ILLUSTRATED KEYS TO THE MOSQUITOES OF THAILAND VI. TRIBE AEDINI

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Abstract. Illustrated keys for the identification of the fourth-instar larvae and adult females of the mosquito species of tribe Aedini in Thailand are presented, along with the geographic distribution of the species and the known habitats of their immature stages. The keys are the first to encompass the recent revisionary studies of tribe Aedini. One hundred and seventy-five species of Aedini belonging to 38 genera and 18 subgenera are recognized in Thailand. Two species of genus *Armigeres*, two of genus *Collessius*, and one of genus *Downsiomyia* are undescribed. *Himalaius simlensis* [formerly *Aedes* (*Finlaya*) *simlensis*], *Hopkinsius* (*Yamada*) *albocinctus* [formerly *Aedes* (*Finlaya*) *albocinctus*], *Downsiomyia nipponica* and *Downsiomyia saperoi* [formerly species of *Aedes* (*Finlaya*)], and *Hulecoeteomyia pallirostris* [formerly *Ochlerotatus* (*Finlaya*) *pallirostris*] are new country records. *Aedimorphus* (formerly a subgenus of *Aedes*), *Cancraedes*, and *Rhinoskusea* (formerly subgenera of *Ochlerotatus*) are recognized as genera, and genus *Petermattinglyius* includes species previously included in *Diceromyia* (formerly a subgenus of *Aedes*) in Thailand. *Heteraspidion, Huangmyia, Stegomyia*, and *Xyele* are newly recognized subgenera of genus *Stegomyia* (formerly a subgenus of *Aedes*), which includes eight species without subgeneric placement. Two unidentified and unplaced species were discovered in Thailand.

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INTRODUCTION

The purpose of the present work is to provide taxonomic information and illustrated keys for the identification of the adult females and fourth-instar larvae of the mosquito species of tribe Aedini that occur in Thailand. Previous publications of this series include an introduction and keys for recognizing the mosquito genera of Thailand (Section I, Rattanarithikul *et al*., 2005a), keys for the identification of species of genera *Culex* and *Lutzia* (Section II, Rattanarithikul *et al*., 2005b), *Aedeomyia*, *Ficalbia*, *Mimomyia*, *Hodgesia*, *Coquillettidia*, *Mansonia*, and *Uranotaenia* (Section III, Rattanarithikul *et al*., 2006a), *Anopheles* (Section IV, Rattanarithikul *et al*., 2006b), and *Orthopodomyia*, *Kimia*, *Malaya*, *Topomyia*, *Tripteroides*, and *Toxorhynchites* (Section V, Rattanarithikul *et al*., 2007). This is the sixth and final publication in the series, and the first attempt to provide keys to all species of Aedini that are known to occur in the country.

Thurman (1959) is the earliest publication that contains references to the aedine mosquitoes of Thailand. The author provided a checklist of 89 species assigned to five genera, namely *Aedes*, *Armigeres*, *Ayurakitia*, *Heizmannia*, and *Udaya*. Thirty-two years later, Harrison *et al*. (1991) listed 155 species assigned to four genera: *Aedes*, *Armigeres*, *Heizmannia*, and *Udaya*. As a result of further discoveries and taxonomic changes, Rattanarithikul *et al*. (2005a) listed 163 species as members of eight genera, *i.e. Aedes*, *Armigeres*, *Ayurakitia*, *Heizmannia*, *Ochlerotatus*, *Udaya*, *Verrallina*, and *Zeugnomyia*, and Reinert *et al*. (2005) listed 162 species classified in 26 genera: *Alanstonea*, *Armigeres*, *Ayurakitia*, *Bothaella*, *Christophersiomyia*, *Diceromyia*, *Downsiomyia*, *Edwardsaedes*, *Finlaya*, *Fredwardsius*, *Gilesius*, *Heizmannia*, *Isoaedes*, *Kenknightia*, *Lorrainea*, *Mucidus*, *Neomelaniconion*, *Ochlerotatus*, *Paraedes*, *Rhinoskusea*, *Scutomyia*, *Stegomyia*, *Tanakaius*, *Udaya*, *Verrallina*, and *Zeugnomyia.*

The reclassification of tribe Aedini began with the removal of *Verrallina*, *Ayurakitia*, and *Ochlerotatus* from the composite genus *Aedes* (Reinert, 1999, 2000b, 2000c, respectively). This was followed by a series of phylogenetic analyses of Aedini (Reinert *et al*., 2004, 2006, 2008, 2009; Harbach, 2007b) that resulted in the formal recognition of 80 genera within the tribe. Thirty-eight of the genera (48% of the aedine genera of the world) include species that occur in Thailand. The 175 Thai species recognized herein belong to genera *Aedimorphus*, *Alanstonea*, *Armigeres* (subgenera *Armigeres* and *Leicesteria*), *Ayurakitia*, *Borichinda*, *Bothaella*, *Bruceharrisonius*, *Cancraedes*, *Christophersiomyia*, *Collessius* (subgenera *Alloeomyia* and *Collessius*), *Danielsia*, *Downsiomyia*, *Edwardsaedes*, *Finlaya*, *Fredwardsius*, *Gilesius*, *Heizmannia* (subgenera

Heizmannia and *Mattinglyia*), *Himalaius*, *Hopkinsius* (subgenus *Yamada*), *Hulecoeteomyia*, *Isoaedes*, *Jihlienius*, *Kenknightia*, *Lorrainea*, *Mucidus* (subgenus *Mucidus*), *Neomelaniconion*, *Ochlerotatus* (subgenus *Empihals*), *Paraedes*, *Petermattinglyius* (subgenera *Aglaonotus* and *Petermattinglyius*), *Phagomyia*, *Rhinoskusea*, *Scutomyia*, *Stegomyia* (subgenera *Heteraspidion*, *Huangmyia*, *Stegomyia*, *Xyele*, and unplaced species), *Tanakaius*, *Tewarius*, *Udaya*, *Verrallina* (subgenera *Harbachius*, *Neomacleaya*, and *Verrallina*), and *Zeugnomyia*.

Many morphological characters previously used for the identification of aedine taxa were found to be unreliable and are not used in the keys presented here. However, many new characters, some listed by Reinert *et al*. (2004, 2006, 2008, 2009), and some elucidated by us during construction of the keys, are included. Although most species of Aedini in Thailand can be identified accurately with these keys, certain species remain difficult to identify because they lack differential characters. Male and female genitalia provide useful characters for separating species, but they require dissection and mounting on microscope slides. For this reason, only external anatomical characters are used in the keys for the identification of adult females. Characters were gleaned from specimens reared from larvae or pupae.

Diagnostic characters are highlighted on drawings and, whenever possible, were chosen so that they could be seen using a dissecting microscope (10–40x). The subregions of Thailand (Fig 1) were defined by Rattanarithikul *et al*. (2005a). The morphological terminology used in the keys follows Harbach and Knight (1980, 1982) and Harbach and Kitching (1998). The keys are structured like those of Harbach (1985). A list of important references to taxa in these keys is found in Table 1. Generic and subgeneric abbreviations listed in Table 2 are those of Reinert (2009e). A checklist of the known species of Aedini in Thailand, with new and old generic assignments, is given in Table 3.

SYSTEMATICS SPECIFIC TO THE THAI AEDINE FAUNA

The earliest important publications containing information on the Aedini of Thailand are Barraud and Christophers (1931), Barraud (1934), Causey (1937a,b), Colless (1958, 1959), Thurman (1954a,b), Thurman (1959), Macdonald (1960), Mattingly (1957, 1958a,b, 1959, 1960, 1961, 1970, 1971), Delfinado (1967, 1968), Tyson (1970), Huang (1972, 1977a,b, 1979), Abercrombie (1977), Knight (1968, 1978), Knight and Harrison (1988), Tanaka *et al*. (1979), Ramalingam (1987), Rattanarithikul and Harrison (1988), Harrison *et al*. (1991), Benjaphong and Rattanarithikul (1991), and Reinert (1970a,b,

1972, 1973a,b,c, 1974, 1976a,b, 1979, 1981, 1985, 1990a,b, 1999).

Reinert *et al.* (2005), based on taxonomic changes proposed by Reinert *et al*. (2004), listed the genera and species of tribe Aedini that were known at the time to occur in Thailand. Since then, additional generic-level taxa traditionally recognized as subgenera of *Aedes* Meigen were elevated to generic status by Reinert *et al*. (2006, 2008, 2009); thus, the aedine species currently known to occur in Thailand are assigned to the 38 genera listed above. *Alanstonea* Mattingly, *Bothaella* Reinert, *Christophersiomyia* Barraud, *Edwardsaedes* Belkin, *Fredwardsius* Reinert, *Isoaedes* Reinert, *Lorrainea* Belkin, *Neomelaniconion* Newstead, *Paraedes* Edwards, *Scutomyia* Theobald, and *Stegomyia* Theobald were previously treated as subgenera of *Aedes* and *Finlaya* Theobald, *Kenknightia* Reinert, *Mucidus* Theobald, and *Rhinoskusea* Edwards were previously treated as subgenera of *Ochlerotatus* (Rattanarithikul *et al*., 2005a). The species previously included in *Ochlerotatus* subgenus *Finlaya* are now classified in 10 genera: a new genus ***Tanakaius*** Reinert, Harbach & Kitching was described to accommodate *Oc*. (*Fin*.) *togoi* (Reinert *et al*., 2004); ***Downsiomyia*** Vargas was reinstated as a genus from synonymy with *Finlaya* for all species of the Niveus Group (Reinert *et al*., 2006; Reinert and Harbach, 2006); ***Finlaya*** was restricted to include species formerly included in the Kochi Group (Reinert *et al*., 2004, 2006; Reinert and Harbach, 2005); ***Hulecoeteomyia*** Theobald was resurrected from synonymy with *Finlaya* for species of the Chrysolineatus Group (Reinert *et al*., 2006); ***Phagomyia*** Theobald was resurrected from synonymy with ***Finlaya*** for the species of the Gubernatoris Group (Reinert *et al*., 2006); ***Collessius*** Reinert, Harbach & Kitching was established for the Pseudotaeniatus Group (Reinert *et al*., 2006), ***Gilesius*** for *Oc*. (*Fin*.) *pulchriventer* (Reinert *et al*., 2006), ***Himalaius*** for *Oc*. (*Fin*.) *gilli* (Reinert *et al*., 2006); ***Hopkinsius*** Reinert, Harbach & Kitching was established for *Oc*. (*Fin*.) *albocinctus* (Reinert *et al*., 2006), ***Jihlienius*** Reinert, Harbach & Kitching for *Oc*. (*Fin*.) *unicinctus* (Reinert *et al*., 2006); and ***Danielsia*** Theobald was resurrected from synonymy with *Finlaya* for species of the Albotaeniatus Group (Reinert *et al*., 2008). Additionally, ***Bruceharrisonius*** [originally described as a subgenus of *Ochlerotatus* by Reinert, 2003a] was raised to generic rank (Reinert *et al*., 2006), *Oc*. subgenus ***Empihals*** was introduced for *Oc*. *vigilax* (Reinert *et al*., 2008), and *Aedes pseudonummatus* was transferred from *Diceromyia* to the new genus ***Tewarius*** (Reinert, 2006).

Reinert *et al.* (2004, 2006, 2008) examined the higher-level relationships within tribe Aedini, *Finlaya* (and allied taxa), and *Ochlerotatus* (and allied taxa), respectively. More recently, the comprehensive phylogenetic study of tribe Aedini by Reinert *et al.* (2009) resulted in a more natural classification of species traditionally placed in *Aedimorphus*,

Diceromyia, and *Stegomyia*. Subgenera ***Aedimorphus*** and ***Cancraedes*** of *Aedes* were raised to generic rank. Oriental species of *Diceromyia* are now placed in genus ***Petermattinglyius*** Reinert, Harbach & Kitching, which is divided into subgenera ***Aglaonotus*** Reinert, Harbach & Kitching and ***Petermattinglyius*** Reinert, Harbach & Kitching. Seven new subgenera were proposed for species of *Stegomyia*, of which ***Heteraspidion*** Reinert, Harbach & Kitching (type species *Stegomyia annandalei* Theobald), ***Huangmyia*** Reinert, Harbach & Kitching (type species *Stegomyia mediopunctata* Theobald), and ***Xyele*** Reinert, Harbach & Kitching (type species *Stegomyia desmotes* Giles) include species in Thailand. Many species of *Stegomyia* are without subgeneric placement, *e.g.* species of the W-alba and Scutellaris Subgroups of the Scutellaris Group.

The aedine genera and species, their authorship, and distributions are listed in Table 4.

ROLE OF AEDINE MOSQUITOES AS DISEASE VECTORS IN THAILAND

Mosquito-borne diseases continue to be a leading cause of morbidity and mortality throughout Thailand and many of these are transmitted by aedine species. The Ministry of Public Health of Thailand historically attributed more fatalities to malaria than to dengue virus infections. However, from 2004 to 2008 there was over a twofold increase in the number of reported dengue virus related deaths and more than a twofold decrease in deaths attributable to malaria (Fig 2) (Ministry of Public Health Thailand, 2009). Furthermore, in 2008 the total number of reported dengue virus cases was more than three times the number of reported malaria cases (Fig 3). While malaria remains an important public health concern in border areas, dengue fever and dengue hemorrhagic fever (DHF) are arguably the most significant mosquito-borne diseases in Thailand. In addition to the increasing dengue burden, a chikungunya virus epidemic recognized in southern Thailand in 2008 resulted in an estimated 48,000 cases in 2009 (Fig 3). Given the importance of aedine species in the transmission of these two viruses, this group of mosquitoes is of tremendous medical significance in the region.

In addition to the major threats of dengue and chikungunya viruses, there are numerous mosquito-borne diseases with low levels of endemicity but which are of potential significance given the recent patterns of emergence of novel health threats and the re-emergence of others. Immunization of large sectors of the public against Japanese encephalitis virus has significantly interrupted transmission to humans, yet the

virus remains endemic through much of the region in a mosquito-animal cycle. Similarly, filarial infections are a relatively minor public health concern. Finally, a number of other arboviruses, including Zika, West Nile (Kunjin), Sindbis, and Wesselsbron viruses, have been reported from Thailand, and are worth mentioning based on the recent epidemics of viruses such as Zika, chikungunya, and West Nile. The adaptive potential of these RNA viruses has facilitated enhanced vector competence of certain mosquito species,*e.g. St. albopicta* and chikungunya virus (Schuffenecker *et al*., 2006; Tsetsarkin *et al*., 2007), underscoring the plasticity of transmission cycles. Rapidly changing epidemiological landscapes, driven partly by urbanization and rapid spread of viruses through international travel, increases the potential for emergence of other epidemiologically important arboviruses, and their associated novel vectors.

Dengue

The four dengue virus serotypes severely impact the health of children annually in both rural and urban areas of Thailand. In certain years, dengue and DHF have become very prominent and the total impact of these two disease entities may cause morbidity expressed in the thousands and mortality expressed in the hundreds. Dengue viruses are transmitted by aedine species of genus *Stegomyia*. Two key species are involved in the transmission of these viruses, *St. aegypti* and *St. albopicta.* The first species, an exceptional vector of dengue viruses, was apparently introduced into Malaysia and Thailand near the beginning of the 20th Century (Leicester, 1908; Daniels, 1908; Scanlon and Esah, 1965), and is now the principal species involved in urban transmission of dengue viruses and associated DHF cases in humans. *Stegomyia aegypti* also occurs in rural and forested areas in both artificial and natural containers very near human populations (Harrison *et al*., 1972). *Stegomyia albopicta* is an indigenous forest species in Southeast Asia that has adapted to inhabiting natural and artificial containers in rural villages and the perimeter of major cities. This species may be more significant in low-level maintenance transmission of dengue viruses in rural populations in Thailand.

Chikungunya

Chikungunya fever outbreaks have occurred periodically in Thailand and both *St. aegypti* and *St. albopicta* are considered vectors. In mid-2009, an outbreak of chikungunya fever affected the southern (peninsular) region of Thailand with thousands of cases (Centers for Disease Control and Prevention, 2009). Although *St. aegypti* is the classic vector of this virus, the occurrence of a single mutation at position 226 of the E1 gene (A226V - an alanine to valine substitution) has been associated with enhanced

specificity of this virus for *St. albopicta* (Tsetsarkin *et al*., 2007). This adaptive mutation apparently provides a fitness advantage for transmission of this virus by *St. albopicta* (de Lamballerie *et al*., 2009). *Stegomyia albopicta* is widely distributed in all subregions of Thailand and is abundant in much of the country. It also has a predilection for oviposition in natural and artificial containers in partially shaded habitats under bamboo and fruit orchards near human settlements. This is particularly significant as orchards are increasing dramatically in Thailand in response to the elimination of forests, and this will favor increased numbers of *St. albopicta* (Vanwambeke *et al*., 2007). To date, the majority of chikungunya cases from the ongoing outbreak in Thailand have occurred in areas with a predominance of *St. albopicta*, and unpublished results of initial virus sequencing performed at the Armed Forces Research Institute of Medical Sciences (AFRIMS) indicates that the current cases are being caused by viruses with the A226V mutation.

Stegomyia albopicta has to date been considered an easily identifiable species. This is no longer true! It is now evident that traditional characters used to identify the species - the pale tip of the palpi, the narrow longitudinal silver stripe on the scutum, and broad pale bands on the hindtarsomeres - are shared with five other *Stegomyia* species in Thailand: *St. malayensis*, *St. novalbopicta*, *St. patriciae*, *St. pseudalbopicta*, and *St. seatoi*. Although most of these species prefer more rural areas, they are found near or in villages and orchards in natural and (occasionally) artificial containers in close association with humans. Accordingly, they are easily misidentified as *St. albopicta* if the most recent keys are not used. Based on this complex taxonomic situation and the emerging role of *St. albopicta* in the transmission of chikungunya virus, public health workers, entomologists, and epidemiologists conducting disease and vector surveillance programs need to be aware of the morphological differences that distinguish these species. To our knowledge, nothing is known regarding the vector competence or vector capacity of these species for any of the arboviruses and the associated role they may play in the transmission of chikungunya virus.

In addition to similarity among adults of these six closely related species, misidentification of larvae is also likely. Readers should be aware that larvae of *St. seatoi* possess thoracic spines and comb scales that look like those of *St. aegypti*, and have been found with larvae of *St. aegypti* in both natural and artificial containers in Thailand. Because larvae of *St. aegypti* are often used as a key indicator for dengue risk, workers calculating larval indices should be aware of this similarity. Fortunately, *St. seatoi* has not been found in densely packed urban areas, but is found most often around rural villages and in orchards. The most reliable way to separate the *Stegomyia* species is to

collect both larvae and females and rear the larvae (preserving the exuviae) to adults to confirm the identity of the females collected separately.

Japanese encephalitis

The majority of cases of Japanese encephalitis are linked to a number of *Culex* species and aedine species are not considered significant vectors. However, Japanese encephalitis virus has also been transmitted (in laboratory studies) by both *St. aegypti* and *St. albopicta* and has been isolated from many members of tribe Aedini, including *Tanakaius togoi*, *St. aegypti*, *St. albopicta*, *Aedimorphus vexans*, and *Ochlerotatus vigilax* (Burke and Leake, 1989). While these species are currently of limited epidemiological significance, they should not be discounted as potentially relevant vectors given the rapidly changing epidemiological landscape of the arboviral diseases.

Other arboviruses

A number of other zoonotic arboviruses have been reported from Thailand, including Kunjin, Sindbis, Wesselsbron, and Zika viruses. These viruses are currently considered insignificant causes of morbidity, but this may simply reflect limitations in current health surveillance systems.

Kunjin virus. According to the latest report by the International Committee on Taxonomy of Viruses (ICTVdB Management, 2006) West Nile viruses can be classified as two subtypes designated as Kunjin and West Nile viruses. Southeast Asian isolates fall in the Kunjin subgroup. The incidence of Kunjin virus in Thailand is unknown but *Culex* species are the primary vectors. However, based on laboratory studies demonstrating transmission of closely related West Nile viruses (Sardelis *et al*., 2002), as well as evidence of natural infection, *St. albopicta* may be an important bridging vector. The potential role of both *St. aegypti* and *St. albopicta* in Kunjin virus epidemics is unknown.

Sindbis virus. Although *Culex* species are considered the primary vectors of Sindbis virus, *St. aegypti* and *St. albopicta* are competent vectors of the virus. Sindbis virus is thought to be broadly distributed in Asia (Dohm *et al*., 1995).

Wesselsbron virus. This virus has been detected in a number of aedine species, including *Aedimorphus mediolineatus* and *Neomelaniconion lineatopenne* in Thailand. *Stegomyia aegypti* is a proven laboratory vector, but it has yet to be associated with human disease in Thailand (Marchette, 1994).

Zika virus. This virus has been isolated from *St. aegypti* in Malaysia and serological evidence indicates exposure to the virus in Thai populations (Marchette *et al.,* 1969). In 2007, an outbreak of Zika virus was reported in Yap Island, Federated States of Micronesia (Duffy *et al*., 2009; Hayes, 2009), underscoring the dynamic nature of the geographic distribution of arboviruses.

Filariasis

One species of *Downsiomyia*, *Do. harinasutai*, is a recognized vector of the subperiodic strain of *Wuchereria bancrofti*, a filarial parasite of humans. This mosquito was described as a new species by Knight (1978), and incriminated as a vector of *W. bancrofti* by Gould *et al*. (1982) in forested areas of Kanchanaburi Province in western Thailand. Harinasuta *et al.* (1970) originally described the focus of human filarial cases in Kanchanaburi. More recently, another focus of this parasite was found in Tak Province (Khamboonruang *et al*., 1987). Adults of *Downsiomyia* species are difficult to distinguish because most specimens collected biting humans or in light traps are not in good condition. The scutum has an anterior patch of white scales that is easily rubbed off. Similar patches of white scales are present on species of *Phagomyia*, *Tewarius*, and several species of *Stegomyia*.

In conclusion, in addition to being the primary vectors of dengue and chikungunya viruses, there are anecdotal reports of aedine species supposedly involved in arbovirus transmission in Thailand. The significance of those reports are difficult to interpret as no further work was undertaken and the original findings have not been confirmed. However, as sampling and laboratory methods improve, it is likely that other aedine species will be found positive for arboviruses and other pathogens in Thailand. Also, with ongoing climatic and ecological changes, novel species may be found to be involved in either enzootic or epizootic outbreaks in humans or domestic animals, or directly involved in human-mosquito-human pathogens.

NOTES ON SYSTEMATICS, HABITATS, AND FEEDING BEHAVIOR OF AEDINI

The immature stages of mosquitoes occupy a spectrum of aquatic environments. They occur primarily in temporary or permanent bodies of ground water, but a large number of species occupy small collections of water in rock holes, leaf axils, and cavities of plants, *e.g*. *Allocasia*/*Colocasia*, *Pandanus*, ginger, pitcher plants, pineapple, bananas, hollow logs, stump holes, root holes, tree holes, bamboos, fallen leaves,

flower bracts, and fruit shells and husks. Some utilize artificial containers as well as normal ground-water habitats, including ponds, swamps, marshes, bogs, ground pools, puddles, flood pools, stream pools, stream margins, seepage, rice fields, wheel tracks and tire depressions, elephant and other animal footprints, salt marshes, mangrove and *Nipa* swamps, and crab holes. Many species live within a few meters of the ground whereas many sylvan species occur primarily in forest canopy. The different types of larval habitats associated with each genus and subgenus of Aedini that occur in Thailand are listed in Table 5. Certain species in a given genus or subgenus of Thai mosquitoes may occur in container habitats, whereas other species in that genus or subgenus may occur in ground water habitats. This overlapping of the two basic habitat types within a genus or subgenus is common, but caution must be used when interpreting habitats recorded on collection records as they may be inaccurate or misleading (Rattanarithikul *et al*., 2005a).

The immature stages of *Aedimorphus*, *Edwardsaedes*, *Lorrainea*, *Mucidus*, *Neomelaniconion*, *Paraedes*, *Petermattinglyius*, *Tewarius*, and *Verrallina* are commonly found in fresh ground-water habitats, whereas those of *Cancraedes*, *Lorrainea*, *Ochlerotatus*, *Rhinoskusea*, and *Tanakaius* normally occur in brackish ground-water pools, salt marshes, mangrove and *Nipa* swamps, and rock pools of coastal areas or near sea level. Species of both groups are sometimes found in freshwater containers. The immature stages of *Borichinda* and *Isoaedes* are only found in freshwater pools inside caves. *Alanstonea*, *Armigeres*, *Ayurakitia*, *Bothaella*, *Bruceharrisonius*, *Christophersiomyia*, *Collessius*, *Danielsia*, *Downsiomyia*, *Finlaya*, *Fredwardsius*, *Gilesius*, *Heizmannia*, *Himalaius*, *Hulecoeteomyia*, *Jihlienius*, *Phagomyia*, *Scutomyia*, *Stegomyia*, *Udaya*, and *Zeugnomyia* include species that utilize natural container habitats.

1. *Aedimorphus*

*Aedimorphu*s includes nine species in Thailand: *Am*. *alboscutellatus*, *Am*. *caecus*, *Am*. *culicinus*, *Am*. *mediolineatus*, *Am*. *orbitae*, *Am*. *pallidostriatus*, *Am. pampangensis*, *Am*. *pipersalatus*, and *Am*. *vexans*. Important features of *Aedimorphus* adults include: vertex with narrow curved decumbent scales medially, numerous erect forked scales that extend anteriorly to the ocular line, lower prealar area without a patch of broad white scales, subspiracular scales present (except *Am*. *orbitae*), paratergite usually with pale scales, hindtarsomeres entirely dark or with basal pale bands less than 0.25 length of tarsomere, and both hindungues simple; females with abdominal segment VIII narrow and completely retracted into segment VII, and usually long and narrow cerci. *Aedimorphus* larvae have seta 6-III branched, setae 4–6-C inserted on level or slightly anterior or posterior to seta 7-C, seta 5-C inserted at level of setae 4- and 6-C (except

Am. vexans), comb with fewer than 30 scales arranged in one to three irregular rows, each scale with median apical spine longer than lateral spicules or pointed with an even lateral and apical fringe.

The immature stages of *Aedimorphus* species are found in freshwater habitats. Larvae live in cavities, particularly those containing foul water or water with a high organic content. Habitats include swamps, marshes and bogs, pits and wells, stump ground pools, ground pools and puddles, flood pools, stream pools, seepage, rice fields, elephant and other footprints, wheel tracks/tire depressions, rock pools and rock holes, and artificial containers. Females of many species readily feed on humans and at times may be very serious pests. Other species prefer to feed on cattle and other animals.

2. *Alanstonea*

Alanstonea is a small genus of two species in Southeast Asia. Only one species, *Al. treubi* is found in Thailand. Adults of this species generally resemble *Armigeres* in size and color and in having the proboscis curved downward and laterally compressed, but can be distinguished by the absence of prescutellar and lower anterior mesepimeral setae. The larvae of *Alanstonea* have pecten spines, which are absent in *Armigeres*, and setae 4–6-C are inserted well anterior to seta 7-C.

The immature stages are found in pitcher plants. This species is recorded only from southern Thailand (Causey, 1937a). Nothing is known about the biology of the adults.

3. *Armigeres*

Armigeres, a large genus, is divided into two subgenera. Thirteen species of subgenus *Armigeres* and 16 species of subgenus *Leicesteria* are known to occur in Thailand. *Armigeres* adults are generally large and usually have the proboscis slightly curved downward and flattened laterally, and have two rows of scales between the eyes on the underside of the head. Postspiracular setae are present in species of subgenus *Armigeres* and absent in those of subgenus *Leicesteria*. *Armigeres* larvae are distinguished from larvae of all other aedine genera within their distribution by the absence of a pecten on the siphon.

The larvae of *Armigeres* occur in hollow logs, rock holes, tree holes, holes in stumps, bamboos, *Pandanus* axils, flowers of ginger plants, palm and banana stumps, coconut shells and husks, and artificial containers that contain organic matter. Adults occur primarily in forested or plantation areas and are mainly active during daytime and crepuscular

periods. Females of both subgenera include a number of species that readily attack and viciously bite humans. *Armigeres subalbatus* females are suspected of transmitting *Wuchereria bancrofti*. None of the species of *Leicesteria* are known to transmit filarial parasites.

4. *Ayurakitia*

Both known species of *Ayurakitia* occur in Thailand. *Ayurakitia* adults are easily distinguished from all other genera of tribe Aedini by the presence of silver ornamentation on the abdomen and mid- and hindfemora, and the absence of postspiracular setae. *Ayurakitia* larvae differ from the larvae of other aedine genera, except *Downsiomyia* and *Hopkinsius*, in having setae 4–6-C multiple branched and inserted slightly anterior or posterior to seta 7-C; comb scales with 19–36 scales, each with a long, strong median apical spine, arranged in two rows, the posterior with distinctly shorter scales.

Larvae of *Ayurakitia* have been collected in clear and colored fresh water in natural container habitats, including tree holes, bamboos, *Pandanus* axils, and banana stumps and axils. Adults have been collected in light traps and resting on tree trunks. Species of *Ayurakitia* are of no known medical or economic importance to humans.

5. *Borichinda*

This genus was introduced for a new species, *Bc. cavernicola*, discovered in a cave in northern Thailand. The adults of *Borichinda* have dense long narrow dark and pale falcate scales on the acrostichal and dorsocentral areas of the scutum, which in general appearance resemble the decumbent and erect scales of *Aedimorphus* species but differ in having a lower anterior mesepimeral seta. Larvae have setae 4- and 6-C inserted anterior to 7-C and fewer than 20 spinelike comb scales with basolateral denticles.

Borichinda larvae have only been found in a rimstone pool in Borichinda Cave, Doi Inthanon, Chiang Mai Province. Nothing is known about the bionomics of the adults.

6. *Bothaella*

Bothaella includes five species in the Oriental Region, principally in Southeast Asia. Two species are known to occur in Thailand. The adults are generally recognized by the following characters: decumbent scales of vertex largely broad, with a dorsomedian triangular patch of silvery scales, and erect scales at the back of head. *Bothaella* larvae are easily recognized by the presence of a well-developed seta 13-P, setae 4- and 6-C inserted far anterior to seta 7-C, and comb scales arranged in two or more rows, each

scale rounded or expanded apically and evenly fringed with fine spicules.

Bothaella larvae have been collected from rock pools and rock holes, occasionally from tree holes, bamboo stumps, and split bamboo. Adults have been collected biting humans, but they are not known to transmit pathogens of human diseases.

7. Bruceharrisonius

Bruceharrisonius is a small genus comprised of eight species in the Oriental and eastern Palaearctic Regions. Two of the species, *Br*. *christophersi* and *Br*. *greenii*, occur in Thailand. The adults of *Bruceharrisonius* are easily distinguished from the adults of other genera by having the maxillary palpus dark-scaled and patches or relatively broad stripes of narrow yellow scales on the acrostichal and dorsocentral areas, basal pale bands on hindtarsomeres 1–4 (both basal and apical pale bands on hindtarsomeres 1–3 in *Br*. *greeni*), decumbent scales of the vertex largely narrow, especially on the dorsomedian line, erect scales numerous, covering most of the dorsal surface of the head. Abdominal segment VII is laterally compressed, segment VIII is not completely retracted into segment VII, and the cerci are short and broad in females. Larvae have numerous comb scales arranged in a triangular patch; setae 4–6-C inserted posterior to seta 7-C; seta 13-C branched; seta 1-C not spiniform; seta 5-C branched; seta 7-C short, not reaching the base of seta 1-A; setae 5- and 6-C very long, extending far beyond the apex of the antenna; and pecten spines, with two or fewer strong basal denticles, not inserted close together.

Larvae of *Bruceharrisonius* species have been found in tree holes, bamboo stumps, bamboo cups, bamboo internodes, banana stumps, and occasionally in artificial containers, hollow logs, and rock pools. Adults of *Br*. *greenii* have been collected in light traps at night and biting humans during the day. Species of *Bruceharrisonius* are of no known medical importance to humans.

8. *Cancraedes*

Cancraedes includes 10 species in Southeast Asia and Sulawesi. Two species, *Ca*. *indonesiae* and *Ca*. *kohkutensis*, occur in Thailand. The adults are rather small, dark mosquitoes. They have largely broad decumbent scales on the vertex, erect scales at the back of the head, and vein 1A of the wing ends before or at the level of the base of the mediocubital crossvein. *Cancraedes* larvae are easily recognized in having distinct long denticles apically on the ventral margin of the pecten spines, short anal papillae,

and numerous comb scales arranged in a triangular patch.

Larvae of *Cancraedes* species have been found in crab holes and ground-pool habitats in mangrove swamp. Nothing is known about the biology of the adults other than having been collected from cattle pens one or two times.

9. *Christophersiomyia*

Christophersiomyia includes five species in the Oriental Region and the Solomon Islands. Three species occur in Thailand. The adults differ from *Bothaella* in having white scales on the postpronotum and scutum, and the proboscis has a median pale band or patch. Larvae generally resemble *Aedimorphus* but differ in having evenly spaced pecten spines on the siphon, the ventral brush without grid bars, and no precratal setae.

Christophersiomyia larvae have been found in rock pools, log holes, tree holes, and stump holes. Adults have been collected in light traps and biting humans. Nothing is known about their biology.

10. *Collessius*

Collessius includes nine species in the Oriental Region. Two species belonging to subgenus *Alloeomyia* and four in subgenus *Collessius* occur in Thailand. Adults of *Collessius* share many characters with *Bruceharrisonius* but the acrostichal and dorsocentral areas have distinct narrow lines of white or yellow scales. The larvae of *Collessius* are distinguished from those of all other aedine genera in Thailand by having multiple-branched setae 4–6-C arranged in a transverse row anterior to seta 7-C, comb scales rounded and evenly fringed, pecten spines evenly spaced, the siphon longer than segment X, seta 1-S inserted within or beyond the proximal 0.75 of the siphon, and seta 4-C inserted at the same level or anterior to seta 6-C.

The immature stages of *Collessius* species are usually found in rock pools, rock holes, and hollow logs, but also occur in tree holes, leaf axils, coconut shells, pits, wells, stream pools, and artificial containers. Females of some species are known to bite humans indoors and outdoors, *e.g. Co*. *pseudotaeniatus*, but nothing else is known about their biology.

11. *Danielsia*

Danielsia is a small genus with three species. Only one species, *Dn*. *albotaeniata*,

is found in Thailand. Adults of this species share many characters with *Christophersiomyia* but differ in having a large patch of white scales on the supraalar area that extends anteromesad to and is connected with the posterior margin of the acrostichal-dorsocentral scale-patch and laterally to a point above the base of the wing. Larvae of *Dn. albotaeniata* have setae 4- and 6-C inserted far anterior to seta 7-C; seta 1-A strongly developed, longer than the diameter of the antenna; thornlike comb scales with a stout median apical spine; a strong spinelike seta 1-S inserted on the distal half of the siphon; and long marginal spines on the saddle.

Larvae of *Dn. albotaeniata* are usually found in tree holes, stump holes, bamboo internodes, bamboo stumps, bamboo pots, split bamboo, ground pools, rock holes, and artificial containers. Adults have been collected in light traps at night and biting humans during the day, but nothing else is known about their bionomics and disease relations.

12. *Downsiomyia*

Sixteen species of *Downsiomyia* occur in Thailand. The adults are easily recognized by the following characters: head with largely broad decumbent scales on the vertex, erect scales at the back of the head; anterior 0.25 or more of the scutum covered with a patch of white scales; postspiracular area without scales; acrostichal and dorsocentral areas without setae. Larvae resemble *Ayurakitia* in having setae 4–6-C multiple branched and inserted slightly anterior or posterior to seta 7-C, but differ in having fewer comb scales arranged in a single row, and seta 12-I present.

Larvae of *Downsiomyia* species have been found in tree holes and occasionally in bamboo stumps, bamboo cups, split bamboo, and bamboo internodes. Adults have been collected biting humans during the day, early morning, and evening. Gould *et al.* (1982) indicated that *Do. harinasutai* [as *Aedes* (*Finlaya*) *harinasutai*] was the primary vector of subperiodic *Wuchereria bancrofti* in western Thailand.

13. *Edwardsaedes*

Edwardsaedes includes three species distributed in areas of the Australasian, Oriental, and eastern Palaearctic Regions. A single species, *Ed. imprimens*, occurs in Thailand. The adults are similar to those of *Aedimorphus* species but differ in having both hindungues toothed and the paratergite usually bare. Larvae are distinguished from *Aedimorphus* in having abdominal segment X completely ringed by the saddle, setae 2- and 3-X with multiple branches, and a large and darkly pigmented lateral spine

on the thoracic plates bearing setae 9–12-M,T.

Larvae of *Ed. imprimens* have been found in flood pools, ground pools, stream pools, and elephant footprints. Adults have been collected biting humans during day and night. Nothing else is known about the biology of this species in Thailand.

14. *Finlaya*

Two species of *Finlaya* are found in Thailand. The adults are black and white or yellow mosquitoes that are distinguished from those of all other aedine genera in having spotted wings and most tarsomeres with apical pale bands. Larvae have setae 4- and 6-C inserted far anterior to seta 7-C, comb scales arranged in a patch, long and narrow pecten spines with a complete ventral and/or dorsal fringe, seta 12-I present, and the ventral brush borne on a boss.

The immature stages of the two species have been collected mostly from *Pandanus* axils, bamboo cups, split bamboo, tree holes, and the axils of *Colocasia*, *Allocasia*, banana, pineapple, and *Nipa*. Adults have been taken biting humans close to larval habitats during day and night. They have also been captured in light traps and animal-baited traps. *Finlaya poicilia* is a known vector of *Wuchereria bancrofti* in the Philippines.

15. *Fredwardsius*

Fredwardsius vittatus is the only species of this genus. Adults of this species have narrow preapical, white-scaled bands on the fore-, mid-, and hindfemora, decumbent scales on the vertex that are narrow and curved, especially on the dorsomedian line, numerous erect forked scales on the vertex and occiput, three pairs of distinct white spots on the scutum, a bare prescutellar area, and hindtarsomere 5 pale-scaled. Larvae of *Fr. vittatus* exhibit the following characteristics: comb of segment VIII composed of 5–10 thornlike scales in an irregular row, seta 4-C slightly posteromesad and near seta 6-C, seta 5-C well separated and posterior to setae 4,6,7-C, ventral brush with lateral grid bars, and pecten with one or more spines widely spaced beyond seta 1-S.

Larvae of *Fr. vittatus* inhabit water in rock pools and rock holes and have occasionally been found in similar habitats, *e.g.* tree holes, bamboo pots, hoof prints, wells, and artificial containers. Adult females are reported to feed on humans. Laboratory studies have shown that the species is capable of transmitting yellow fever virus to monkeys (Philip, 1929). It was a suspected vector during a yellow fever epidemic in the Nuba

Mountains of Sudan (Lewis, 1943).

16. *Gilesius*

Two species belong to genus *Gilesius*, but only one of them, *Gi. pulchriventer*, occurs in Thailand. In general appearance, this species resembles species of *Bruceharrisonius*, but differs in having entirely dark tarsi, abdominal terga with basal silvery bands, and sterna with conspicuous patches of orange or yellow scales. Larvae resemble *Collessius* larvae but differ in having seta 4-C inserted at the same level or posterior to seta 6-C and seta 1-VIII longer than seta 2-VIII.

Larvae of *Gi. pulchriventer* have been found in ground pools, seepage pools, rock pools, artificial containers, tree stumps, tree holes, and holes in fallen trees. Adults have been collected biting humans at dusk. Nothing else is known about the bionomics of this species.

17. *Heizmannia*

Heizmannia is a large genus of 40 species in the Oriental Region. Thirty-four species belong to subgenus *Heizmannia* and six are included in subgenus *Mattinglyia*. Seventeen species occur in Thailand: 15 in subgenus *Heizmannia* and two in subgenus *Mattinglyia*. *Heizmannia* exhibit many of the characteristics found in other species of Aedini but are separable from those of other genera as follows. Adults have broad decumbent scales on the vertex and erect scales restricted to the back of the head, or occasionally absent, a broad, round scutum with bright metallic flat scales, and usually large and dorsally approximated antepronota. Larvae closely resemble the larvae of some other aedine genera in having setae 4- 5- and 7-C large and multiple branched, seta 6-C usually single or with two or three unequal branches, and some species have a mixture of spinelike and evenly fringed comb scales.

Heizmannia larvae usually inhabit tree holes, stump holes, bamboo stumps, bamboo cups, bamboo internodes, split bamboo, and banana stumps, but some species are occasionally found in ground pools, rock pools, and artificial containers. Adults bite humans in forests during the day. Nothing is known about their vector status in Thailand.

18. *Himalaius*

Himalaius includes two species, *Hi. gilli* and *Hi. simlensis*, both of which occur in Thailand. The adults generally resemble species of *Bruceharrisonius* but differ in having a patch of golden-white scales on the anterior 0.60 of the scutum and hindtarsomeres

1–3 with basal pale bands. Larvae of *Himalaius* are distinguished from larvae of *Bruceharrisonius* in having a spiniform seta 1-C, seta 5-C single, and a long seta 7-C that nearly reaches or extends beyond the base of seta 1-A.

Larvae of *Hi. gilli* have been found in tree holes. Nothing is known about the bionomics of the adults.

19. *Hopkinsius*

Hopkinsius includes two subgenera, *Hopkinsius* and *Yamada*, in the Oriental Region. Only *Hk. albocinctus* of subgenus *Yamada* occurs in Thailand. The adults of *Hk. albocinctus* resemble the adults of *Stegomyia* but are easily recognized by having the anterior 0.50-0.60 of the scutum pale-scaled, maxillary palpus dark-scaled at the apex, no pale scales on the lateral surfaces of the antennal pedicel, and hindtarsomeres 1–3 with basal pale bands. Larvae of *Hk. albocinctus* resemble larvae of *Downsiomyia* and *Ayurakitia*, but differ in having a fine fringe along the entire length of the pecten spines.

Larvae of *Hk. albocinctus* have been collected from tree holes. Nothing else is known about the bionomics of this species.

20. *Hulecoeteomyia*

Hulecoeteomyia includes 13 species in the Oriental and eastern Palaearctic Regions. Seven species occur in Thailand. Six species were recorded previously by Harrison *et al*. (1991) and Reinert *et al.* (2005). The presence of *Hl. pallirostris* in Thailand is reported here for the first time. Adults of *Hulecoeteomyia* resemble those of *Collessius* and *Tanakaius* in having conspicuous narrow stripes of yellowish scales on the anterior acrostichal and anterior and posterior dorsocentral areas, but they are distinguished by the presence of basal pale bands on hindtarsomeres 1–3. Larvae of *Hulecoeteomyia* also resemble larvae of *Collessius* and *Tanakaius*, but differ in having spinelike comb scales with lateral fringes or strong denticles (occasionally rounded with an even fringe in *Hl. harveyi* and *Hl. pallirostris*), and the siphon usually with one or more simple pecten spines inserted at or beyond the insertion of seta 1-S.

The immature stages of *Hulecoeteomyia* are commonly found in ground-pool habitats, crab holes, artificial containers, rock pools, hollow logs, tree stumps, tree holes, bamboo stumps, bamboo cups, bamboo internodes, split bamboo, *Pandanus*, *Nipa* and other leaf axils, ginger plants, pitcher plants, banana stumps, fallen leaves, and

coconut shells. Adults have been collected biting humans. Nothing else is known about the bionomics of *Hulecoeteomyia* species or their vector status in Thailand.

21. *Isoaedes*

Isoaedes cavaticus is the only species in this genus. Adults resemble *Borichinda cavernicola* but can be separated by having the thoracic pleura uniformly pale, the scutum entirely dark-scaled, narrow scales on the midlobe of the scutellum, and the absence of postspiracular and subspiracular scales. Larvae are distinguished from *Bc. cavernicola* in having numerous comb scales arranged in a patch, the distal pecten spines more widely spaced, and seta 1-S single or double.

Larvae of *Ia. cavaticus* have only been found in two widely separated caves in Kanchanaburi Province. Nothing is known about the biology of this species.

22. *Jihlienius*

Of the three known species of *Jihlienius*, only *Ji. unicinctus* occurs in Thailand. The adults are generally recognized by the following characters: largely broad decumbent scales on the vertex, erect scales restricted to the back of the head; entirely dark-scaled proboscis; presence of mesepimeral, upper proepisternal, and postpronotal scales; absence of anterior acrostichal setae; scutum with white-scaled patches covering the acrostichal and dorsocentral areas that broaden into a triangular patch at the juncture of the prescutal suture and extend to the caudal margin of the scutum; and the hindtarsus dark-scaled except for a basal pale band on tarsomere 1. Larvae have a distinct median labral plate separated from the dorsal apotome by a well-developed suture; seta 1-C stout and spiniform; seta 4-C inserted at the same level as seta 6-C; seta 4-P usually single; seta 12-I present; and comb scales arranged in a patch, the scales evenly fringed with a slightly longer median apical element.

Larvae of *Ji. unicinctus* have been collected from bamboo stumps and tree holes. Nothing else is known about the bionomics of this species.

23. *Kenknightia*

Kenknightia comprises 12 species in Southeast Asia, but only two species occur in Thailand. The adults are easily recognized by the following characters: decumbent scales of the vertex largely broad, erect scales restricted to the back of head, postpronotum covered with overlapping broad silvery scales; paratergite with scales, and the tarsi of

all legs entirely dark-scaled. Larvae are distinguished from *Bruceharrisonius* larvae in having setae 5- and 6-C not extending beyond the apex of the antenna and relatively close-set pecten spines, each with 3–5 strong basal denticles.

Larvae of *Kenknightia* in Thailand have been collected from artificial containers, rock pools, stump holes, tree holes, bamboo stumps, split bamboo, *Colocasia* axils, and coconut shells. Nothing is known about the biology of the adults.

24. *Lorrainea*

Lorrainea includes five species variously distributed in countries from Thailand and the Philippines southward and eastward to the Solomon Islands, but only *Lo*. *amesii* and *Lo*. *fumida* are found in Thailand. The adults resemble the adults of *Cancraedes* but mesepimeral and upper proepisternal scales are present, postpronotal scales and lower anterior mesepimeral setae are absent, all lobes of the scutellum are covered with broad dark scales, and the alula of the wing has broad scales. Larvae resemble *Finlaya* larvae but seta 12-I is absent, seta 1-S is single, and the ventral brush is borne on a grid.

Lorrainea larvae have been found in mangrove and *Nipa* swamps, crab holes, rock pools, hollow logs, root holes, tree holes, and stump holes. Nothing is known about the biology of the adults.

25. *Mucidus*

Mucidus includes 14 species in the Afrotropical, Australasian, and Oriental Regions. Two species are found in Thailand. The adults are generally large yellow, white, and brown mosquitoes with a shaggy appearance; the wing membrane is clouded at the radiomedial crossvein, the base of vein R_{4+5}, and the mediocubital crossvein. *Mucidus* larvae are very large and easily recognized. Their mouth brushes are modified for predation and the ventral brush is borne on a boss that extends the entire length of segment X.

The larvae of all *Mucidus* species are predacious. They feed mainly on the larvae of other mosquito species. Larvae have been collected in flood pools containing floating leaves. Adults have been collected while feeding on humans. Species of *Mucidus* are not known to be of medical importance.

26. *Neomelaniconion*

Species of *Neomelaniconion* predominantly occur in the Afrotropical Region. One

species, *Ne. lineatopenne*, extends through the Oriental Region, including Thailand, and southward into Australia. Adults of *Ne. lineatopenne* have conspicuous broad lateral stripes of yellow scales on the scutum and a lower anterior mesepimeral seta is present. Larvae resemble *Paraedes* larvae but seta 5-C is inserted posterior to setae 4- and 6-C. Larvae of *Ne. lineatopenne* are distinguished from *Verrallina* larvae by the character of the comb scales.

Larvae of this species have been found in ditches, ground pools, flood pools, rice fields, elephant footprints, and occasionally artificial containers. Adults have been collected biting humans and in animal-baited traps. Nothing else is known about the bionomics of the species.

27. *Ochlerotatus*

Ochlerotatus (*Empihals*) *vigilax* is the only species of this genus in Thailand. Both adults and larvae resemble those of *Aedimorphus*. Adults can be separated by the following characters: lower prealar area with a patch of broad white scales, subspiracular scales absent, hindtarsomeres with broad basal pale bands that are 0.25 or more the length of the tarsomeres. Larvae differ in having seta 4-C inserted closer to seta 6-C than to seta 5-C, pecten spines evenly spaced, and short anal papillae that are shorter than half the length of the saddle.

Larvae of *Oc. vigilax* are found primarily in brackish water in mangrove swamps and salt marshes. They have been found in freshwater ground pools, ponds, ditches, pits or wells, flood pools, and rock pools. Adults have been collected biting humans and animals. Nothing else is known about the bionomics of this species in Thailand.

28. *Paraedes*

Paraedes includes eight species distributed in the Oriental Region from India and Sri Lanka to the Philippines. Two species of the genus, *Pr. ostentatio* and *Pr. thailandensis*, are recognized in Thailand. Adults resemble *Aedimorphus* adults but acrostichal setae are usually absent, the tarsi are entirely dark-scaled, the scutum has a median stripe of golden scales on the acrostichal area, and similar patches of scales on the dorsocentral areas that extend from the scutal angle and supraalar area to near the median stripe. Larvae are separated from *Aedimorphus* larvae in having seta 5-C inserted on level with setae 4- and 6-C, seta 6-III single, comb scales arranged in a single row, and the apical 0.4 of the siphon heavily pigmented.

Paraedes larvae have been found in elephant footprints, wheel tracks, and freshwater crab holes. Adults have been collected biting humans and resting in bamboo groves. Little else is known about the bionomics of *Paraedes* species.

29. *Petermattinglyius*

Petermattinglyius includes five species, four in the nominotypical subgenus and one in subgenus *Aglaonotus*. Four of the five species occur in Thailand: *Pe. whartoni* of subgenus *Aglaonotus* and *Pe. franciscoi*, *Pe. iyengari*, and *Pe*. *scanloni* of subgenus *Petermattinglyius*. Adults of *Petermattinglyius* are easily recognized by the presence of distinctive pale bands or patches on the fore-, mid-, and hindfemora, the unornamented scutum, and wings entirely dark-scaled or with some pale scales. Larvae of *Petermattinglyius* are distinguished from the larvae of other aedine genera in having setae 4- and 6-C inserted anterior to seta 7-C and a comb with few scales arranged in one or two rows. The comb scales are blunt with a rounded apex (except in *Pe*. *whartoni* larvae, which have apically pointed comb scales). Seta 1-S is single in most species of the genus.

The immature stages of *Petermattinglyius* have been found in fresh, colored water in large and small split bamboo, bamboo internodes, bamboo stumps and bamboo cups or pots, tree holes, and the hollow of a log lying on the ground. Females have been collected in human-baited traps and biting humans. Adults have been collected in light traps and resting in houses. Species of *Petermattinglyius* are not known to be involved in the transmission of pathogens.

30. *Phagomyia*

Phagomyia includes 16 species that occur primarily in the Oriental Region. Five species are present in Thailand. Adults generally resemble *Christophersiomyia*, *Downsiomyia*, and *Jihlienius* in having a white scale-patch covering the anterior 0.30–0.70 of the acrostichal, dorsocentral, and scutal fossal areas, and the hindtarsomeres with both basal and apical pale bands. Larvae resemble those of *Jihlienius*, but seta 1-C is slender or stout and spiniform, the median labral plate is indistinguishably fused with the dorsal apotome, seta 4-C is inserted slightly posterior to seta 6-C, seta 7-C is inserted far posterior to the base of the antenna, and the comb scales are rounded and evenly fringed.

Larvae of *Phagomyia* are commonly found in rock pools, rock holes, tree holes,

stump holes, bamboo stumps, bamboo pots, bamboo internodes, split bamboo, and occasionally in artificial containers. Adults have been collected biting humans. Species of *Phagomyia* are not known to be vectors of pathogens in Thailand.

31. *Rhinoskusea*

Rhinoskusea includes four species in the Oriental Region, but only *Rh. longirostris* occurs in Thailand. Adults are separated from *Cancraedes* adults by the presence of acrostichal setae and the absence of anterior lower mesepimeral setae, the alula of the wing has narrow scales, and vein 1A is long, ending well beyond the furcation of crossvein mcu and vein CuA. Larvae resemble *Cancraedes* larvae but differ in having seta 1-S inserted near the apex of the siphon, and the pecten spines are without long denticles on their ventral margins.

Rhinoskusea longirostris larvae are found primarily in brackish water in mangrove swamps and salt marshes, ground pools and crab holes near sea level. Adults have been collected biting humans and in net traps with human bait. Nothing else is known about the biology of this species.

32. *Scutomyia*

Scutomyia includes nine species in the Oriental and Australasian Regions, but only one species, *Sc. albolineata*, occurs in Thailand and elsewhere on the Southeast Asian mainland. Adults of this species resemble the adults of *Stegomyia albopicta*, but differ in having the maxillary palpus dark-scaled apically, the antennal pedicel without scales on the lateral surfaces, no subspiracular scales, and hindtarsomere 5 entirely dark-scaled. Larvae differ from *Stegomyia* larvae in having seta 1-A branched, longer than the diameter of the antenna, setae 4- 5- and 7-C multiple branched, and seta 6-C single to 12-branched.

Larvae of *Sc. albolineata* have been found in rock pools, tree holes, stump holes, bamboo stumps, bamboo pots, bamboo internodes, split bamboo, coconut husks, artificial containers, and the axils of *Allocasia*, *Pandanus*, banana, and *Nipa*. Adults have been found resting in tree holes, bamboo stumps, and leaf axils. Nothing else is known about the biology of this species.

33. *Stegomyia*

Stegomyia is a large genus of 130 species with natural distributions in the Afro-

tropical, Australasian, and Oriental Regions, and two species widely introduced around the world. Fourteen species of *Stegomyia* are recorded from Thailand. Reinert *et al*. (2009) described subgenus *Heteraspidion* for species previously included in the Annandalei Subgroup (*St*. *annandalei* and *St*. *craggi*), subgenus *Huangmyia* for species in the Mediopunctatus Subgroup (*St. malikuli* and *St. perplexa*), and subgenus *Xyele* for the Desmotes Subgroup (*St*. *desmotes***)**. Subgenus *Stegomyia* only includes *St*. *aegypti*. Six of the Thai species are assigned to subgenera and eight are currently without subgeneric placement.

Adults of *Stegomyia* are generally common, brightly colored mosquitoes with patches and/or stripes of silvery or white scales on the scutum and legs. They have white scales at the apex of the maxillary palpus, the antennal pedicel has scales on the lateral surface, subspiracular scales are present (except some *St. malayensis*), and hindtarsomere 5 is partly white-scaled. Larvae of *Stegomyia* have seta 1-A weakly developed, no longer than the diameter of the antenna, and the comb scales arranged in a single row.

Stegomyia larvae are commonly found in artificial containers, hollow logs, rock pools, rock holes, bamboo stumps, cut bamboo, bamboo pots, bamboo internodes, split bamboo, coconut shells, coconut husks, and the axils of *Allocasia*, *Pandanus*, pineapple, banana, and *Nipa*. Adult females of most species have been captured biting humans. *Stegomyia aegypti* and *St. albopicta* are the most important species of Thai *Stegomyia* because they are the principal vectors of dengue fever and chikungunya viruses.

34. *Tanakaius*

Tanakaius is a small genus of two species. Only one of them, *Ta. togoi*, occurs in Thailand. Adults are similar to those of *Collessius* species but differ in having a lower anterior mesepimeral seta and in lacking a narrow stripe of yellowish scales on the anterior surface of the midfemur. *Tanakaius togoi* larvae have the siphon as long as or shorter than segment X, seta 1-S inserted on the distal 0.25 of the siphon, and anal papillae shorter than segment X.

Tanakaius togoi is a coastal species. Larvae occur in brackish water but are sometimes found in fresh water in containers and rock pools. Adults bite humans at all times of the day. *Tanakaius togoi* has been found to be a natural vector of *Brugia malayi* in other countries.

35. *Tewarius*

Tewarius is a small genus of four species in the Oriental Region, but only one of

them, *Te*. *pseudonummatus*, is known to occur in Thailand. Adults are very similar to the adults of *Downsiomyia* but differ in having dorsocentral setae and pale scales on the postspiracular area. The larvae of *Tewarius* are similar to those of *Petermattinglyius* but differ in the development of seta 1-S. The larva of *Te. pseudonummatus* is unknown.

Pupae of *Te*. *pseudonummatus* have been found in tree holes. Nothing is known about the bionomics or vector status of the adults.

36. *Udaya*

Three species of *Udaya* are known in the Oriental Region, but only one, *Ud*. *argyrurus*, is found in Thailand. The adults of this species are yellow-brown mosquitoes characterized by a spoon-shaped patch of broad overlapping silver scales that separates the eyes and extends to the antennal pedicels, absence of acrostichal setae, a patch of broad silver scales on the antepronotum that separates the setae into two groups, absence of scales on the postpronotum and postspiracular area, broad overlapping silver scales on the paratergite, upper calypter bare or with a few short setae or hairlike scales, and the alula of the wing has broad flat scales on the dorsal margin. Larvae have setae 4-, 5- and 6-C inserted well anterior to seta 7-C, never in a transverse line, seta 7-C inserted posterior to the level of seta 5-C, seta 6-C inserted far forward of the antennal base, closer to seta 5-C, ventral brush borne on a grid with only transverse bars, and seta 1-VIII is usually single, long, and extends beyond the base of the siphon.

Larvae of *Ud*. *argyrurus* are found in tree holes, bamboo internodes, bamboo stumps, and split bamboo. Adults have been collected in light traps and biting humans. Nothing else is known about the biology of this species.

37. *Verrallina*

Twenty-three species of *Verrallina* are known to occur in Thailand: two species of subgenus *Harbachius*, 18 species of subgenus *Neomacleaya*, and three species of subgenus *Verrallina*. *Verrallina* are dark mosquitoes without special ornamentation. The adults resemble the adults of *Cancraedes*, *Lorrainea*, and *Rhinoskusea* in having largely broad decumbent scales on the vertex and erect scales at the back of head. They differ from *Lorrainea* in having all lobes of the scutellum covered with narrow scales, and the females differ in having abdominal segment VII dorsoventrally flattened and segment VIII broad and not retracted into segment VII. Larvae of *Verrallina* are very similar to *Neomelaniconion* larvae, but can be separated by the character of the comb scales.

Females of *Verrallina* are particularly difficult to distinguish because most species lack conspicuous differences. The male and female genitalia are very useful for diagnosing most species, but they require dissection and mounting on microscope slides. Current knowledge of species in this genus is far from complete.

Verrallina larvae have been found in swamps, marshy depressions and bogs, ditches, pits, ground pools, flood pools, stream pools, seepage pools, rice fields, wheel tracks, elephant and other footprints, crab holes, and rock pools. Most *Verrallina* adults have been collected in light traps and biting humans.

38. *Zeugnomyia*

Zeugnomyia includes four species in eastern areas of the Oriental Region, principally in the Philippine Islands. Only *Ze. gracilis* occurs in Thailand. Adults of this species are generally easily recognized by the absence of postspiracular setae and a conspicuous vertical stripe of broad silver scales that extends from or above the paratergite to the midcoxa. Larvae are similar to *Udaya* larvae but seta 6-C is inserted very near the base of the antenna, the ventral brush is borne on a boss, and seta 1-VIII is branched.

Larvae of *Ze*. *gracilis* have been found in water held in fallen leaves. Nothing is known about the biology of the adults.

CONCLUDING REMARKS

This publication is the last in the series of six publications (Sections I–VI) that have resulted from the project "Illustrated Keys to the Mosquitoes of Thailand", but this should not be interpreted as meaning the Thai culicid fauna is completely known. That is far from the truth! In Section I (Rattanarithikul *et al.,* 2005a), 436 species were documented in Thailand, including 15 new records for described species and 14 known undescribed species. During the period between Section I and the completion of the present section (Section VI), five important species listed as undescribed in Section I were described: *An. cracens, An. scanloni, An. baimaii*, and *An. latens* were described for *An*. *dirus* B, *An. dirus* C, *An*. *dirus* D, and *An*. *leucosphyrus* A, respectively (Sallum *et al*., 2005), *An. epiroticus* was described for *An. sundaicus* A (Linton *et al*., 2005), and *An. harrisoni* was described for *An. minimus* C (Harbach *et al*., 2007a). Also, *Baimaia*, a new subgenus of *Anopheles,* was described for *An. kyondawensis* (Harbach *et al*., 2005), and two new genera and one species (*Borichinda cavernicola* and *Kimia*) were discovered during

the project and described by Harbach *et al*. (2007b, 2007c, respectively). Additional described and undescribed mosquito species that were not mentioned in Section I were discovered in Thailand and published in subsequent sections. These include two new records for described species and the discovery of nine new undescribed species included in Table 1 and the keys of Section V, and six new records for described species and the discovery of six more new undescribed species included in Table 3 of the present section. The 436 species (classified in 23 genera and 48 subgenera) reported in Section I plus the 23 species recognized subsequently brings the number of mosquito species currently known to occur in Thailand to 459 (classified in 53 genera and 40 subgenera outlined herein in Tables 6 and 7).

Thurman (1959) documented 275 species in Thailand and postulated that 300 species might eventually be found in the country. The present level of culicid diversity in Thailand, a country approximately the same size as the state of California in the USA, is shocking. The 459 described and undescribed species reported here represent a 67% increase in the Thai culicid fauna in the 50 years since Thurman, and far exceeds her projected 300 species. Obviously, much work on the Thai culicid fauna is still needed because only six of the 29 undescribed species reported in Sections I–VI have been described and named, and additional new records and undescribed species almost certainly will be found in the future.

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