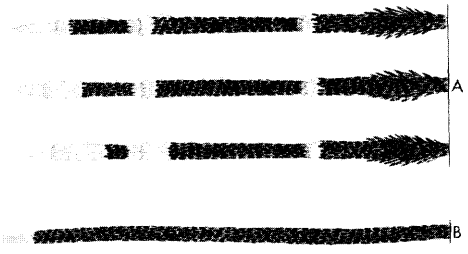


varuna (Legs)

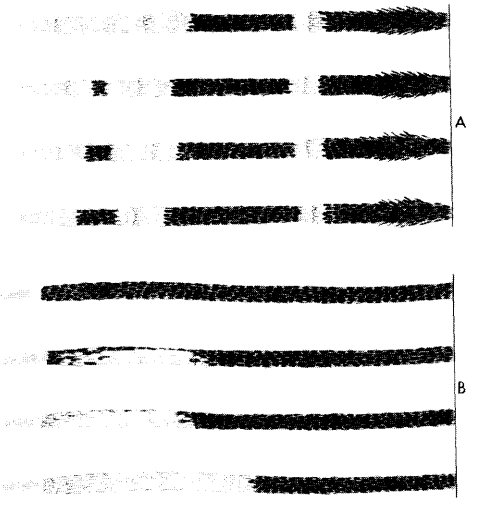
Variations of Palpus & Proboscis



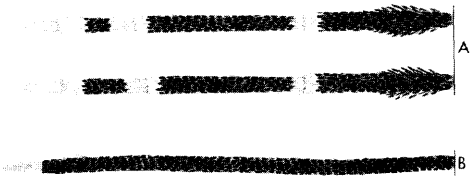
culicifacies ♀



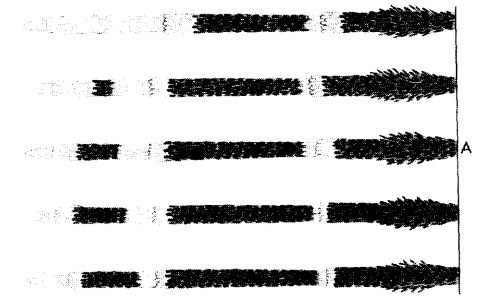
jeyporiensis ♀

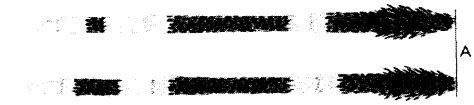


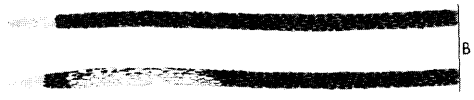
aconitus ♀



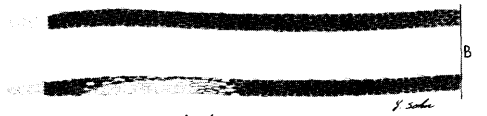
pampanai ♀







varuna ♀



minimus ♀

Fig. 7

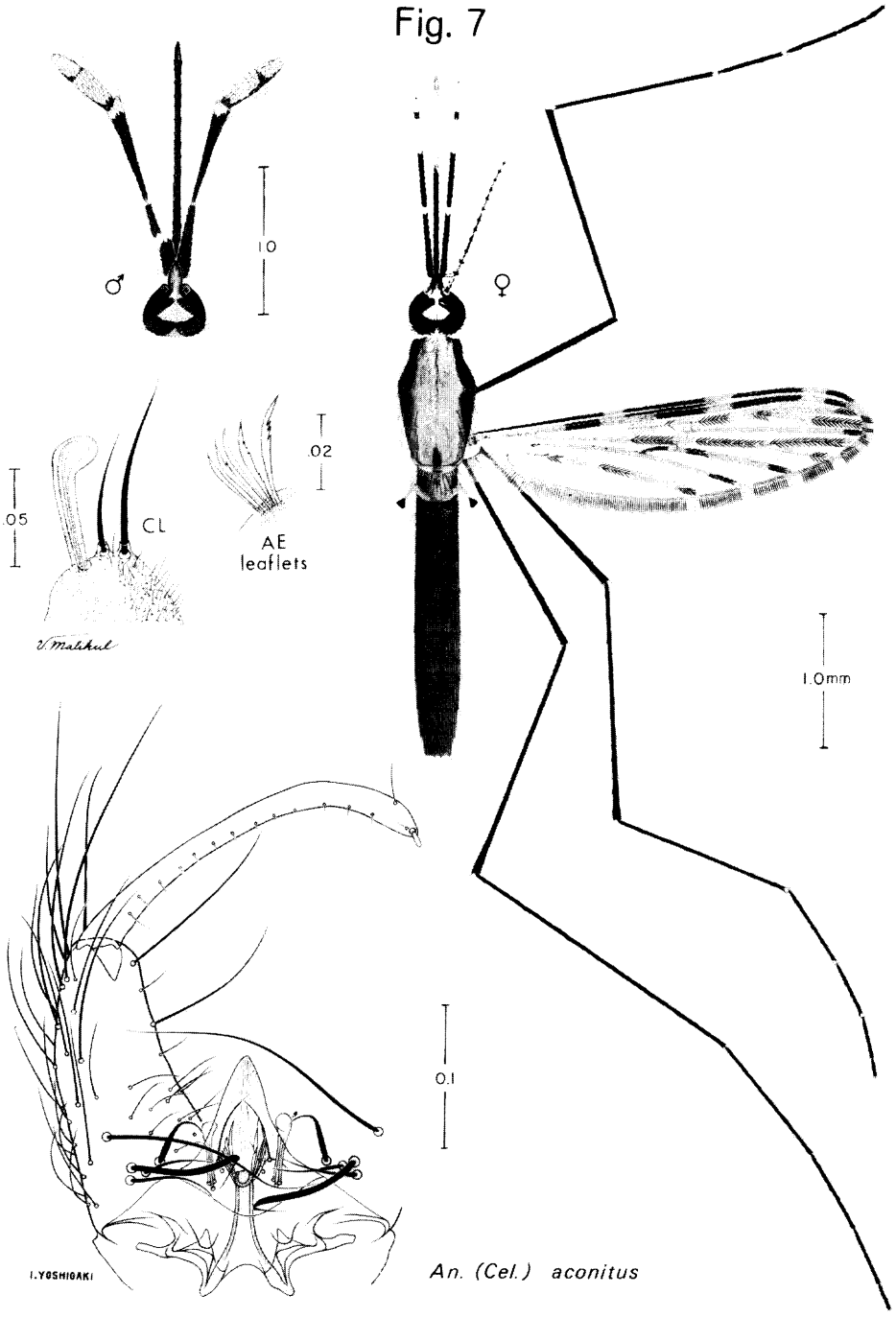
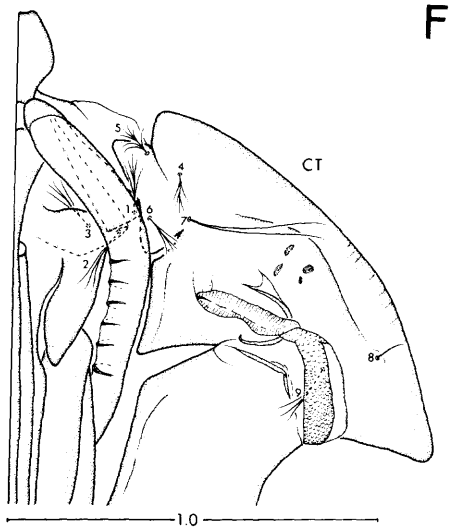
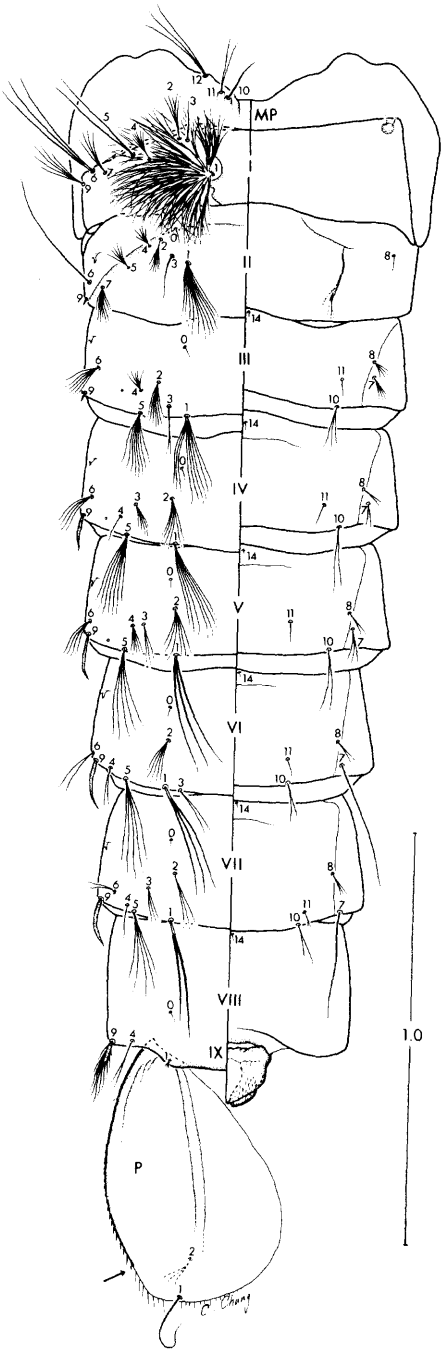
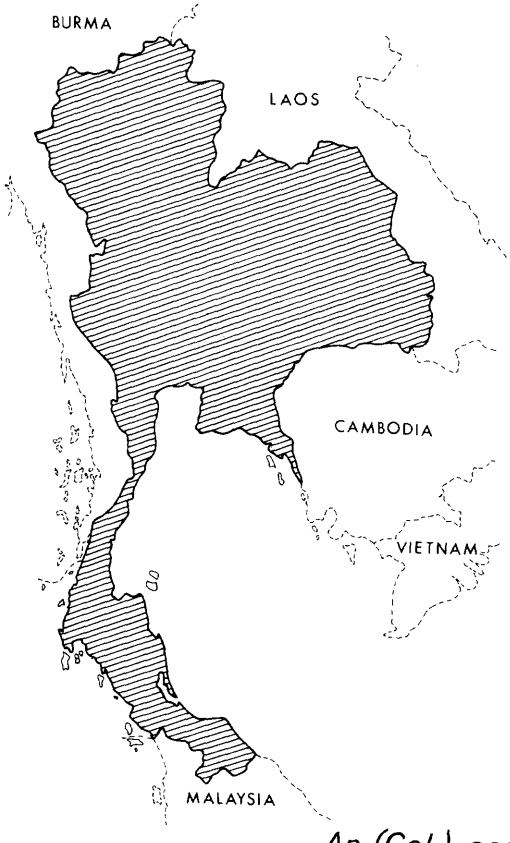

♂
.10
.05
CL
.02
AE
leaflets
V. Malkhul
♀
1.0mm
0.1
I.YOSHIOAKI
An. (Cel.) aconitus

Fig. 8

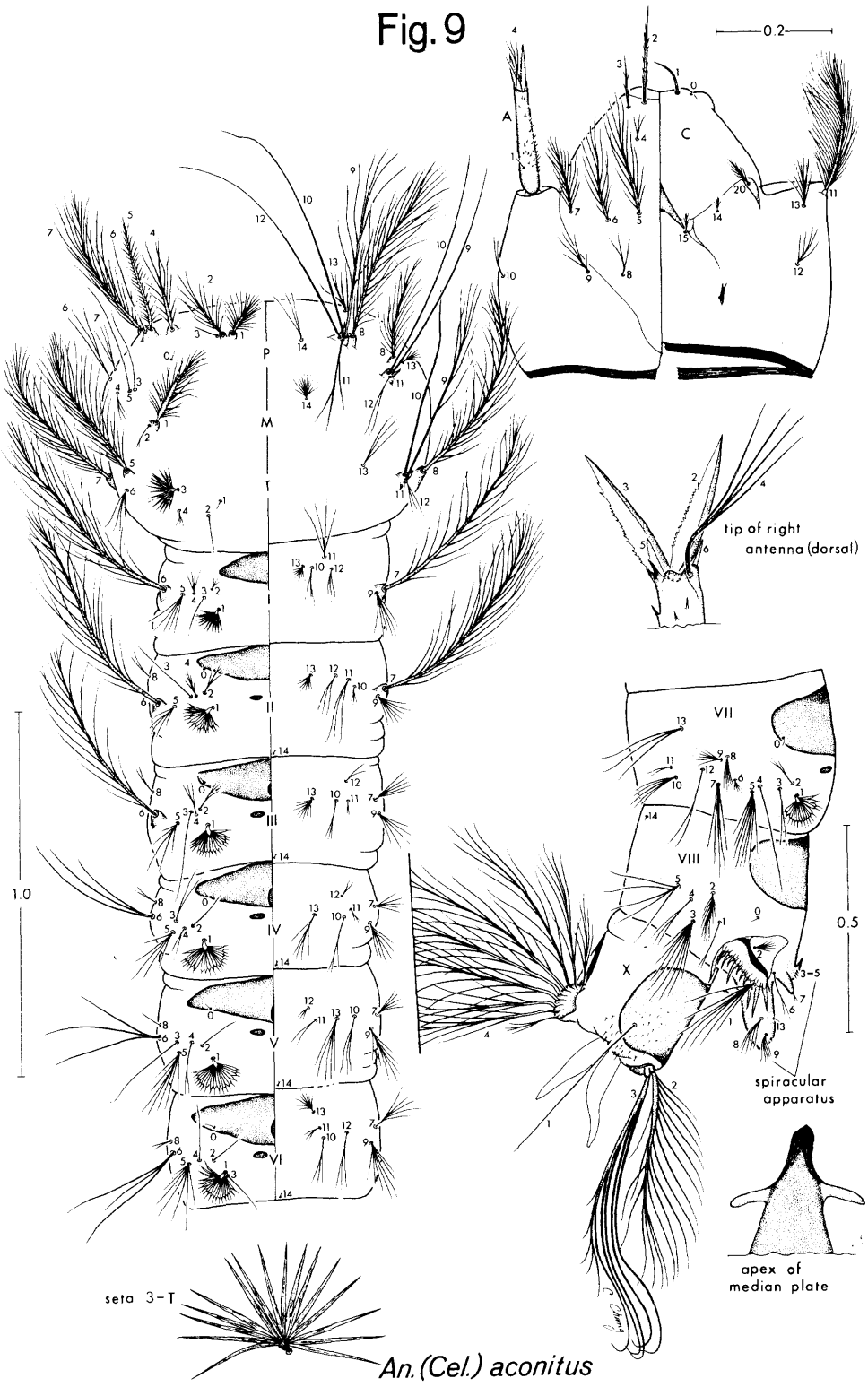






An. (Cel.) aconitus

Fig. 9



An. (Cel.) aconitus

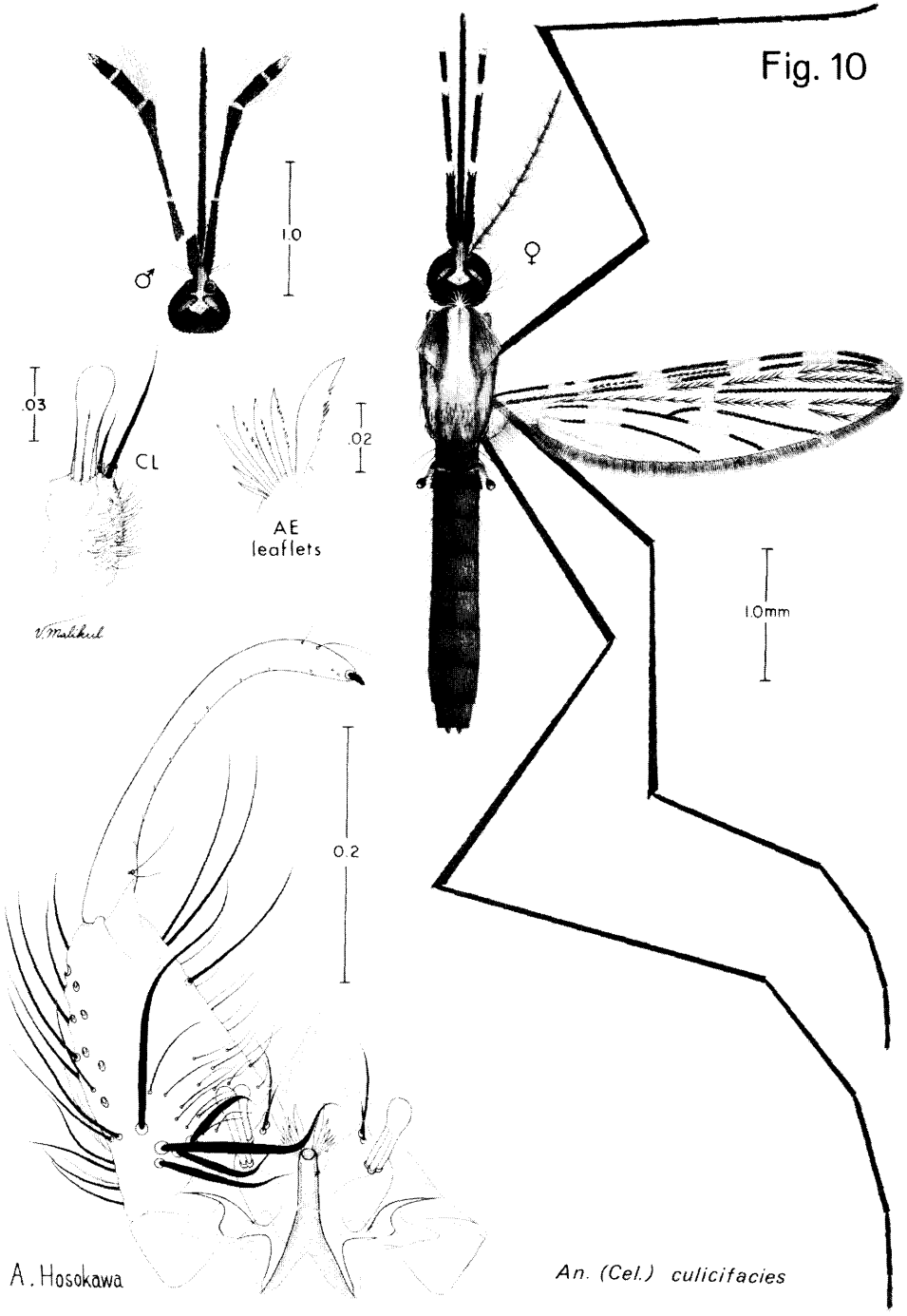
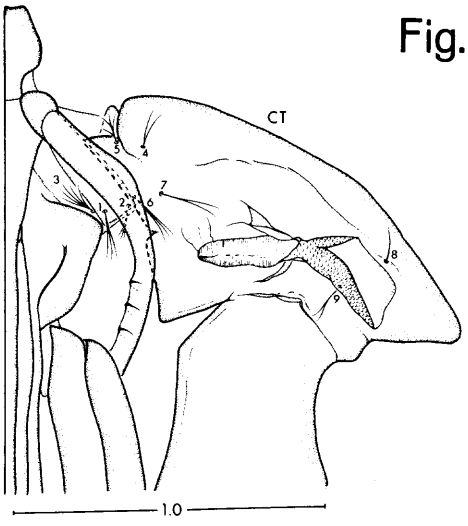
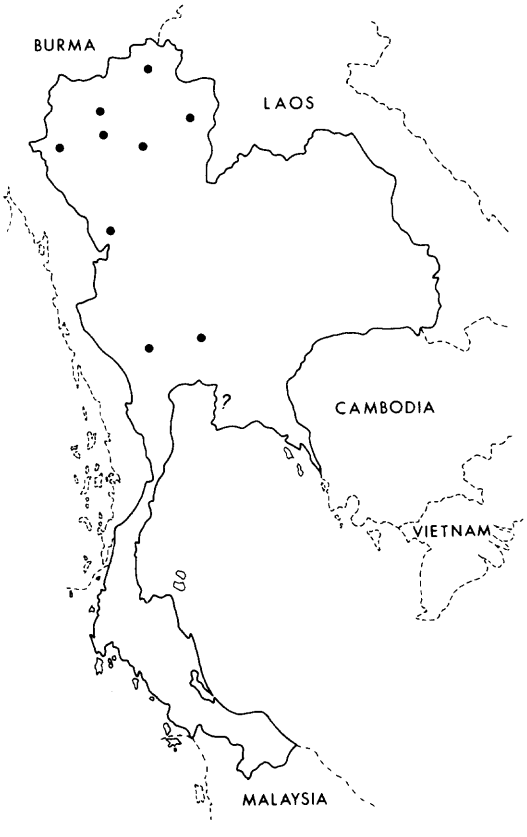
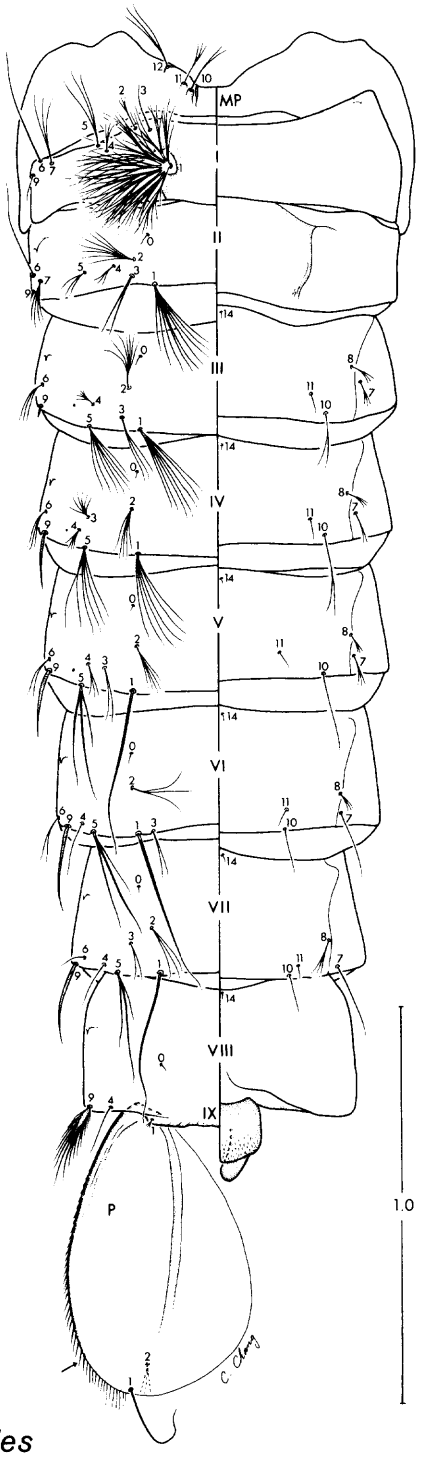


Fig. 10
♂
1.0
.03
CL
.02
AE
leaflets
♀
1.0mm
0.2
A. Hosokawa
An. (Cel.) culicifacies

Fig.11

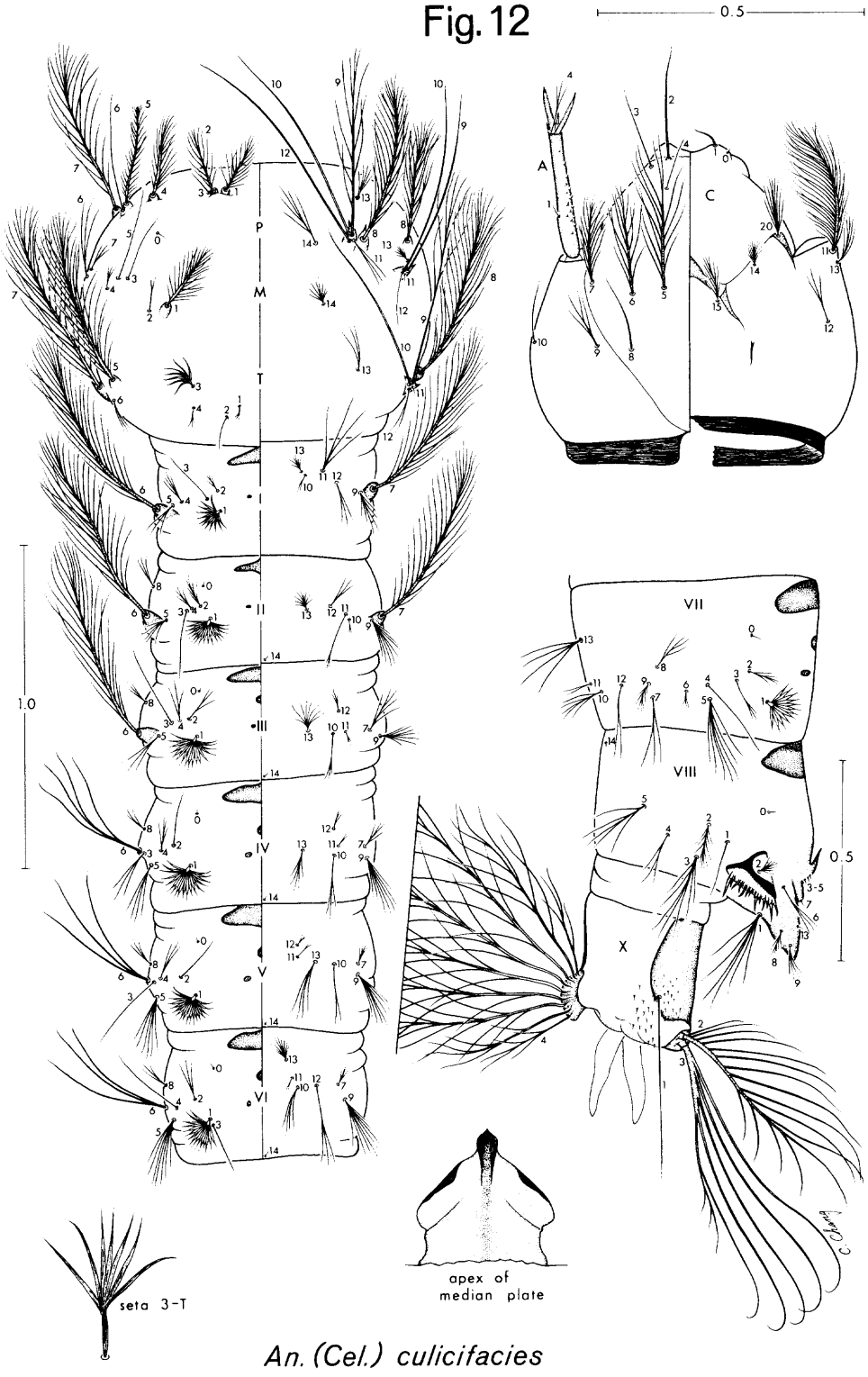






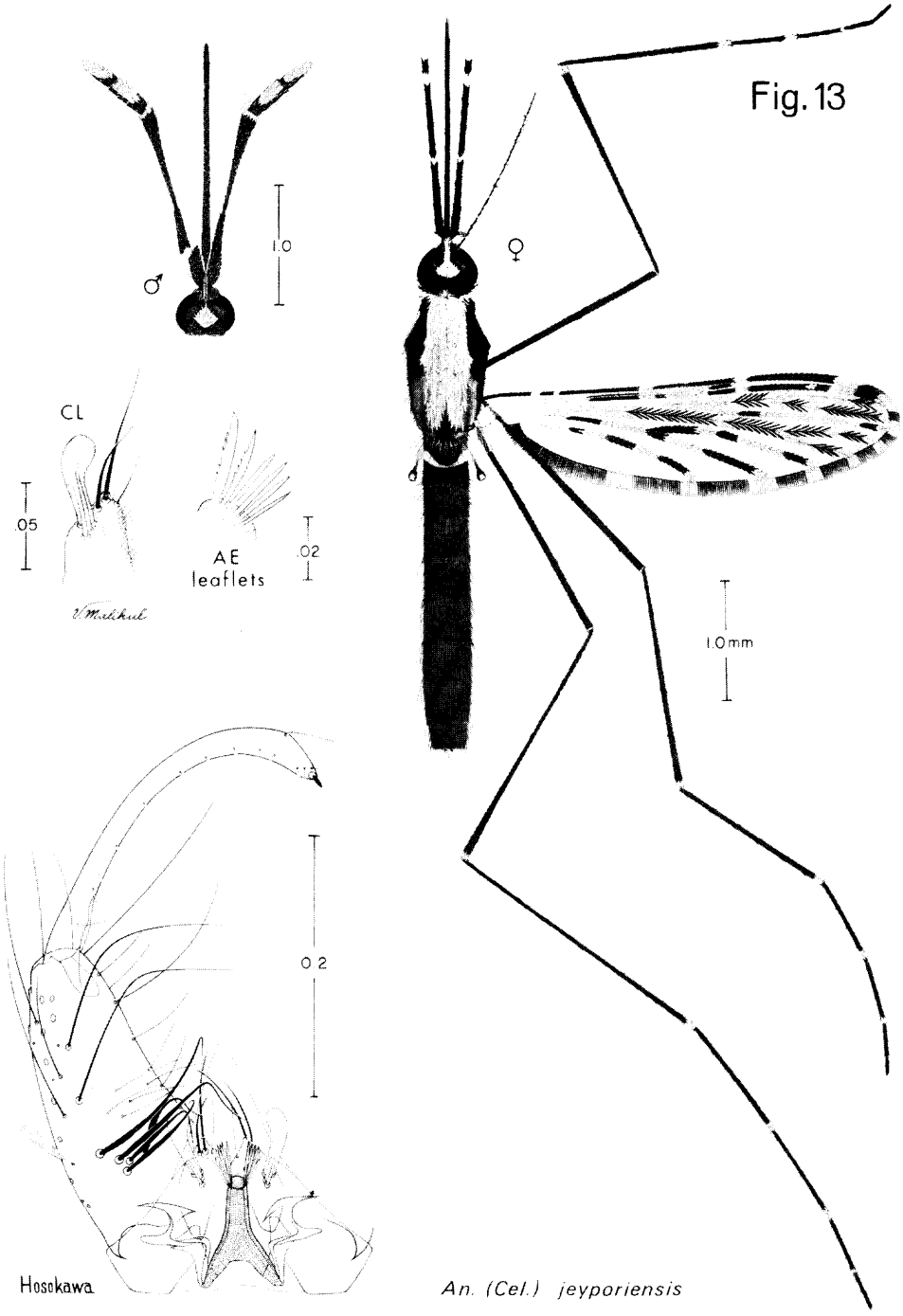
An. (Cel.) culicifacies

Fig. 12



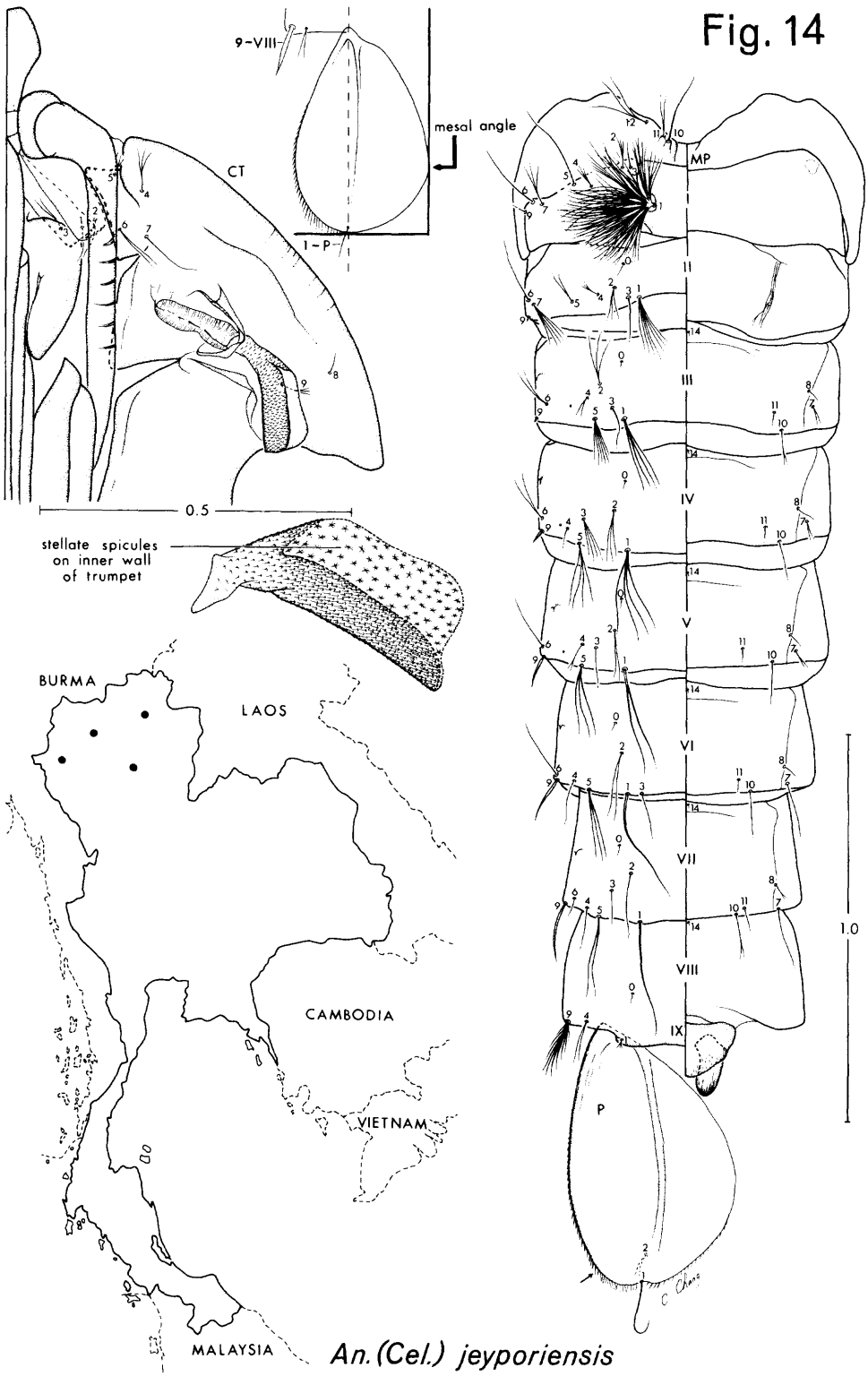
An. (Cel.) culicifacies

Fig. 13



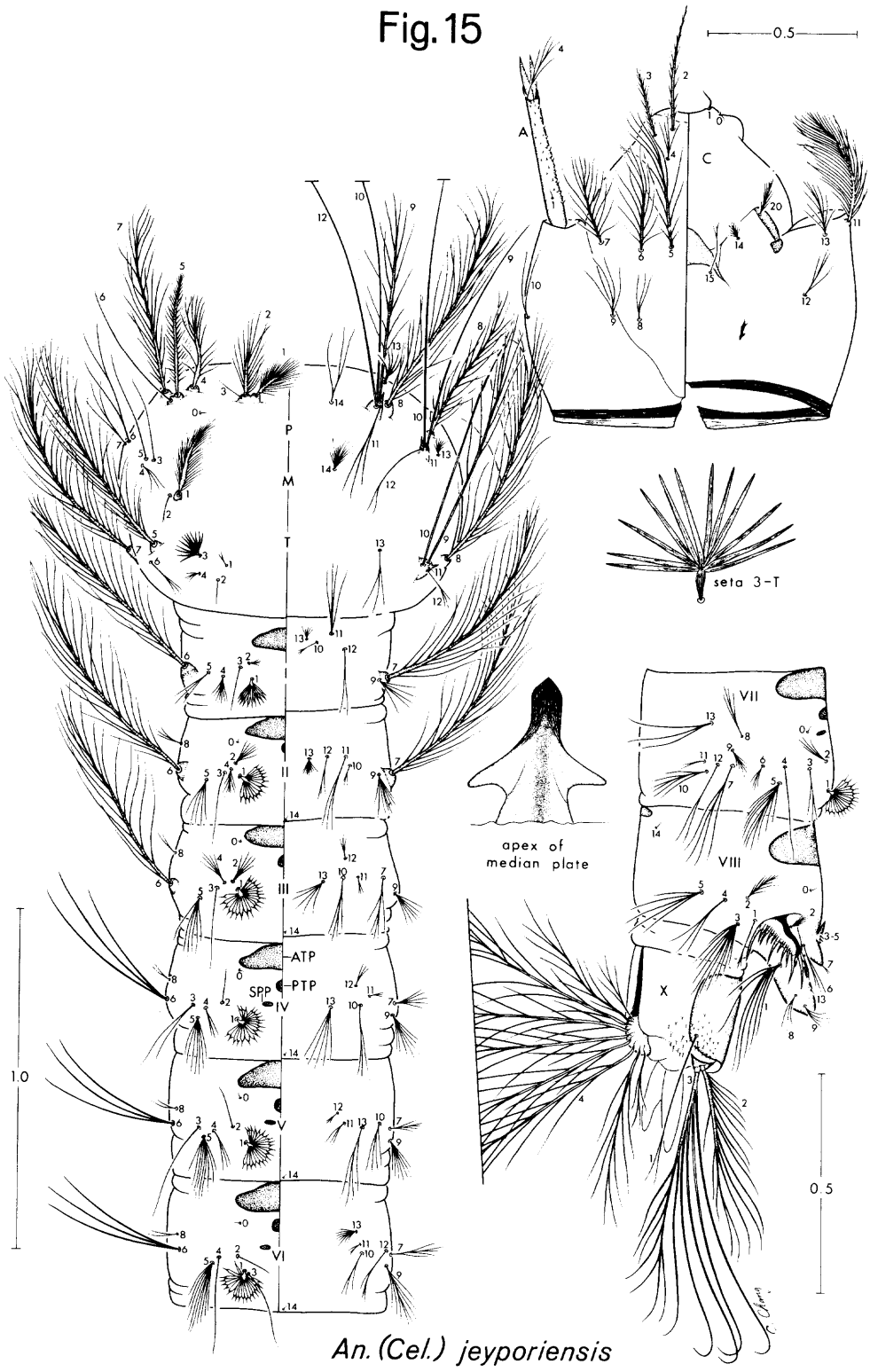
An. (Cel.) jeyporiensis

Fig. 14



An.(Cel.) jeyporiensis

Fig. 15



An. (Cel.) jeyporiensis

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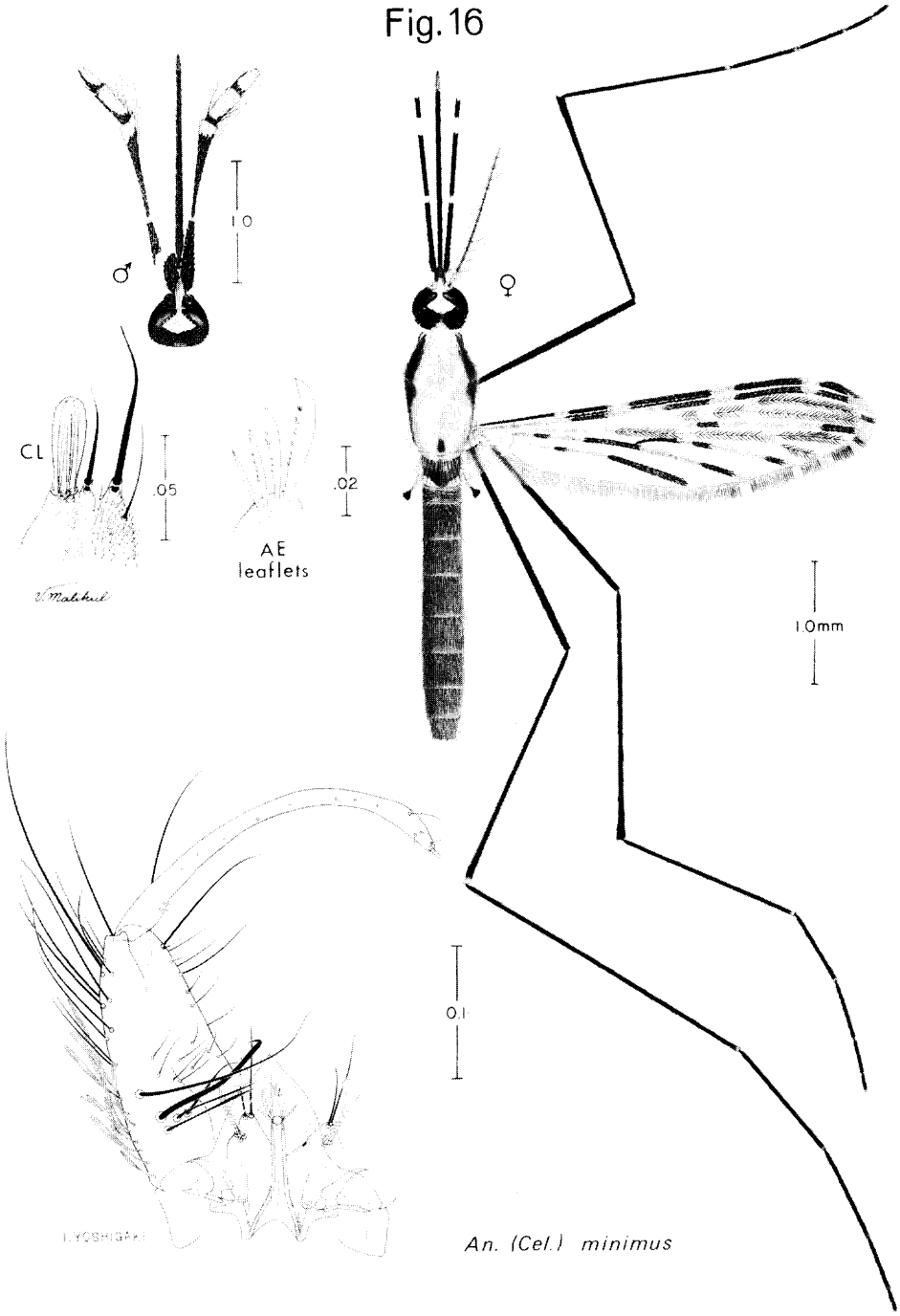

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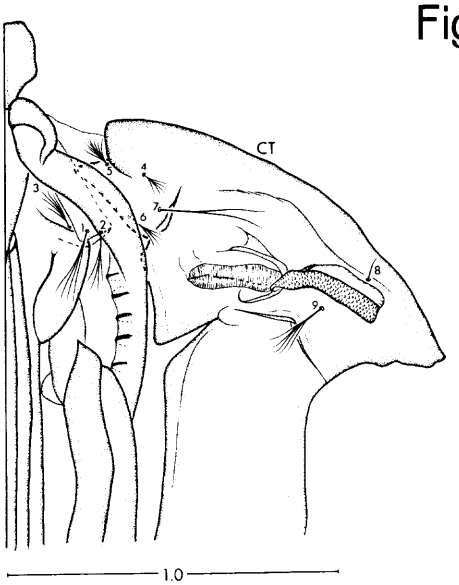
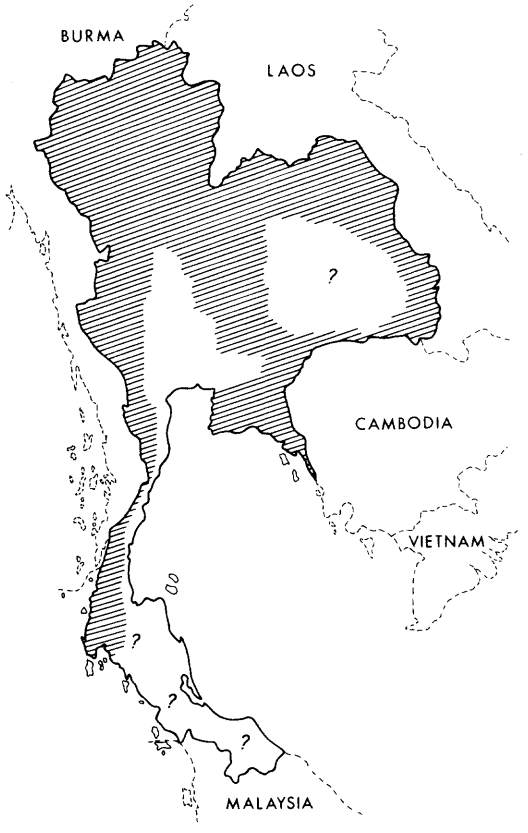
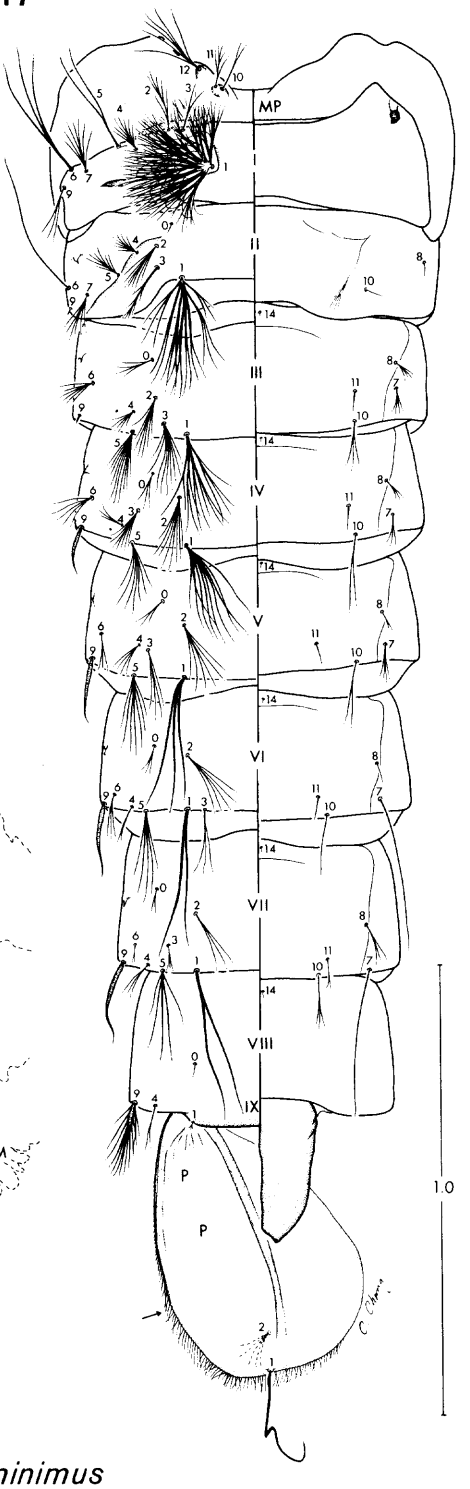
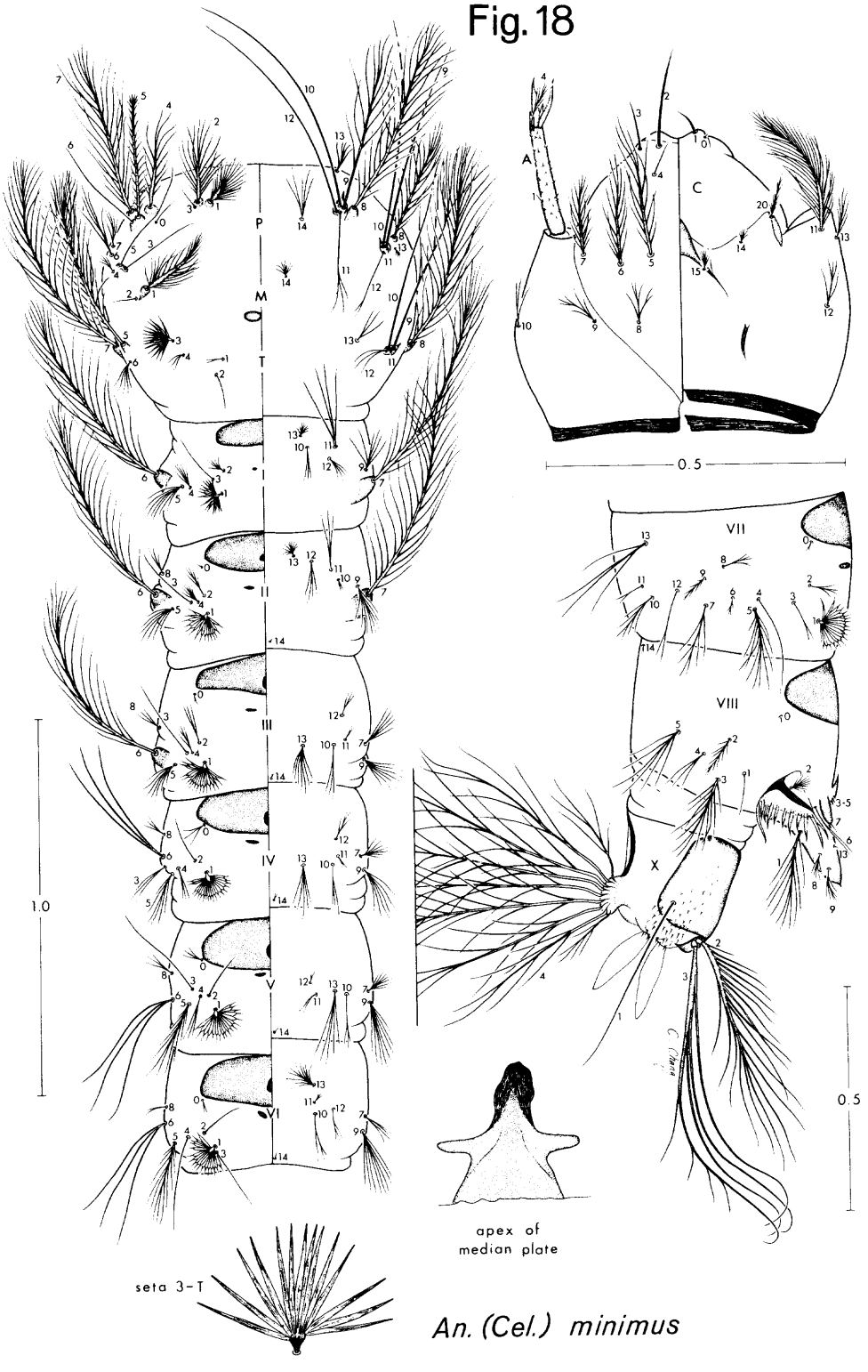






An. (Cel.) minimus

Fig. 18



An. (Cel.) minimus

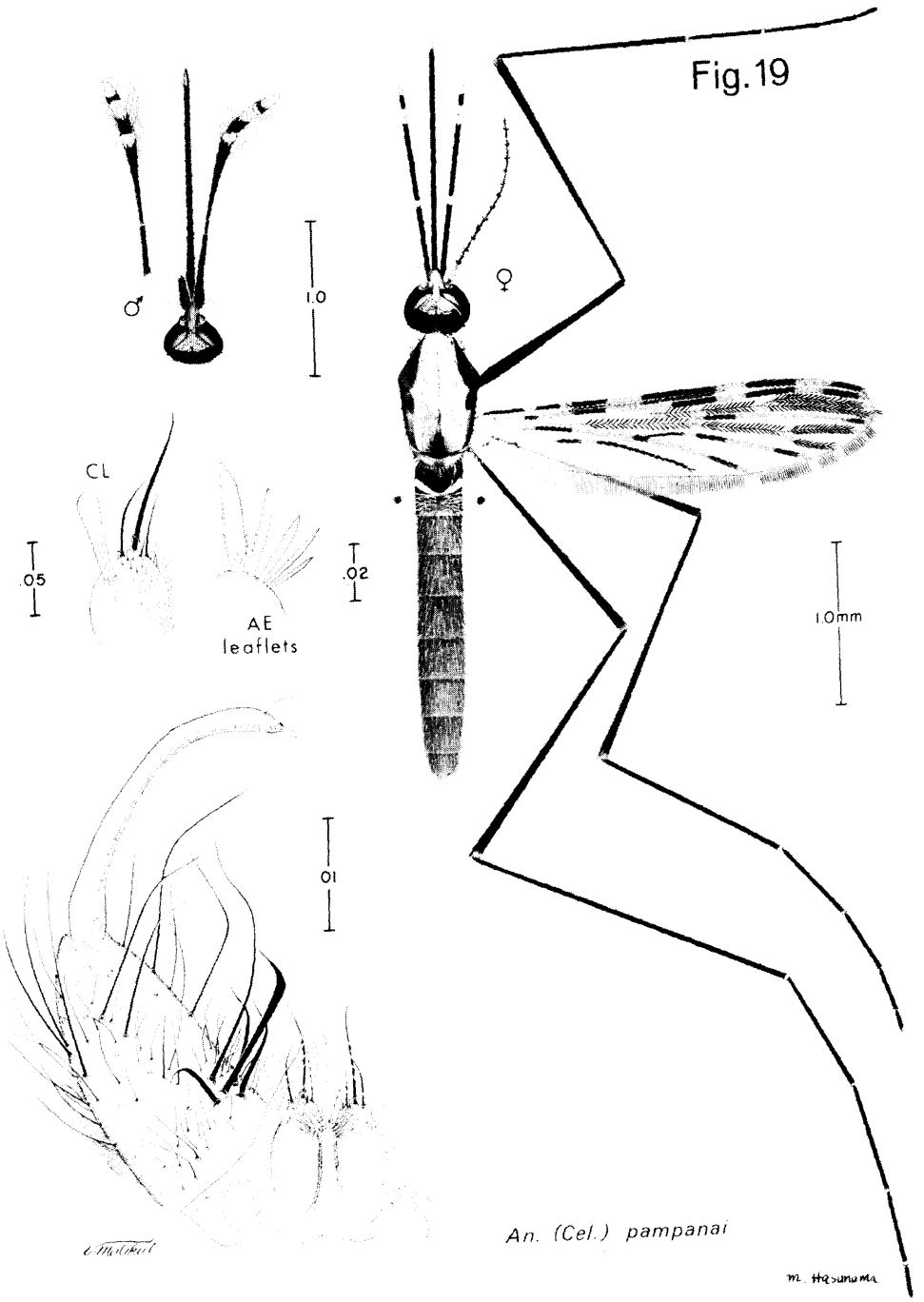
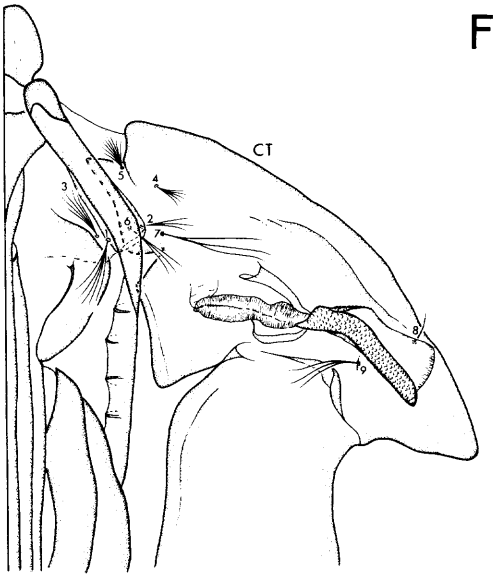
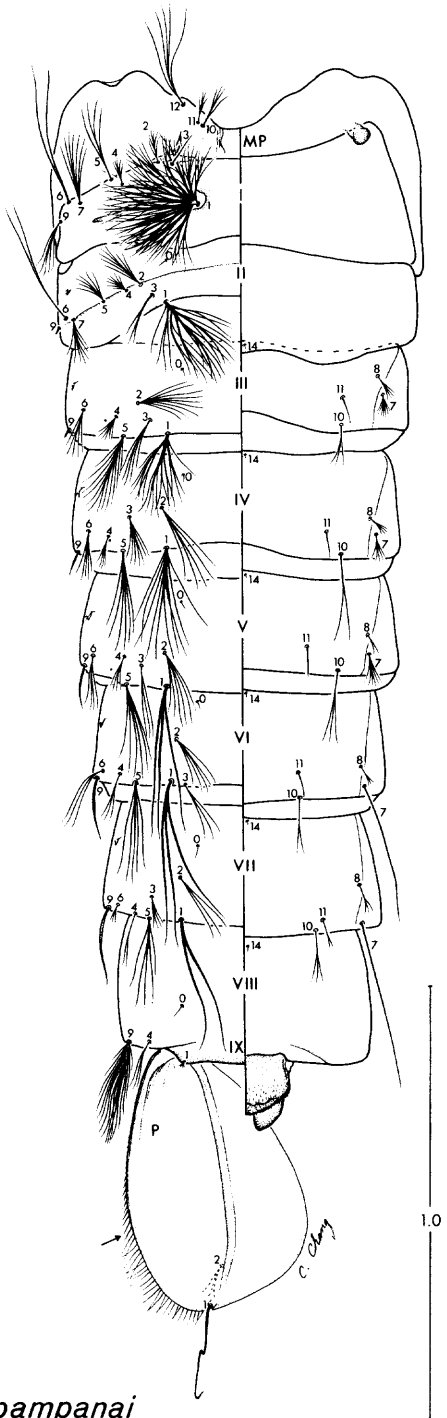
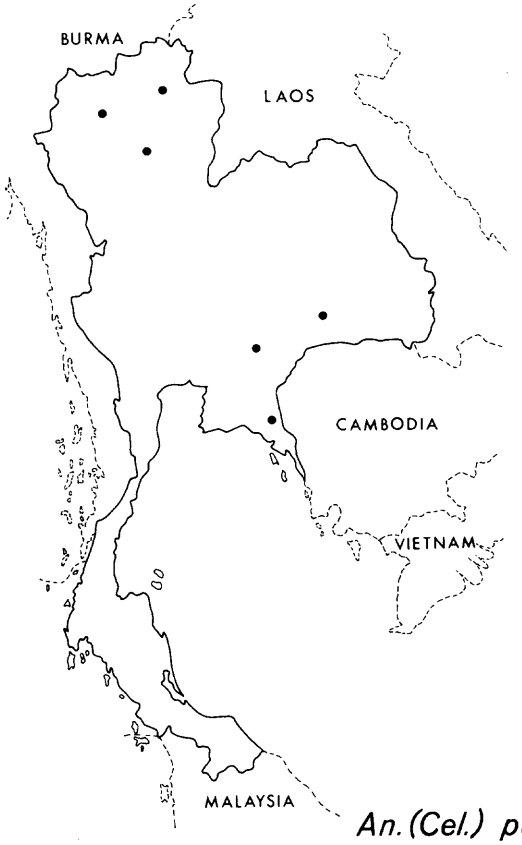


Fig.19
♂
1.0
♀
CL
.05
.02
AE
leaflets
1.0mm
.01
An. (Cel.) pampanai

Fig. 20

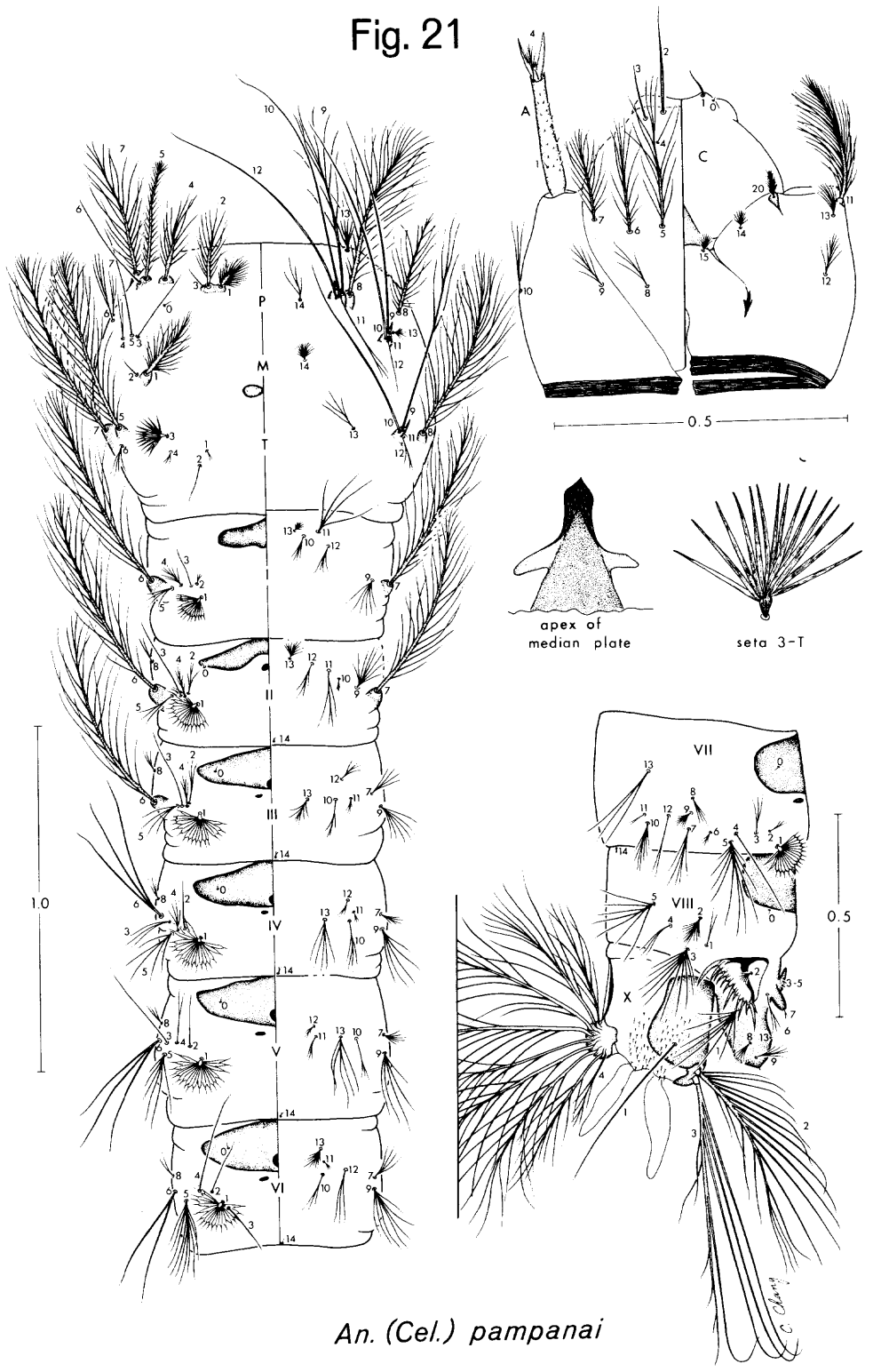






An. (Cel.) pampanai

Fig. 21



An. (Cel.) pampanai

Fig. 22

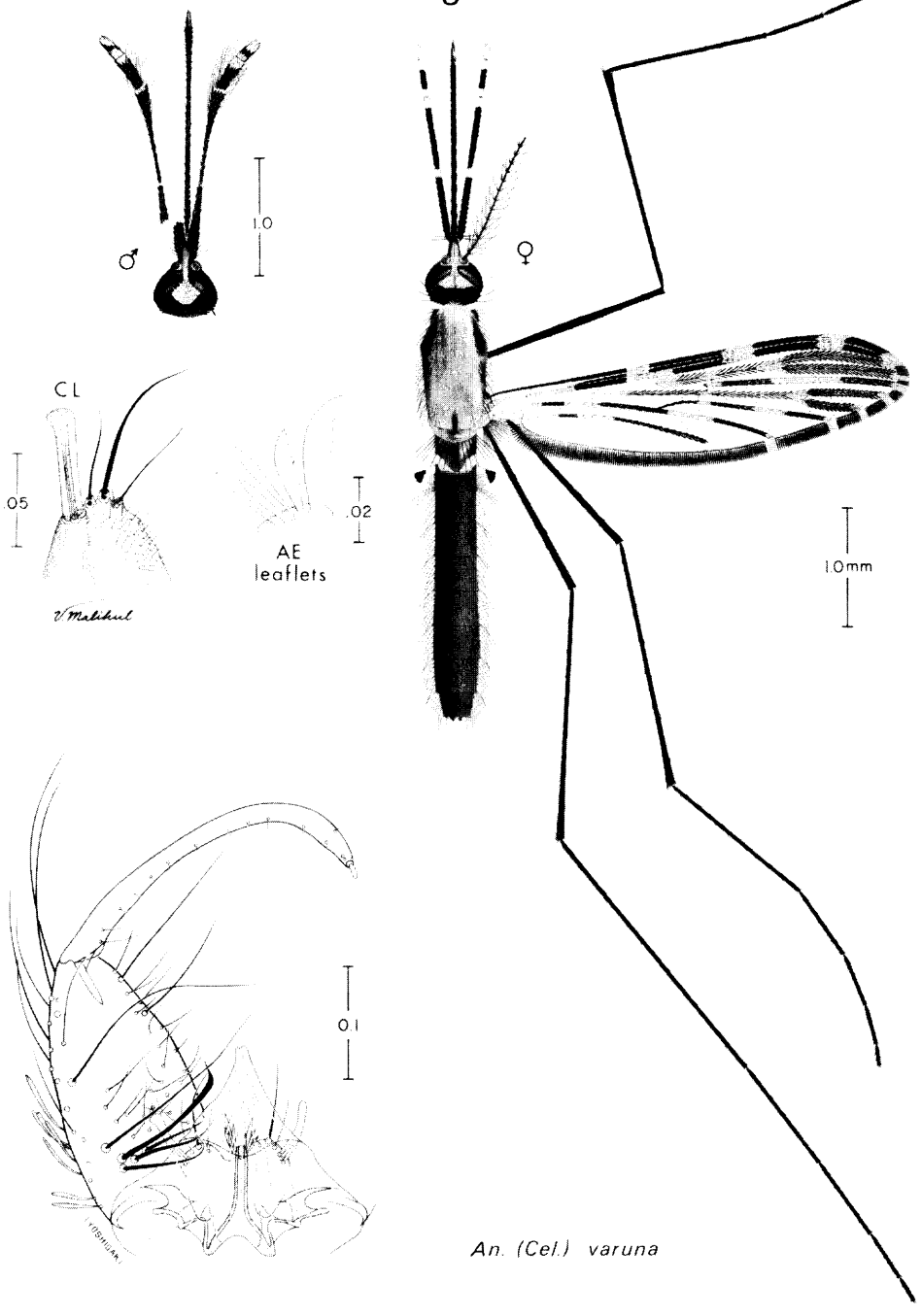
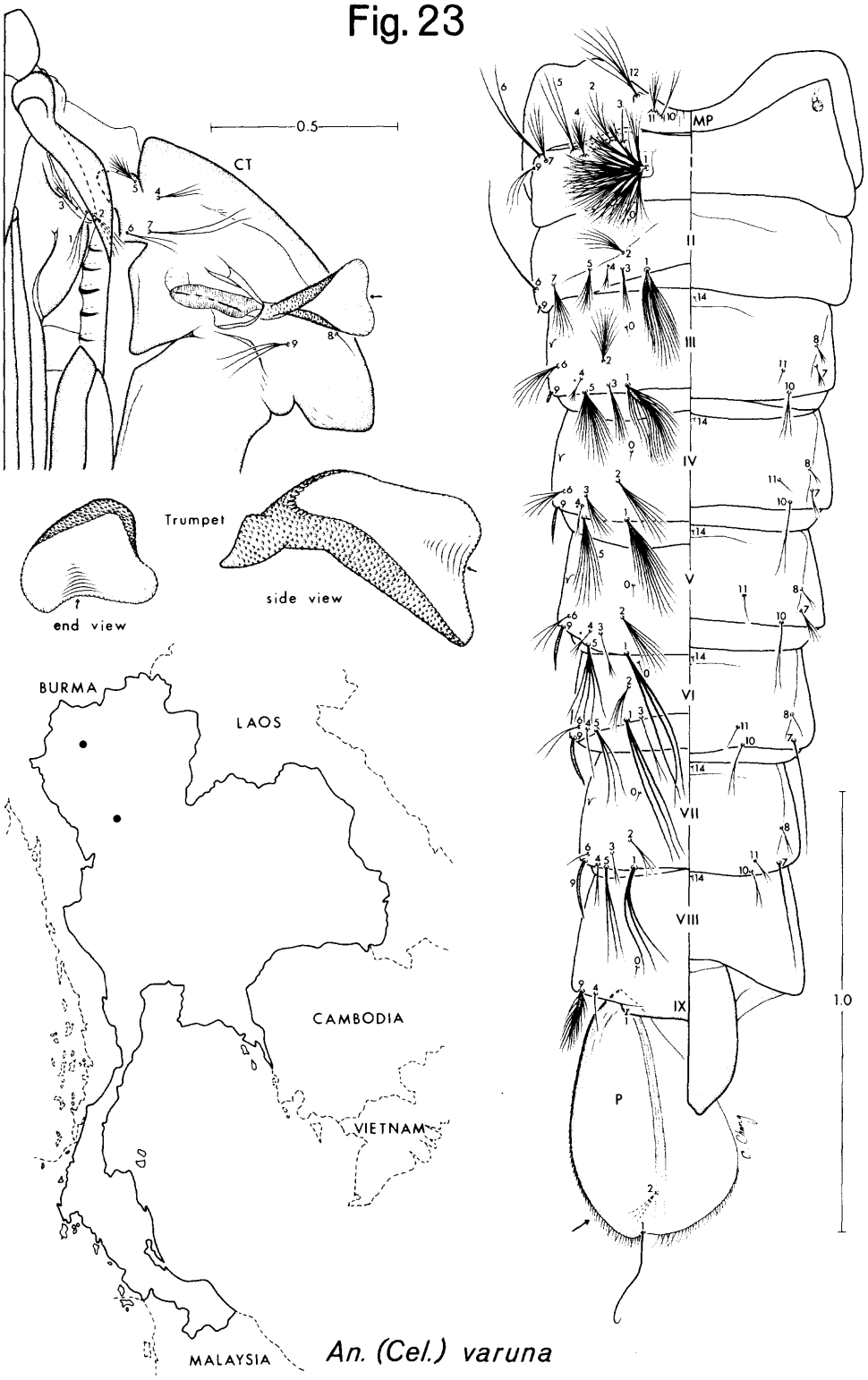
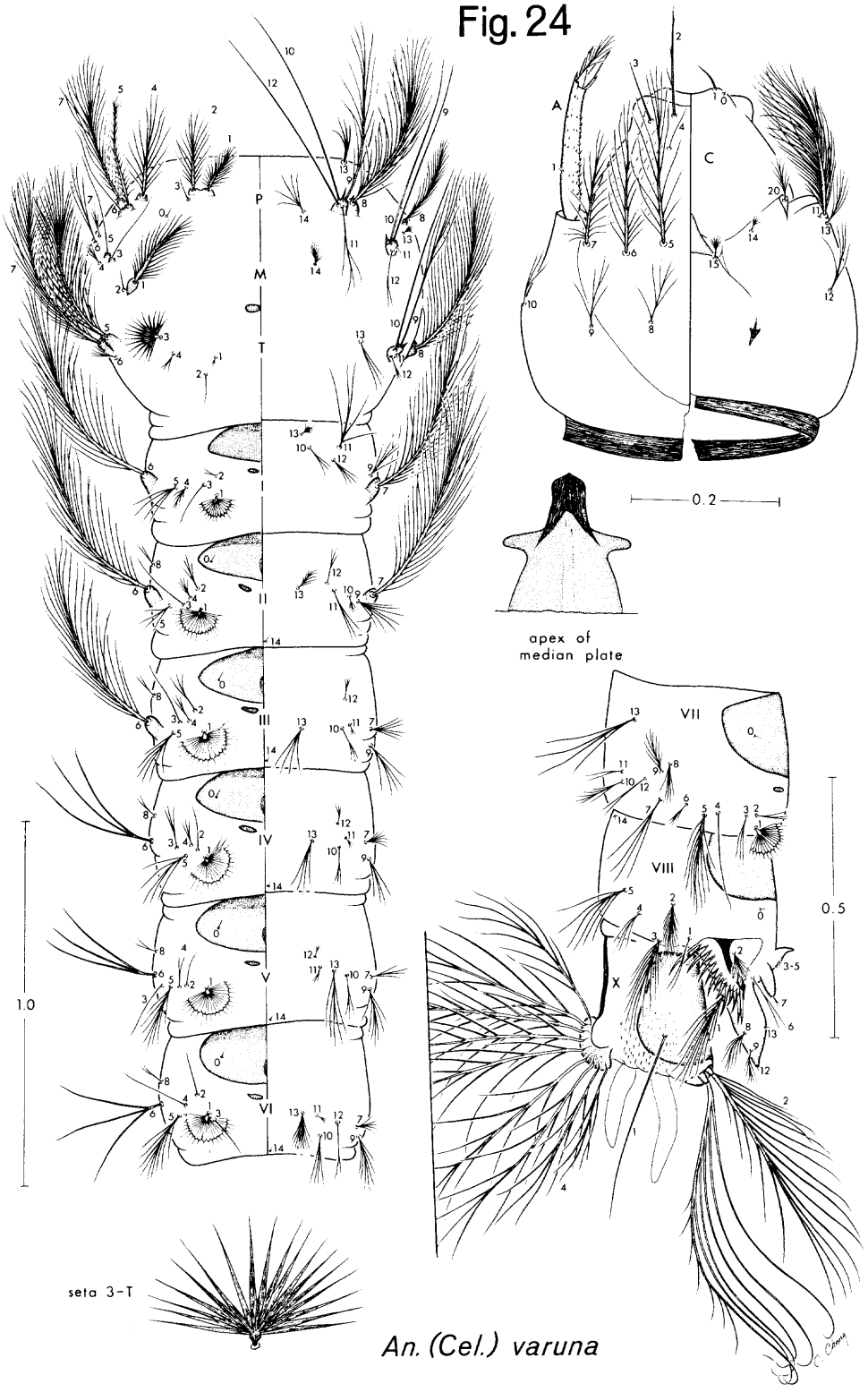


Fig. 23



An. (Cel.) varuna

Fig. 24



An. (Cel.) varuna

APPENDIX

TABLE 8. Setal branching on pupae of *Anopheles (Cellia) aconitus* (counts from 10 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Cephalothorax			Abdomen III			Abdomen V (Cont.)		
1	3-6	4	0	1-2	1	9	1	1
2	2-4	3	1	7-17	11	10	1-2	1
3	3-6	4	2	3-9	5	11	1	1
4	3-6	4	3	1-4	2	14	1	1
5	6-11	6	4	4-8	5			
6	3-4	3	5	7-11	8	Abdomen VI		
7	2-3	2	6	4-6	5			
8	1	1	7	2-5	4	0	1-2	1
9	3-5	3	8	2-4	3	1	2-5	3
			9	1	1	2	3-6	4
Metanotal Plate			10	3-4	3	3	1-3	2
			11	1	1	4	2-3	2
10	1-2	1	14	1-2	1	5	4-6	5
11	2-4	4				6	2-3	2
12	3-6	4	Abdomen IV			7	1	1
13	-	-				8	1-3	2
			0	1-2	1	9	1	1
Abdomen I			1	7-9	7	10	1-2	1
			2	3-8	5	11	1	1
1	45+	-	3	4-8	6	14	1	1
2	5-8	7	4	1-4	2			
3	1-2	1	5	6-8	7	Abdomen VII		
4	6-10	6	6	2-5	3			
5	1-3	2	7	1-4	2	0	1	1
6	1-3	2	8	1-3	3	1	1-4	3
7	4-6	6	9	1	1	2	2-4	3
9	2-5	3	10	1-2	2	3	2-3	3
			11	1	1	4	1-2	1
Abdomen II			14	1-2	1	5	3-7	3
						6	1-2	2
0	1	1	Abdomen V			7	1	1
1	8-21	13				8	3-4	4
2	4-7	5	0	1-2	1	9	1	1
3	1-4	2	1	2-7	3	10	2	2
4	5-9	6	2	3-6	4	11	2-3	2
5	4-6	4	3	2-3	3	14	1	1
6	1	1	4	3-6	4			
7	3-9	6	5	4-6	6	Abdomen VIII		
8	0-2	0	6	3-4	3			
9	1	1	7	2-5	4	0	1	1
10	0-1	0	8	1-2	2	4	1-2	2
						9	7-13	13
						14	1	1

TABLE 8. Continued

Seta	Range	Mode	Seta	Range	Mode
	Abdomen IX			Paddle	
1	3-7	3	1	1	1
			2	3-4	3

TABLE 9. Setal branching on pupae of *Anopheles (Cellia) culicifacies* (counts from 10 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Cephalothorax			Abdomen II (Cont.)			Abdomen V	
1	2-3	3	6	1	1	0	1-2	1
2	2-3	3	7	4-8	4	1	1	1
3	3-5	4	8	-	-	2	3-5	3
4	2-4	3	9	1	1	3	2-3	2
5	4-7	6	10	-	-	4	3-5	4
6	2-3	3				5	3-5	4
7	1-3	3		Abdomen III		6	1-3	2
8	1-2	1				7	1-4	3
9	1-3	2	0	1-2	1	8	1-4	2
			1	5-8	5	9	1	1
	Metanotal Plate		2	5-9	8	10	1-2	1
			3	2-5	4	11	1-2	1
10	1-3	3	4	4-8	4	14	1	1
11	3	3	5	6-8	7			
12	3-4	3	6	2-5	3		Abdomen VI	
13	0-2	0	7	1-5	3			
			8	2-5	3	0	1-2	1
	Abdomen I		9	1	1	1	1	1
			10	1-3	3	2	3-5	3
1	45+	-	11	1-2	1	3	1-3	2
2	3-5	3	14	1	1	4	1-3	2
3	1-2	1				5	3-5	3
4	2-5	4		Abdomen IV		6	1-2	2
5	2-3	3				7	1	1
6	1	1	0	1	1	8	2-3	2
7	3-6	4	1	3-7	5	9	1	1
9	1-2	1	2	3-6	5	10	1-2	2
			3	5-7	5	11	1-2	1
	Abdomen II		4	3-6	4	14	1	1
			5	4-7	5			
0	1-2	1	6	2-3	3		Abdomen VII	
1	8-13	9	7	1-4	3			
2	5-8	6	8	1-3	2	0	0-1	1
3	2-3	3	9	1	1	1	1	1
4	3-8	5	10	1-2	2	2	3-5	3
5	2-4	4	11	1-2	1	3	2-3	2
			14	1	1	4	1-2	1

TABLE 9. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Abdomen VII (Cont.)			Abdomen VIII			Paddle		
5	2-4	3	0	1	1	1	1	1
6	1-2	1	4	1-2	1	2	1-4	3
7	1	1	9	14-19	18			
8	1-3	3	14	1	1			
9	1-2	1						
10	1-3	2	Abdomen IX					
11	1-3	2						
14	1	1	1	2-5	3			

TABLE 10. Setal branching on pupae of *Anopheles (Cellia) jeyporiensis* (counts from 10 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Cephalothorax			Abdomen II			Abdomen IV		
1	1-2	1	0	1	1	0	1	1
2	1	1	1	5-8	7	1	3-5	4
3	1-2	2	2	2-4	3	2	1-3	3
4	2-3	2	3	1	1	3	3-5	4
5	2-4	3	4	2-6	4	4	1-3	2
6	1-3	2	5	1-2	2	5	3-5	4
7	1	1	6	1	1	6	1-2	1
8	1	1	7	2-6	5	7	1-3	2
9	2-3	2	8	-	-	8	1-2	1
			9	1-2	1	9	1	1
Metanotal Plate			10	-	-	10	1-2	1
						11	1	1
10	1	1	Abdomen III			14	1	1
11	2-4	3						
12	2-5	3	0	1	1	Abdomen V		
13	-	-	1	4-6	5			
			2	3-4	3	0	1	1
Abdomen I			3	1-2	1	1	1-3	2
			4	2-4	3	2	1-3	1
1	45+	-	5	3-6	5	3	1-2	1
2	3-5	5	6	1-3	1	4	1-3	2
3	1	1	7	1-3	3	5	2-5	3
4	2-4	3	8	1-2	1	6	1	1
5	1-2	1	9	1	1	7	1-3	2
6	1	1	10	1-3	2	8	1-2	1
7	2-5	3	11	1	1	9	1	1
9	1	1	14	1	1	10	1-2	1
						11	1-2	1
						14	1	1

TABLE 10. Continued.

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Abdomen VI			Abdomen VII			Abdomen VIII	
0	0-1	1	0	1	1	0	1	1
1	1-2	1	1	1-2	1	4	1-3	2
2	1-3	2	2	1-3	1	9	7-11	9
3	1-2	1	3	1-3	2	14	1	1
4	1	1	4	1-2	1			
5	1-3	3	5	1-4	2		Abdomen IX	
6	1	1	6	1-2	1			
7	1-2	1	7	1	1	1	3-4	3
8	1-2	1	8	1-2	2			
9	1	1	9	1	1		Paddle	
10	1-2	1	10	1-3	2			
11	1-2	1	11	1-2	1	1	1	1
14	1	1	14	1	1	2	1-3	2

TABLE 11. Setal branching on pupae of *Anopheles (Cellia) minimus* (counts from 10 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Cephalothorax			Abdomen I (Cont.)			Abdomen III (Cont.)	
1	4	4	7	3-7	7	6	4-7	4
2	3-6	4	9	3-5	4	7	3-7	5
3	3-5	4				8	1-5	5
4	3-7	4		Abdomen II		9	1	1
5	7-10	9				10	1-5	4
6	3-5	4	0	1	1	11	1	1
7	2-3	2	1	17-44	21	14	1	1
8	1	1	2	4-7	4			
9	4-6	4	3	5-10	7		Abdomen IV	
			4	5-8	8			
	Metanotal Plate		5	5-8	7	0	1-6	3
			6	1-2	1	1	6-13	10
10	2-3	2	7	3-9	5	2	5-11	8
11	3-6	5	8	0-1	0	3	7-9	7
12	3-6	4	9	1-2	1	4	1-6	3
13	-	-	10	0-1	0	5	5-8	8
						6	3-5	4
	Abdomen I			Abdomen III		7	1-5	3
						8	1-4	3
1	45+	-	0	1-5	4	9	1	1
2	5-9	6	1	11-26	14	10	1-3	3
3	2-4	2	2	6-10	10	11	1	1
4	7-9	7	3	5-11	8	14	1-2	1
5	2-3	2	4	4-7	4			
6	2-3	2	5	9-13	10			

TABLE 11. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Abdomen V			Abdomen VI (Cont.)			Abdomen VII (Cont.)	
0	1-7	2	5	4-7	5	10	2-4	3
1	1-5	1	6	2-3	3	11	1-3	3
2	5-8	6	7	1	1	14	1-2	1
3	2-4	2	8	1-3	1			
4	3-4	4	9	1	1		Abdomen VIII	
5	5-7	5	10	1-2	2			
6	2-4	3	11	1	1	0	1	1
7	2-6	4	14	1-2	1	4	2-3	2
8	1-3	3				9	7-14	13
9	1	1		Abdomen VII		14	1	1
10	1-3	1						
11	1	1	0	1-3	1		Abdomen IX	
14	1-2	1	1	1-4	1			
			2	3-5	3	1	3-5	4
	Abdomen VI		3	2-4	2			
			4	1-3	2		Paddle	
0	1-3	1	5	2-7	5			
1	1-3	1	6	1-3	1	1	1	1
2	3-6	5	7	1	1	2	3-5	4
3	2-3	2	8	2-4	3			
4	1-3	3	9	1-2	1			

TABLE 12. Setal branching on pupae of *Anopheles (Cellia) pampanai* (counts from 8 setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Cephalothorax			Abdomen I			Abdomen II (Cont.)	
1	4-5	5	1	45+	-	6	1-3	3
2	3-6	4	2	4-7	6	7	6-14	7
3	5-6	5	3	1-2	1	8	-	-
4	5-7	5	4	5-6	6	9	1	1
5	5-10	8	5	2-4	3	10	0-1	0
6	3-4	4	6	2-3	3			
7	2-4	3	7	5-9	7		Abdomen III	
8	1-3	1	9	3-6	5			
9	3-6	4				0	1-2	1
				Abdomen II		1	13-27	17
	Metanotal Plate					2	7-12	9
			0	1	1	3	3-6	4
10	2-5	3	1	16-33	27	4	4-9	6
11	4-5	4	2	5-10	7	5	7-15	12
12	3-6	5	3	3-5	4	6	5-8	5
13	-	-	4	6-10	7	7	5-9	7
			5	5-7	6	8	3-6	4

TABLE 12. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Abdomen III (Cont.)			Abdomen V (Cont.)			Abdomen VII (Cont.)		
9	1-2	1	5	5-8	7	1	2-4	3
10	3-4	4	6	3-5	4	2	3-4	3
11	1	1	7	5-6	5	3	3-5	3
14	1	1	8	1-3	3	4	2-3	3
			9	1	1	5	5-7	5
Abdomen IV			10	2-3	2	6	2-5	3
			11	1	1	7	1-2	1
0	1-2	1	14	1	1	8	3-5	4
1	7-11	11				9	1	1
2	5-6	6	Abdomen VI			10	3-4	3
3	6-9	7				11	2-3	3
4	4-6	5	0	1	1	14	1	1
5	6-9	6	1	2-4	3			
6	4-6	5	2	5-6	5	Abdomen VIII		
7	5-6	5	3	2-3	3			
8	2-4	4	4	2-4	3	0	1	1
9	1	1	5	4-7	6	4	2-4	3
10	2-3	2	6	2-3	3	9	11-24	20
11	1-2	1	7	1-2	1	14	1	1
14	1-2	1	8	2-5	3			
			9	1	1	Abdomen IX		
Abdomen V			10	2-3	2			
			11	1-2	1	1	4-5	4
0	1-2	1	14	1-2	1			
1	2-4	3				Paddle		
2	4-7	6	Abdomen VII					
3	3-4	4				1	1	1
4	4-5	5	0	1	1	2	3-4	3

TABLE 13. Setal branching on pupae of *Anopheles (Cellia) varuna* (counts from 14 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Cephalothorax			Metanotal Plate			Abdomen I (Cont.)		
1	2-5	4	10	1-3	1	3	1-2	1
2	3-5	4	11	3-5	5	4	4-10	7
3	3-6	5	12	3-7	4	5	1-3	3
4	2-5	3	13	-	-	6	1-3	2
5	6-8	6				7	4-7	5
6	2-4	3	Abdomen I			9	2-5	3
7	2-3	2						
8	1	1	1	45+	-			
9	2-5	3	2	6-8	6			

TABLE 13. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Abdomen II			Abdomen IV (Cont.)			Abdomen VI (Cont.)	
0	1	1	5	6-10	9	8	1-2	2
1	12-19	15	6	4-7	6	9	1	1
2	4-7	6	7	2-5	3	10	1-2	1
3	3-5	4	8	1-2	2	11	1	1
4	3-6	4	9	1	1	14	1	1
5	5-7	6	10	1-2	2			
6	1-3	1	11	1	1		Abdomen VII	
7	4-10	7	14	1	1			
8	-	-				0	1	1
9	1	1		Abdomen V		1	3-4	3
10	-	-				2	2-5	3
			0	1	1	3	1-4	2
	Abdomen III		1	3-4	3	4	1-2	2
			2	3-9	7	5	2-5	4
0	1-2	1	3	2-4	3	6	1-2	1
1	15-21	17	4	2-5	4	7	1-2	1
2	7-14	10	5	4-6	5	8	2-3	3
3	4-6	5	6	2-4	3	9	1	1
4	3-5	4	7	3-5	4	10	2-3	2
5	10-19	15	8	1-2	2	11	2-3	2
6	4-10	6	9	1	1	14	1	1
7	2-5	4	10	1-2	2			
8	2-5	3	11	1	1		Abdomen VIII	
9	1	1	14	1	1			
10	2-5	3				0	1	1
11	1	1		Abdomen VI		4	1-2	2
14	1	1				9	12-17	16
			0	1	1	14	1	1
	Abdomen IV		1	3-4	3			
			2	3-6	3		Abdomen IX	
0	1	1	3	1-3	2			
1	8-15	12	4	1-2	2	1	2-4	3
2	4-13	8	5	3-5	3			
3	5-8	6	6	1-3	2		Paddle	
4	1-3	2	7	1-3	2			
						1	1	1
						1	2-5	3

TABLE 14. Setal branching on larvae of *Anopheles (Cellia) aconitus* (counts from 10 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Antenna			Mesothorax			Abdomen (Cont.)	
1	1	1	1	30-39	33	12	2-4	3
2	1	1	2	1-3	2	13	6-10	8
3	1	1	3	1	1			
4	4-7	5	4	3-5	3		Abdomen II	
5	1	1	5	1	1			
6	1	1	6	3-5	4	0	1-2	1
			7	2-5	3	1	16-19	16
	Head		8	18-24	21	2	3-5	4
			9	1-2	1	3	1	1
1	1	1	10	1	1	4	4-7	6
2	9-18	14	11	1	1	5	3-5	5
3	1-9	6	12	2	2	6	26-30	29
4	1-6	3	13	5-10	8	7	28-31	29
5	11-16	12	14	8-15	11	8	1-4	3
6	12-17	14				9	6-9	9
7	15-18	17		Metathorax		10	3	3
8	1-5	3				11	3	3
9	5-9	5	1	1-2	2	12	3-4	3
10	2-4	3	2	1-2	1	13	7-11	9
11	42-50	45	3	11-17	15	14	1-3	2
12	3-8	6	4	2-4	3			
13	7-13	9	5	32-40	34		Abdomen III	
14	5-6	5	6	3-5	4			
15	4-7	6	7	30-35	31	0	1-3	1
20	8-11	9	8	32-39	36	1	17-23	20
			9	5-7	5	2	3-4	3
	Prothorax		10	1	1	3	1	1
			11	1	1	4	3-6	3
0	1-2	1	12	3-4	3	5	4-6	6
1	19-24	21	13	3-4	3	6	17-22	20
2	10-14	14				7	4-8	5
3	1	1		Abdomen I		8	2-3	2
4	10-14	12				9	4-8	6
5	36-45	38	1	12-14	14	10	2-4	3
6	1	1	2	1-3	3	11	2-4	3
7	23-29	25	3	1	1	12	2-3	3
8	29-33	29	4	4-6	4	13	7-12	8
9	9-11	9	5	4-6	5	14	1-3	2
10	1	1	6	27-37	32			
11	2-4	3	7	24-28	26		Abdomen IV	
12	1	1	9	4-7	6			
13	4-8	5	10	2-4	3	0	1-2	1
14	3-5	4	11	4	4	1	18-22	20

TABLE 14. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Abdomen IV (Cont.)			Abdomen VI			Abdomen VII (Cont.)		
2	1-2	1	0	1-2	2	13	3-4	3
3	1-4	2	1	17-21	19	14	-	-
4	2-4	2	2	1	1			
5	3-5	4	3	1	1	Abdomen VIII		
6	3	3	4	1	1			
7	3-7	5	5	6-9	8	0	1-2	1
8	1-3	2	6	3	3	1	2-4	2
9	4-7	6	7	5-6	5	2	8-11	9
10	2-4	3	8	2-3	2	3	8-11	10
11	2-3	3	9	7-10	7	4	3-4	4
12	2-3	3	10	3-4	3	5	4-5	5
13	4-8	5	11	2-4	3	14	1-2	2
14	1-3	2	12	3-4	3			
			13	6-10	8	Spiracular Lobe		
Abdomen V			14	2	2			
						1	6-8	7
0	1-3	1	Abdomen VII			2	4-7	6
1	17-21	21				3	0	0
2	1	1	0	1-2	2	4	1	1
3	1-2	1	1	16-18	17	5	1	1
4	1-3	2	2	2-5	4	6	2-3	2
5	5-8	7	3	2-3	3	7	2	2
6	3	3	4	1-2	1	8	4-6	5
7	4-6	5	5	7-10	9	9	4-6	5
8	1-2	2	6	3-5	4	10	1	1
9	6-9	6	7	4-8	5	11	1	1
10	2-3	3	8	4-5	5	12	1	1
11	2-3	3	9	5-9	9	13	1	1
12	3-4	4	10	4-7	5			
13	4-5	4	11	2-3	3	Abdomen X		
14	1-2	2	12	2-3	3			
						1	1	1
						2	17-22	20
						3	9-12	11
						4	9 pairs	9

TABLE 15. Setal branching on larvae of *Anopheles (Cellia) culicifacies* (counts from 10 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Antenna			Mesothorax			Abdomen I (Cont.)	
1	1	1	1	24-30	26	12	3-4	3
2	1	1	2	2-4	2	13	4-7	6
3	1	1	3	1	1			
4	3-7	5	4	3-4	3		Abdomen II	
5	1	1	5	1	1			
6	1	1	6	3-4	3	0	1-2	1
			7	3-4	3	1	14-18	17
	Head		8	18-28	22	2	3-6	4
			9	1	1	3	1	1
1	1	1	10	1	1	4	4-6	4
2	1	1	11	1	1	5	3-5	4
3	1	1	12	1-2	1	6	27-34	32
4	1	1	13	6-10	7	7	25-32	31
5	11-16	14	14	7-13	10	8	3-4	3
6	12-14	14				9	6-9	8
7	16-21	17		Metathorax		10	2-4	3
8	1	1				11	2-4	3
9	4-6	4	1	2-4	3	12	3	3
10	1-2	1	2	1	1	13	7-10	8
11	38-44	43	3	5-10	7	14	1	1
12	3-4	3	4	2-3	3			
13	4-7	6	5	35-41	35		Abdomen III	
14	10-15	11	6	2-4	2			
15	8-15	11	7	26-35	32	0	1-2	1
20	7-15	10	8	30-41	38	1	15-21	17
			9	4-14	8	2	3-4	3
	Prothorax		10	1	1	3	1	1
			11	1	1	4	3-6	3
0	1	1	12	1-4	2	5	3-5	4
1	16-25	17	13	3-4	3	6	21-27	25
2	9-14	12				7	4-7	5
3	1	1		Abdomen I		8	2-3	3
4	11-18	13				9	6-9	8
5	27-42	34	1	11-14	12	10	2-3	3
6	1	1	2	2-4	3	11	2-3	3
7	17-27	23	3	1	1	12	2-4	3
8	27-41	35	4	2-4	4	13	7-11	8
9	6-13	9	5	2-4	3	14	1-2	1
10	1	1	6	25-36	28			
11	2-5	4	7	23-28	28		Abdomen IV	
12	1	1	9	5-6	5			
13	4-6	5	10	1-3	2	0	1	1
14	4-7	4	11	3-5	4	1	17-23	18

TABLE 15. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Abdomen IV (Cont.)			Abdomen VI			Abdomen VIII		
2	1	1	0	1-2	1	0	1-2	1
3	2-5	3	1	13-22	17	1	1-2	1
4	2-4	3	2	1-3	3	2	8-10	9
5	3-5	4	3	1	1	3	6-8	8
6	3-4	3	4	1	1	4	2-3	2
7	4-6	5	5	5-10	8	5	4-6	5
8	2-4	3	6	3-4	3	14	1-2	1
9	6-8	6	7	3-4	4			
10	2-3	3	8	2-3	3	Spiracular Lobe		
11	2-3	2	9	7-11	7			
12	3-4	3	10	2-4	3	1	6-7	7
13	3-5	5	11	2-4	3	2	6-9	7
14	1-3	2	12	2-3	2	3	0	0
			13	7-12	8	4	1	1
Abdomen V			14	1-3	1	5	1	1
						6	2-3	2
0	1-2	1	Abdomen VII			7	1-2	2
1	16-23	18				8	6-7	7
2	1	1	0	1	1	9	3-6	5
3	1	1	1	12-20	16	10	1	1
4	2-4	3	2	4-8	5	11	1	1
5	5-7	6	3	2-3	3	12	1	1
6	3-4	3	4	1	1	13	1	1
7	4-5	5	5	6-10	8			
8	2-3	3	6	3-5	3	Abdomen X		
9	6-9	7	7	3-4	3			
10	2-3	3	8	4-6	4	1	1	1
11	2-4	3	9	6-8	7	2	14-19	16
12	2-4	3	10	4-6	5	3	7-12	9
13	3-5	4	11	2-3	2	4	9 pairs	9
14	1-2	1	12	2-3	2			
			13	3-5	3			

TABLE 16. Setal branching on larvae of *Anopheles (Cellia) jeyporiensis* (counts from 10 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Antenna			Head			Head (Cont.)		
1	1	1	1	1	1	7	13-16	16
2	1	1	2	20-25	20	8	2-4	3
3	1	1	3	15-20	16	9	3-6	4
4	3-6	4	4	2-5	4	10	2-4	3
5	1	1	5	13-16	14	11	40-46	41
6	1	1	6	12-15	15	12	3-4	3

TABLE 16. Continued

Seta	Range	Mode
	Head (Cont.)	
13	5-9	6
14	10-14	12
15	2-4	3
20	8-21	9
	Prothorax	
0	1	1
1	23-35	30
2	10-15	14
3	1-2	1
4	14-18	17
5	49-60	57
6	1	1
7	24-32	32
8	29-36	32
9	10-12	12
10	1	1
11	3-5	4
12	1	1
13	4-6	5
14	3-4	4
	Mesothorax	
1	35-53	37
2	1-3	2
3	1	1
4	3-4	3
5	1	1
6	2-4	3
7	3-4	3
8	23-31	28
9	1	1
10	1	1
11	1	1
12	2-3	3
13	5-9	8
14	10-16	12
	Metathorax	
1	2-3	3
2	1	1
3	10-19	13
4	2-4	3
5	31-39	34
6	3-4	3
7	25-38	30
8	28-36	30
9	11-14	12
10	1	1
11	1	1
12	2-5	4
13	3	3
	Abdomen I	
1	10-16	12
2	3-5	3
3	1	1
4	4-9	7
5	3-5	4
6	26-33	30
7	22-31	26
9	4-7	5
10	3-4	3
11	3-4	4
12	3-5	5
13	5-8	7
	Abdomen II	
0	1	1
1	12-17	14
2	4-12	8
3	1	1
4	6-9	8
5	4-8	7
6	23-31	28
7	27-34	27
8	3-4	3
9	8-11	8
10	3-4	4
11	3-6	3
12	2-5	4
13	7-11	8
14	1-2	1
	Abdomen III	
0	1	1
1	15-22	21
2	4-6	5
3	1	1
4	3-6	5
5	5-8	7
6	17-23	20
7	5-6	6
8	2-3	3
9	4-9	5
10	3-5	4
11	3-5	3
12	2-4	3
13	4-9	5
14	1-2	1
	Abdomen IV	
0	1	1
1	17-21	19
2	1-2	1
3	2-4	3
4	2-3	3
5	6-9	7
6	3-4	3
7	4-7	6
8	2-4	3
9	6-7	7
10	3-5	4
11	2-4	3
12	3-4	3
13	4-9	5
14	1-2	1
	Abdomen V	
0	1	1
1	16-21	20
2	1	1
3	1-2	1
4	3-4	3
5	7-12	9
6	3-4	4
7	5-7	5
8	2-3	2
9	5-8	7
10	3-4	4
11	2-4	3
12	2-6	3

TABLE 16. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Abdomen V (Cont.)			Abdomen VII			Spiracular Lobe		
13	4-5	4	0	1	1	1	5-9	8
14	1-2	2	1	14-19	16	2	5-8	6
			2	3-5	3	3	0	0
Abdomen VI			3	2-4	3	4	1	1
			4	1	1	5	1	1
0	1	1	5	9-13	11	6	3	3
1	17-20	18	6	3-5	4	7	2	2
2	1-3	1	7	4-6	4	8	3-5	3
3	1	1	8	3-5	4	9	4-6	5
4	1-2	1	9	5-8	7	10	1	1
5	8-14	9	10	6-7	6	11	1	1
6	3-4	4	11	2-4	3	12	1	1
7	4-5	5	12	2-4	3	13	1	1
8	2-4	3	13	3-4	3			
9	6-10	8				Abdomen X		
10	3-5	3	Abdomen VIII					
11	2-4	3				1	2-3	2
12	3-4	3	0	1	1	2	15-18	17
13	7-12	8	1	1-3	3	3	11-13	12
14	1-2	1	2	10-13	11	4	9-9 1/2 pairs	
			3	7-11	11			
			4	3-5	3			
			5	4-8	5			
			14	1-2	1			

TABLE 17. Setal branching on larvae of *Anopheles (Cellia) minimus* (counts from 10 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Antenna			Head			Head (Cont.)		
1	1	1	1	1	1	7	15-20	19
2	1	1	2	1	1	8	5-10	6
3	1	1	3	1	1	9	4-7	6
4	5-9	6	4	1-2	1	10	3-4	3
5	1	1	5	6-14	10	11	39-48	45
6	1	1	6	12-15	13	12	5-7	5

TABLE 17. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Head (Cont.)		6	3-6	4		Abdomen III (Cont.)	
			7	30-38	31			
13	6-9	6	8	32-38	32	5	5-8	6
14	6-8	8	9	4-10	9	6	17-25	20
15	7-11	8	10	1	1	7	5-8	6
20	9-13	9	11	1-2	1	8	2-3	3
			12	3-5	4	9	6-8	7
	Prothorax		13	3-4	3	10	2-4	3
						11	2-4	3
0	1	1		Abdomen I		12	3	3
1	18-28	22				13	6-11	10
2	13-19	14	1	11-16	13	14	1-3	2
3	1	1	2	3-6	5			
4	10-14	14	3	1	1		Abdomen IV	
5	32-46	42	4	4-8	6			
6	1-2	1	5	4-7	7	0	2-5	3
7	21-28	25	6	26-34	29	1	18-23	20
8	27-38	36	7	26-33	29	2	1-2	1
9	10-15	11	9	5-7	6	3	2-3	2
10	1	1	10	1-4	3	4	2-5	3
11	2-5	3	11	4-5	4	5	6-8	7
12	1	1	12	3-5	4	6	3	3
13	3-7	5	13	7-9	8	7	4-8	6
14	3-5	4				8	2-3	2
				Abdomen II		9	4-8	6
	Mesothorax					10	3	3
			0	1-2	1	11	1-4	3
1	24-32	29	1	13-18	17	12	2-4	3
2	1-3	1	2	3-6	5	13	5-7	5
3	1	1	3	1	1	14	1-3	1
4	3-6	4	4	5-9	7			
5	1	1	5	5-7	5		Abdomen V	
6	3-6	4	6	24-31	27			
7	2-5	4	7	24-36	32	0	2-4	3
8	14-23	22	8	1-3	2	1	17-22	18
9	1	1	9	6-10	10	2	1	1
10	1	1	10	3-4	3	3	1	1
11	1	1	11	2-3	3	4	2-3	3
12	1-3	1	12	2-5	3	5	9-11	10
13	4-13	7	13	4-10	9	6	3	3
14	6-12	8	14	1-3	3	7	6-8	6
						8	2-4	2
	Metathorax			Abdomen III		9	6-9	8
						10	1-3	3
1	1-2	2	0	1-3	2	11	1-4	3
2	1	1	1	17-25	18	12	1-4	4
3	12-18	16	2	3	3	13	3-5	5
4	3-4	3	3	1	1	14	1-4	2
5	31-44	39	4	3-6	5			

TABLE 17. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Abdomen VI			Abdomen VII (Cont.)			Spiracular Lobe	
0	1-3	2	4	1-2	1	1	8-12	10
1	15-22	20	5	8-14	10	2	7-11	9
2	1-2	1	6	2-4	3	3	0	0
3	1	1	7	4-7	5	4	1	1
4	1	1	8	4-6	4	5	1	1
5	9-12	11	9	4-9	7	6	2-4	3
6	3-4	3	10	5-8	5	7	1-2	2
7	4-6	5	11	2-4	2	8	5-8	7
8	2-3	2	12	2-3	2	9	5-7	7
9	8-9	9	13	3-5	3	10	1	1
10	2-4	3				11	1	1
11	1-4	3		Abdomen VIII		12	1	1
12	2-4	3				13	1	1
13	6-10	9	0	1-2	1			
14	1-3	2	1	1-2	1		Abdomen X	
			2	8-14	11			
	Abdomen VII		3	10-14	12	1	1	1
			4	3-5	4	2	18-22	21
0	1-3	2	5	5-7	6	3	6-14	8
1	16-21	19	14	2-3	3	4	9 pairs	9
2	2-4	3						
3	1-3	3						

TABLE 18. Setal branching on larvae of *Anopheles (Cellia) pampanai* (counts from 10 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Antenna			Head (Cont.)			Prothorax (Cont.)	
1	1	1	8	3-6	5	4	12-14	14
2	1	1	9	4-8	7	5	37-47	41
3	1	1	10	3-5	3	6	1	1
4	5-7	6	11	39-48	48	7	25-30	26
5	1	1	12	6-10	8	8	34-41	37
6	1	1	13	7-11	8	9	7-12	9
			14	8-15	11	10	1	1
	Head		15	8-10	8	11	2-4	4
			20	16-20	18	12	1	1
1	1	1				13	5-9	6
2	1	1		Prothorax		14	3-5	4
3	1	1						
4	1	1	0	1	1		Mesothorax	
5	11-14	13	1	16-27	23			
6	12-16	15	2	14-20	16	1	24-30	25
7	17-22	19	3	1	1	2	1-3	1

TABLE 18. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Mesothorax (Cont.)			Abdomen II (Cont.)			Abdomen IV (Cont.)	
3	1	1	1	16-21	18	12	3-5	3
4	2-3	2	2	4-6	5	13	4-6	4
5	1	1	3	1	1	14	1-2	2
6	3-5	4	4	4-8	6			
7	3-5	3	5	3-5	4		Abdomen V	
8	20-29	24	6	26-35	28			
9	1	1	7	27-36	33	0	1	1
10	1	1	8	2-4	3	1	17-20	20
11	1	1	9	6-10	9	2	1-2	1
12	1	1	10	3-4	4	3	1-2	1
13	7-12	8	11	3-4	3	4	1-3	3
14	9-16	13	12	3-5	4	5	4-9	7
			13	7-13	9	6	2-3	3
	Metathorax		14	1-2	2	7	5-8	6
						8	3-4	3
1	2-3	3		Abdomen III		9	5-8	6
2	1	1				10	3	3
3	13-20	16	0	1	1	11	2-4	4
4	2-4	3	1	16-21	20	12	3-5	4
5	35-44	40	2	3-5	3	13	4-5	4
6	3-5	3	3	1	1	14	1-3	1
7	30-36	32	4	3-4	3			
8	31-35	34	5	3-5	4		Abdomen VI	
9	3-7	4	6	19-24	22			
10	1	1	7	3-6	6	0	1-2	1
11	1	1	8	2-4	3	1	16-20	19
12	2-4	3	9	5-7	6	2	1	1
13	3-4	4	10	3-5	3	3	1	1
			11	2-4	3	4	1	1
	Abdomen I		12	3-5	3	5	7-11	9
			13	6-12	8	6	2-3	3
1	12-18	15	14	1-2	2	7	4-5	4
2	2-4	3				8	2-3	3
3	1	1		Abdomen IV		9	6-7	7
4	4-8	6				10	3-4	3
5	3-5	4	0	1	1	11	3-5	3
6	27-31	29	1	16-22	20	12	3-4	3
7	26-34	27	2	1	1	13	7-12	10
9	5-7	6	3	2-5	3	14	1-2	1
10	3-5	3	4	3-5	3			
11	3-5	4	5	3-6	4		Abdomen VII	
12	3-5	4	6	3	3			
13	7-10	7	7	5-8	5	0	1-2	1
			8	2-4	3	1	16-19	18
	Abdomen II		9	4-6	5	2	2-4	3
			10	3-4	3	3	3	3
0	1	1	11	2-5	4	4	1	1

TABLE 18. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Abdomen VII (Cont.)			Abdomen VIII (Cont.)			Spiracular Lobe		
5	6-11	10	2	10-13	12	7	2	2
6	4-6	4	3	6-12	9	8	4-8	5
7	4-6	5	4	3-5	4	9	3-6	5
8	4-6	5	5	5-3	6	10	1	1
9	6-11	8	14	1-2	2	11	1	1
10	5-8	7				12	1	1
11	2-3	3	Spiracular Lobe			13	1	1
12	2-3	2						
13	3-5	4	1	6-9	8	Abdomen X		
			2	5-8	8			
Abdomen VIII			3	0	0	1	1	1
			4	1	1	2	17-20	19
0	1	1	5	1	1	3	8-12	11
1	1-2	1	6	2-3	3	4	9 pairs	9

TABLE 19. Setal branching on larvae of *Anopheles (Cellia) varuna* (counts from 12 or more setae)

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
Antenna			Prothorax			Mesothorax (Cont.)		
1	1	1	0	1	1	8	20-26	21
2	1	1	1	21-29	23	9	1	1
3	1	1	2	16-21	20	10	1	1
4	6-9	8	3	1-2	1	11	1	1
5	1	1	4	13-18	14	12	1-2	2
6	1	1	5	25-40	34	13	5-11	6
			6	1	1	14	10-16	13
Head			7	25-34	30			
			8	34-41	39	Metathorax		
1	1	1	9	10-15	12			
2	1-4	3	10	1	1	1	2-3	2
3	1-2	1	11	3-5	3	2	1	1
4	1	1	12	1	1	3	15-23	18
5	14-17	16	13	3-5	5	4	2-5	3
6	15-18	16	14	3-6	4	5	37-44	42
7	18-20	19				6	4-5	4
8	3-9	6	Mesothorax			7	34-39	35
9	3-7	5				8	33-41	37
10	3-5	3	1	23-33	29	9	6-9	6
11	43-50	44	2	1-2	1	10	1	1
12	4-7	6	3	1	1	11	1	1
13	6-8	6	4	3-5	4	12	3-5	4
14	6-9	7	5	1	1	13	3-4	3
15	7-11	10	6	3-5	4			
20	6-10	8	7	3-4	3			

TABLE 19. Continued

Seta	Range	Mode	Seta	Range	Mode	Seta	Range	Mode
	Abdomen I			Abdomen IV			Abdomen VI (Cont.)	
1	13-21	15	0	1-2	1	12	2-4	3
2	2-3	3	1	19-26	20	13	9-13	11
3	1	1	2	1	1	14	1-2	1
4	5-8	6	3	2-4	3			
5	4-6	5	4	2-3	3		Abdomen VII	
6	28-35	31	5	4-7	5			
7	28-35	32	6	3	3	0	1-2	2
9	4-5	5	7	5-8	6	1	17-19	19
10	3-5	4	8	2-3	2	2	2-4	3
11	4-7	4	9	3-5	4	3	2-3	3
12	4-5	4	10	2-3	3	4	1	1
13	7-10	9	11	2-4	3	5	9-11	11
			12	2-4	3	6	4-6	4
	Abdomen II		13	4-6	4	7	4-5	4
			14	1-2	1	8	4-7	5
0	1-2	1				9	5-10	8
1	17-23	22		Abdomen V		10	5-9	6
2	3-5	5				11	2-3	3
3	1	1	0	1-2	1	12	1-3	2
4	5-7	5	1	19-22	20	13	3-5	4
5	4-6	4	2	1	1			
6	28-38	37	3	1	1		Abdomen VIII	
7	33-40	35	4	1-3	3			
8	2-4	2	5	6-9	8	0	1	1
9	6-10	8	6	3	3	1	2	2
10	2-5	4	7	5-8	6	2	11-14	13
11	2-4	3	8	2-3	2	3	9-15	12
12	3-5	4	9	5-8	7	4	3-5	4
13	9-12	10	10	2-4	3	5	4-7	5
14	1-2	1	11	2-4	3	14	1-2	1
			12	2-4	3			
	Abdomen III		13	3-5	4		Spiracular Lobe	
			14	1-2	1			
0	1	1				1	6-9	8
1	19-23	22		Abdomen VI		2	7-12	9
2	3-4	3				3	0	0
3	1-2	1	0	1-3	1	4	1	1
4	3-4	3	1	16-22	19	5	1	1
5	4-6	6	2	1	1	6	2-3	2
6	19-24	23	3	1	1	7	1-2	2
7	4-9	7	4	1	1	8	5-8	7
8	2-3	2	5	7-11	9	9	4-9	6
9	4-6	5	6	2-3	3	10	1	1
10	2-4	3	7	4-5	5	11	1	1
11	2-4	3	8	2-3	3	12	1	1
12	3	3	9	7-9	7	13	1	1
13	3-5	5	10	2-4	3			
14	1-2	1	11	3-4	3			

TABLE 19. Continued

Seta	Range	Mode
	Abdomen X	
1	1	1
2	17-21	19
3	9-13	13
4	9 pairs	9

CONSPECTUS OF TAXONOMIC CHANGES

CHANGES IN TAXONOMIC STATUS

CHANGE IN AUTHORSHIP

LECTOTYPE SELECTIONS

INDEX

Valid names are in roman type, while synonyms, rejected names and non-valid combinations are italicized. Italicized pages designate the primary treatment of the species. The letters "k" or "t" after a page number indicate a key or table, respectively. Numbers in parentheses refer to figures for that species.