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Research Article

Mosquitoes (Diptera: Culicidae) of Singapore: Updated Checklist and New Records

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Abstract

Prior to 1965, Singapore was part of the Malaya (now Malaysia) and was usually not mentioned when mosquito records were reported for Malaya. Consequently, many species that occurred in Singapore were not listed in the world mosquito catalog, and the available checklist for Singapore since 1986 is incomplete, with some imprecise species information. In updating this checklist, we examined and verified mosquito specimens collected from Singapore in various depositories, including a thorough review of past taxonomic literature. Here, we report a checklist of 182 mosquito species, 33 new distribution records, and a consolidated status list of vectors for Singapore. As Singapore is a travel hub and hosts one of the busiest container ports in the world, there is a risk of introducing mosquito species and their associated pathogens of human disease to the country. Hence, the distribution records are important to increase our knowledge on mosquito ecology as well as to understand the risk of newly introduced vectors and their associated pathogens.

Key words: *Aedes*, *Anopheles*, *Culex*, taxonomy, Southeast Asia

Singapore is located 137 km north of the equator (1.28° N, 103.83° E) and about 1.6 km south of Peninsular Malaysia across the Straits of Johor. As a tropical country, Singapore has year-round hot and humid conditions with an average temperature of 27.5°C, mean daily relative humidity of 83.9%, and mean annual rainfall of 232.9 cm (Metereological Services Singapore 2017). Much of Singapore is covered with greenery (56%), which includes nature reserves, urban parks, mangroves, and adventitious vegetation (Yee et al. 2011). These, together with human-made habitats in urban areas, provide an ideal environment for inhabitation by diverse mosquito species (Colless 1957a, Laird 1988).

More than 3,500 species of mosquitoes have been described globally (Harbach 2018, Walter Reed Biosystematics Unit 2018) and at least 871 species are present in Southeast Asia. In Singapore, much of the earlier work on mosquitoes was carried out by a few prominent taxonomists from the 1920s to 1960s (Edwards 1926; Edwards and Given 1928; Reid 1950, 1968; Colless 1957a,b, 1958, 1965; Mattingly 1959, 1965). During this period, species collected in Singapore were often recorded under Malaya, which included contemporary Singapore and Malaysia. Consequently, many species that occurred in Singapore were not listed under Singapore in the world catalogs of mosquitoes (Stone et al. 1959, Knight and Stone 1977). Apiwathnasorn (1986) listed species in 11 Southeast Asian countries (including 126 species in Singapore); however, the list was incomplete and included some imprecise information. Recent sampling efforts on mainland Singapore and surrounding islands had contributed additional records and increased the number of recorded species to 140 in 2012 (Jeffery et al. 2010, Lee et al. 2012). These included three species, *Culex* (*Culiciomyia*) *fragilis* Ludlow, *Lutzia* (*Metalutzia*) *halifaxii* (Theobald), *Lutzia* (*Mlt.*) *vorax* Edwards, which were recorded in the checklist for Ubin Island, but not indicated as new records at that time (Lee et al. 2012). In recent years, considerable advances have been made in mosquito taxonomy, including taxonomic revisions, publication of keys, and new species descriptions (Rattanarithikul et al. 2005, 2006a,b, 2007, 2010), and in molecular tools, such as DNA barcoding (Linton et al. 2005). All of these have aided in species delineation and have improved the accuracy of mosquito identification (Chan et al. 2014).

Historically, Singapore not only has held a significant place in the recognition and documentation of the diversity of mosquitoes, but also the training of many mosquito taxonomists and medical entomologists in the Malay Archipelago, including D. H. Colless, J. A. Reid, and A. A. Sandosham. Much of our knowledge of the taxonomy of mosquitoes and the various pathogens of human diseases they transmit in Southeast Asia come from the works of these scientists. Although considerable efforts have been expended by taxonomists to define the mosquito fauna in Singapore, a comprehensive checklist of vector and nonvector species has never been accrued and published. To show that a species is a vector of pathogens of human diseases, it is necessary to demonstrate all of the following: 1) an association in space and time between species of mosquitoes and cases of disease in humans, 2) evidence of direct contact between the mosquito species and humans through landing/biting catches, 3) evidence that the species collected under natural conditions harbors the pathogen in its infective stage, and 4) proof of efficient transmission of the pathogen in laboratory conditions (Beier 2002, Eldridge and Edman 2012, Wilson et al. 2017). However, it is often difficult to obtain all necessary evidence and many species incriminated in the past were based on inferences and indirect evidence.

Singapore is a travel hub and hosts one of the busiest container ports in the world. Consequently, there is a risk of introducing mosquito species and their associated disease-causing pathogens into the country (Institute of Medicine 2010, Heng 2015). The occurrence records of mosquitoes are important not only to enhance our knowledge of mosquito systematics, but also to assess the risk of associated vector-borne disease agents (Hutchings et al. 2016). Our objectives in this paper are to: 1) present an annotated and updated checklist of mosquito species in Singapore with detailed taxonomic notes, 2) document new distribution records from Singapore, 3) rectify erroneous past species records, and 4) provide a consolidated vector status list.

Materials and Methods

We examined and verified mosquito specimens collected from Singapore in various depositories and thoroughly reviewed past taxonomic literature. Specimens deposited by past collectors were first examined in two local depositories, Environmental Health Institute of National Environment Agency (EHI) and Lee Kong Chian Natural History Museum (LKCNHM), and the checklist was then supplemented by verifying the collections in foreign depositories, such as the National Museum of Natural History (NMNH) in Washington D.C., the Natural History Museum (NHM) in London, and the Muzium Zoologi Universiti Malaya (MZUM) of the Universiti Malaya (UM) in Kuala Lumpur. Whenever necessary, anatomical characters of the male genitalia were examined to confirm the identification.

Among the local depositories, EHI has amassed the larger mosquito collection of over 7,000 pinned adult specimens and 1,600 larval specimens, belonging to more than 100 species collected from mainland Singapore and a few off-shore islands. The collection dates back to the 1970s when mosquito surveillance was conducted as part of the national-integrated vector control program. It was initially carried out by the Vector Control and Research Department until 2002, when the National Environment Agency and its public health laboratory, EHI, was founded and continued the collection.

The collection represents specimens collected from different habitat types across multiple locations using a range of methods. Larvae were collected from aquatic habitats using standard larval dippers (350 ml, 13 cm diameter; BioQuip, Rancho Dominguez, CA) and plastic pipettes, and locality details were recorded. The larvae were preserved at the larval stage or individually reared to adults, which were preserved as morphological voucher specimens along with their associated larval and pupal exuviae. Adults were collected using traps, including modified CDC Light Traps (CDC-LT; U.S. Centers for Disease Control and Prevention) baited with dry ice, BG-Sentinel traps (Biogents AG, Germany) and Gravitraps (EHI, Singapore). In some military-restricted areas, adults are collected by human landing catch by the Singapore Armed Forces. GPS coordinates were obtained using Garmin handheld devices (Garmin Ltd., USA) or from Google Maps, and expressed in degrees, minutes, and seconds format.

In addition to examining specimens, past taxonomic literature and catalogs (Stone et al. 1959, Knight and Stone 1977, Apiwathnasorn 1986, Townsend et al. 1990) that reported species from Singapore were also crosschecked and reviewed to rectify inaccurate species records and other records that were overlooked. We reviewed over 100 published references (Notes) and provide explanations for the exclusion or inclusion of species, as well as useful taxonomical remarks. To prepare the vector list, we reviewed literature on vector species and their associated diseases in Singapore and neighboring countries (Malaysia, southern Thailand, Indonesia, and Brunei Darussalam).

Results

Mosquito Species Diversity

This study represents the first comprehensive list of mosquitoes from Singapore, including 182 species in subfamilies Anophelinae and Culicinae, based on confirmed records and verified specimens (Table 1). Ten out of the 11 tribes of subfamily Culicinae are reported here (Harbach and Kitching 1998) and of these, 20 genera and 43 subgenera are represented (Wilkerson et al. 2015) (Fig. 1). *Culex* has the highest number of species (46), followed by *Aedes* (37) and *Anopheles* (21) (Fig. 1).

In our updated checklist, 42 species are added (Notes), and 10 species erroneously reported in the older publications are removed (Excluded Species). Among the 182 species listed, 33 new species records with ecological information (Table 2) are reported for the first time. Other new taxonomic records include two genera (*Hodgesia* and *Udaya*) and five subgenera, *Ae.* (*Edwardsaedes*), *Ae.* (*Finlaya*), *Ae.* (*Phagomyia*), *Cx.* (*Acalleomyia*), and *Verrallina* (*Harbachius*).

Among the new records, 21 species were only found in forested areas, 11 species in both forested and urban areas, and one species, *Verrallina* (*Har.*) *consonensis* (Reinert), only in urban areas. In forested areas, the highest number of new species recorded was from Tekong Island (12 species), an offshore island comprising secondary forests, coastal forests, and reclaimed land. This is followed by Bukit Timah (seven species) and Sungei Buloh Wetland Reserve (five species) (Fig. 2), which are areas with primary and mature secondary forests, and mangroves, respectively.

Mosquitoes of Public Health Importance

About 25 mosquito species are known vectors or potential vectors of human disease-causing pathogens in neighboring countries and Singapore (Table 3). Of these, nine are recognized as vectors in Singapore (Table 3). Some of the indicated vector species do not have available natural infection information or

Table 1. Updated checklist of mosquito species in Singapore, including a collation of specimens deposited locally in the Environmental Health Institute (EHI) of National Environment Agency and the Lee Kong Chian Natural History Museum (LKCNHM)

Species	First Singapore record	Location of specimen(s) in Singapore
Aedeomyia (*Aedeomyia*) *catasticta* Knab, 1909	Brug and Bonne-Wepster 1947	EHI
Aedes (*Aedimorphus*) *caecus* (Theobald, 1901)	Colless 1957a	EHI
Ae. (*Adm.*) *orbitae* Edwards, 1922	Edwards and Given 1928	
Ae. (*Adm.*) *vexans* (Meigen, 1830)	Colless 1957a	EHI
Ae. (*Cancraedes*) *masculinus* Mattingly, 1958	Edwards 1928 (Note 1)	
Ae. (*Downsiomyia*) *inermis* Colless, 1958*	Colless 1958	
Ae. (*Dow.*) *leonis* Colless, 1958*	Colless 1958 (Note 2)	EHI
Ae. (*Dow.*) *litoreus* Colless, 1958*	Colless 1958	
Ae. (*Dow.*) *mikrokopion* Knight and Harrison, 1988	New record	EHI, LKCNHM
Ae. (*Dow.*) *niveoides* Barraud, 1934	New record	EHI, LKCNHM
Ae. (*Dow.*) *pexus* Colless, 1958*	Colless 1958	
Ae. (*Dow.*) *pseudoniveus* (Theobald, 1905)*	Theobald 1905	
Ae. (*Dow.*) *subniveus* Edwards, 1922*	Colless 1958	
Ae. (*Dow.*) *vanus* Colless, 1958*	Colless 1958	
Ae. (*Edwardsaedes*) *imprimens* (Walker, 1860)	New record	EHI
Ae. (*Finlaya*) *flavipennis* (Giles, 1904)	Edwards 1926	
Ae. (*Fin.*) *poicilius* (Theobald, 1903)	New record	EHI
Ae. (*Hulecoeteomyia*) *jugraensis* (Leicester, 1908)	Edwards and Given 1928	
Ae. (*Hul.*) *saxicola* Edwards, 1922	Edwards and Given 1928	
Ae. (*Lorrainea*) *amesii* (Ludlow, 1903)	Edwards 1928 (Note 3)	EHI
Ae. (*Lor.*) *fumidus* Edwards, 1928*	Edwards 1928	EHI
Ae. (*Mucidus*) *aurantius* (Theobald, 1907)	Edwards and Given 1928	EHI
Ae. (*Muc.*) *laniger* (Wiedemann, 1820)	Mattingly 1961	EHI
Ae. (*Muc.*) *quasiferinus* Mattingly, 1961	Mattingly 1961	EHI
Ae. (*Neomelaniconion*) *lineatopennis* (Ludlow, 1905)	Colless 1957a	
Ae. (*Ochlerotatus*) *vigilax* (Skuse, 1889)	Chan et al. 2014	EHI
Ae. (*Paraedes*) *collessi* Mattingly, 1958	Jeffery et al. 2010	EHI
Ae. (*Petermattinglyius*) *franciscoi* Mattingly, 1959*	Mattingly 1959	EHI
Ae. (*Phagomyia*) near *khazani* Edwards, 1922	New record (Note 4)	LKCNHM
Ae. (*Rhinoskusea*) *longirostris* (Leicester, 1908)	Edwards 1926	EHI
Ae. (*Rhi.*) *pillaii* Mattingly, 1958	Reinert 1976	EHI
Ae. (*Scutomyia*) *albolineatus* Theobald, 1904	Jeffery et al. 2010	EHI
Ae. (*Stegomyia*) *aegypti* (Linnaeus, 1762)	Leicester 1908	EHI, LKCNHM
Ae. (*Stg.*) *albopictus* (Skuse, 1895)	Colless 1957a	EHI, LKCNHM
Ae. (*Stg.*) *annandalei* Theobald, 1910	New record	EHI
Ae. (*Stg.*) *desmotes* (Giles, 1904)	Jeffery et al. 2010	EHI
Ae. (*Stg.*) *gardnerii imitator* (Leicester, 1908)	Jeffery et al. 2010	EHI
Ae. (*Stg.*) *malayensis* Colless, 1962*	Colless 1957a,c (Note 5)	EHI
Anopheles (*Anopheles*) *baezai* Gater, 1933	Gater 1933	EHI
An. (*Ano.*) *barbirostris sensu lato*	Colless 1959b (Note 6)	EHI
An. (*Ano.*) *brevirostris* Reid, 1950	Colless 1957a	
An. (*Ano.*) *fragilis* (Theobald, 1903)	New record (Note 7)	EHI
An. (*Ano.*) *hodgkini* Reid, 1962	New record	EHI
An. (*Ano.*) *paraliae* Sandosham, 1959	Reid 1953 (Note 8)	EHI
An. (*Ano.*) *letifer* Sandosham, 1944	Harrison and Scanlon 1975	EHI
An. (*Ano.*) *nitidus* Harrison, Scanlon, and Reid, 1973	Colless 1959b (Note 9)	EHI
An. (*Ano.*) *separatus* (Leicester, 1908)	Jeffery et al. 2010	EHI
An. (*Ano.*) *sinensis* Wiedemann, 1828	Reid 1953	EHI, LKCNHM
An. (*Ano.*) *umbrosus* (Theobald, 1903)	Colless 1957a	EHI
An. (*Cellia*) *aconitus* Dönitz, 1902	Harrison 1980	
An. (*Cel.*) *annularis* van der Wulp, 1884	Apiwathnasorn 1986	
An. (*Cel.*) *epiroticus* Linton and Harbach, 2005	James and Stanton 1912 (Note 10)	EHI
An. (*Cel.*) *karwari* (James, 1902)	Apiwathnasorn 1986	EHI
An. (*Cel.*) *kochi* Dönitz, 1901	Colless 1959b	EHI
An. (*Cel.*) *maculatus sensu lato*	Chan 1969 (Note 11)	EHI
An. (*Cel.*) *subpictus* Grassi, 1899	Leicester 1908 (Note 12)	
An. (*Cel.*) *tessellatus* Theobald, 1901	Apiwathnasorn 1986	EHI
An. (*Cel.*) *vagus* Dönitz, 1902	Colless 1959b	EHI
Armigeres (*Armigeres*) *confusus* Edwards, 1915	Jeffery et al. 2010	EHI, LKCNHM
Ar. (*Arm.*) *conjungens* Edwards, 1914	Colless 1957a	

Table 1. *Continued*

Species	First Singapore record	Location of specimen(s) in Singapore
Ar. (*Arm.*) *giveni* Edwards, 1926*	Edwards 1926	
Ar. (*Arm.*) *hybridus* Edwards, 1914	Colless 1957a	
Ar. (*Arm.*) *jugraensis* (Leicester, 1908)	Edwards and Given 1928	EHI
Ar. (*Arm.*) *kesseli* Ramalingam, 1987	Ramalingam 1987	EHI
Ar. (*Arm.*) *kuchingensis* Edwards, 1915	Barr and Chellappah 1963	
Ar. (*Arm.*) *malayi* (Theobald, 1901)	Edwards and Given 1928	EHI
Ar. (*Arm.*) *subalbatus* (Coquillett, 1898)	Colless 1957a (Note 13)	EHI, LKCNHM
Ar. (*Leicesteria*) *digitatus* (Edwards, 1914)	New record	EHI
Ar. (*Lei.*) *flavus* (Leicester, 1908)	Edwards and Given 1928	
Coquillettidia (*Coquillettidia*) *crassipes* (van der Wulp, 1881)	Edwards and Given 1928 (Note 14)	EHI, LKCNHM
Cq. (*Coq.*) *nigrosignata* (Edwards, 1917)	Jeffery et al. 2010	EHI, LKCNHM
Cq. (*Coq.*) *ochracea* (Theobald, 1903)	Edwards and Given 1928	EHI
Culex (*Acalleomyia*) *obscurus* (Leicester, 1908)	New record	EHI
Cx. (*Culex*) *alienus* Colless, 1957	Colless 1957b	EHI
Cx. (*Cux.*) *alis* Theobald, 1903	Colless 1957c (Note 15)	
Cx. (*Cux.*) *fuscocephala* Theobald, 1907	Colless 1959a	EHI
Cx. (*Cux.*) *gelidus* Theobald, 1901	Colless 1957a	EHI, LKCNHM
Cx. (*Cux.*) *hutchinsoni* Barraud, 1924	Colless 1955	EHI
Cx. (*Cux.*) *mimulus* Edwards, 1915	Colless 1957a	EHI
Cx. (*Cux.*) *perplexus* Leicester, 1908	Colless 1957b	EHI
Cx. (*Cux.*) *propinquus* Colless, 1955*	Colless 1955	
Cx. (*Cux.*) *pseudovishnui* Colless, 1957*	Colless 1957b	EHI
Cx. (*Cux.*) *quinquefasciatus* Say, 1823	Colless 1957a (Note 16)	EHI, LKCNHM
Cx. (*Cux.*) *sitiens* Wiedemann, 1828	Leicester 1908	EHI
Cx. (*Cux.*) *tritaeniorhynchus* Giles, 1901	Colless 1957a	EHI, LKCNHM
Cx. (*Cux.*) *vishnui* Theobald, 1901	Colless 1957a (Note 17)	EHI
Cx. (*Cui.*) *fragilis* Ludlow, 1903	Colless 1957a	EHI
Cx. (*Cui.*) *nigropunctatus* Edwards, 1926	Edwards 1926	EHI, LKCNHM
Cx. (*Cui.*) *spathifurca* (Edwards, 1915)	Edwards 1926	EHI, LKCNHM
Cx. (*Eumelanomyia*) *brevipalpis* (Giles, 1902)*	Theobald 1901 (Note 18)	EHI
Cx. (*Eum.*) *malayi* (Leicester, 1908)	New record	EHI
Cx. (*Lophoceraomyia*) *acutipalus* Colless, 1965*	Colless 1965	
Cx. (*Lop.*) *alphus* Colless, 1965	Colless 1965	
Cx. (*Lop.*) *brevipalpus* (Theobald, 1905)*	Theobald 1905	
Cx. (*Lop.*) *cinctellus* Edwards, 1922	Colless 1965	EHI
Cx. (*Lop.*) *coerulescens* Edwards, 1928	Edwards and Given 1928	
Cx. (*Lop.*) *cubitatus* Colless, 1965*	Colless 1965	
Cx. (*Lop.*) *curtipalpis* (Edwards, 1914)	Edwards 1928	EHI
Cx. (*Lop.*) *eminentia* (Leicester, 1908)	Edwards 1928	
Cx. (*Lop.*) *hewitti* (Edwards, 1914)	Edwards and Given 1928	
Cx. (*Lop.*) *jenseni* (de Meijere, 1910)	Edwards and Given 1928	
Cx. (*Lop.*) *lucaris* Colless, 1965*	Colless 1965	EHI
Cx. (*Lop.*) *macdonaldi* Colless, 1965*	Colless 1965	
Cx. (*Lop.*) *mammiifer* (Leicester, 1908)	Brug and Bonne-Wepster 1947	
Cx. (*Lop.*) *minor* (Leicester, 1908)	Edwards 1928 (Note 19)	
Cx. (*Lop.*) *navalis* Edwards, 1926*	Edwards 1926	
Cx. (*Lop.*) *pairoji* Sirivanakarn, 1977	Sirivanakarn 1977	
Cx. (*Lop.*) *quadripalpis* (Edwards, 1914)	Colless 1965	
Cx. (*Lop.*) *reidi* Colless, 1965*	Edwards 1928 Edwards and Given 1928 (Note 20)	
Cx. (*Lop.*) *rubithoracis* (Leicester, 1908)	Colless 1957a	
Cx. (*Lop.*) *traubi* Colless, 1965	Colless 1965	
Cx. (*Lop.*) *variatus* (Leicester, 1908)	Colless 1965	
Cx. (*Lop.*) *whartoni* Colless, 1965*	Colless 1965	
Cx. (*Oculeomyia*) *bitaeniorhynchus* Giles, 1901	Colless 1957a	EHI
Cx. (*Ocu.*) *geminus* Colless, 1955*	Colless 1955	
Cx. (*Ocu.*) *infula* Theobald, 1901	New record	EHI
Cx. (*Ocu.*) *pseudosinensis* Colless, 1955*	Colless 1955	
Cx. (*Ocu.*) *sinensis* Theobald, 1903	New record	EHI
Ficalbia minima (Theobald, 1901)	Edwards and Given 1928	EHI
Heizmannia (*Heizmannia*) *funerea* (Leicester, 1908)	Mattingly 1970	
Hz. (*Hez.*) *indica* (Theobald, 1905)*	Theobald 1905	
Hz. (*Hez.*) *reidi* Mattingly, 1957	New record	EHI
Hz. (*Hez.*) *scintillans* Ludlow, 1905	Edwards and Given 1928 (Note 21)	EHI, LKCNHM
Hodgesia sp. (Damaged)	New record	EHI

Table 1. *Continued*

Species	First Singapore record	Location of specimen(s) in Singapore
Lutzia (*Metalutzia*) *fuscana* (Wiedemann, 1820)	Colless 1957a	EHI
Lt. (*Mlt.*) *halifaxii* Theobald, 1903	Lee et al. 2012	EHI
Lt. (*Mlt.*) *vorax* Edwards, 1921	Lee et al. 2012	EHI
Malaya genurostris Leicester, 1908	Colless 1957a	EHI
Mansonia (*Mansonioides*) *annulata* Leicester, 1908	New record	EHI
Ma. (*Mnd.*) *annulifera* (Theobald, 1901)	Colless 1959b	EHI
Ma. (*Mnd.*) *bonneae* Edwards, 1930	Jeffery et al. 2010	EHI
Ma. (*Mnd.*) *dives* (Schiner, 1868)*	Ramalingam 1975	
Ma. (*Mnd.*) *indiana* Edwards, 1930	Colless 1957a	EHI
Ma. (*Mnd.*) *uniformis* (Theobald, 1901)	Edwards and Given 1928	EHI
Mimomyia (*Etorleptiomyia*) *elegans* (Taylor, 1914)	New record	EHI
Mi. (*Eto.*) *luzonensis* (Ludlow, 1905)	Leicester 1908 (Note 22)	EHI
Mi. (*Ingramia*) *fusca* (Leicester, 1908)	Edwards and Given 1928	
Mi. (*Mimomyia*) *aurea* (Leicester, 1908)	Mattingly 1957a	EHI
Mi. (*Mim.*) *chamberlaini metallica* (Leicester, 1908)	Edwards and Given 1928	EHI
Mi. (*Mim.*) *hybrida* (Leicester, 1908)	Leicester 1908	EHI
Orthopodomyia albipes Leicester, 1904	Theobald 1904 (Note 23)	EHI, LKCNHM
Or. andamanensis Barraud, 1934	Zavortink 1968	
Or. anopheloides (Giles, 1903)	Edwards 1926 (Note 24)	
Toxorhynchites (*Toxorhynchites*) *acaudatus* (Leicester, 1908)*	Leicester 1908	EHI, LKCNHM
Tx. (*Tox.*) *leicesteri* Theobald, 1904	Edwards 1926	
Tx. (*Tox.*) *magnificus* (Leicester, 1908)	Edwards 1926	
Tx. (*Tox.*) *quasiferox* (Leicester, 1908)*	Leicester 1908	LKCNHM
Tx. (*Tox.*) *splendens* (Wiedemann, 1819)	Brunetti 1920 (Note 25)	EHI, LKCNHM
Tripteroides (*Rachionotomyia*) *nepenthis* (Edwards, 1915)	Edwards 1926	
Tp. (*Rah.*) *nepenthisimilis* Mattingly, 1981	Mattingly 1981	
Tp. (*Rah.*) *tenax* (de Meijere, 1910)	Edwards 1928 (Note 26)	EHI
Tp. (*Tripteroides*) *denticulatus* Delfinado and Hodges, 1968	New record	
Tp. (*Trp.*) *mendacis* (Daniels, 1908)	New record	
Tp. (*Trp.*) *tarsalis* Delfinado and Hodges, 1968	New record	EHI
Tp. (*Trp.*) *vicinus* (Edwards, 1914)	Barr and Chellappah 1963	
Udaya argyrurus (Edwards, 1934)	New record	
Uranotaenia (*Pseudoficalbia*) *bicolor* Leicester, 1908	New record	EHI
Ur. (*Pfc.*) *hirsutifemora* Peters, 1964	Peyton 1977	
Ur. (*Pfc.*) *maculipleura* Leicester, 1908	New record	EHI
Ur. (*Pfc.*) *moultoni* Edwards, 1914	Edwards 1926 (Note 27)	
Ur. (*Pfc.*) *nivipleura* Leicester, 1908*	Leicester 1908	
Ur. (*Pfc.*) *obscura* Edwards, 1915	Edwards and Given 1928	EHI
Ur. (*Pfc.*) *patriciae* Peyton, 1977	Peyton 1977	
Ur. (*Pfc.*) *xanthomelaena* Edwards, 1925	Barr and Chellappah 1963	
Ur. (*Uranotaenia*) *bimaculiala* Leicester, 1908	New record	EHI
Ur. (*Ura.*) *campestris* Leicester, 1908	New record	EHI
Ur. (*Ura.*) *hebes* Barraud, 1931	New record	EHI
Ur. (*Ura.*) *lateralis* Ludlow, 1905	Lee et al. 1989	EHI
Ur. (*Ura.*) *longirostris* Leicester, 1908	New record	EHI
Ur. (*Ura.*) *macfarlanei* Edwards, 1914	New record	EHI
Ur. (*Ura.*) *micans* Leicester, 1908	New record	EHI
Ur. (*Ura.*) *prajimi* Peyton and Rattanarithikul, 1970	New record	EHI
Ur. (*Ura.*) *subnormalis* Martini, 1920*	Martini 1920	
Ur. (*Ura.*) *testacea* Theobald, 1905*	Theobald 1905	
Ur. (*Ura.*) *trilineata* Leicester, 1908	New record	EHI
Verrallina (*Harbachius*) *consonensis* (Reinert, 1973)	New record	EHI
Ve. (*Neomacleaya*) *andamanensis* (Edwards, 1922)	Edwards 1928	
Ve. (*Nma.*) *cyrtolabis* (Edwards, 1928)*	Delfinado 1967	EHI
Ve. (*Nma.*) *varietas* (Leicester, 1908)	Colless 1959b	
Ve. (*Verrallina*) *butleri* (Theobald, 1901)	Edwards and Given 1928 (Note 28)	EHI
Ve. (*Ver.*) *dux* (Dyar and Shannon, 1925)	Brug and Bonne-Wepster 1947	
Zeugnomyia gracilis Leicester, 1908	Edwards and Given 1928	EHI, LKCNHM

*Singapore as the type locality of the species.

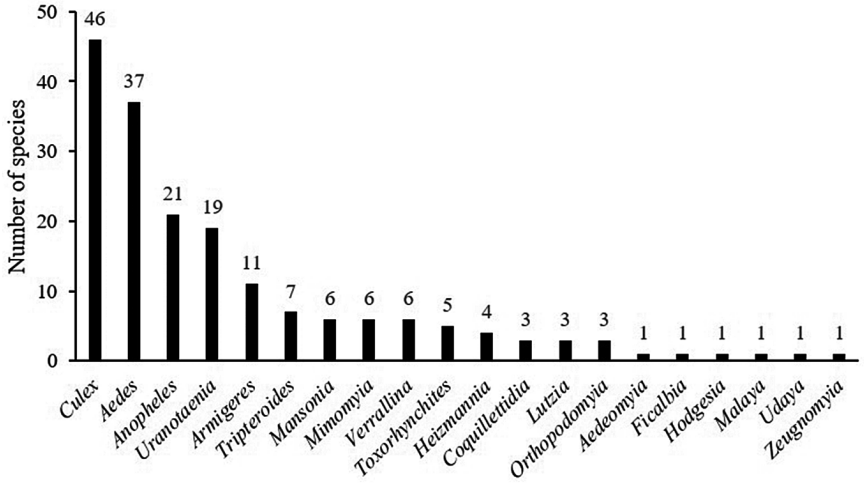

Fig. 1. Number of mosquito species in each genus in Singapore.

published records, but are still included in the list based on past studies. The remaining 16 species are listed as potential vectors in Singapore based on inference from field evidence (*Anopheles kochi* Dönitz), laboratory susceptibility tests on local species strains (*Aedes malayensis*), and vector records in neighboring countries (14 species).

Discussion

Mosquito Species Diversity

Our study provides a comprehensive review of the historical literature and confirmation of species that have been recorded from Singapore. The 182 species reported here represent a broad spectrum of culicid taxa from the two subfamilies, Anophelinae and Culicinae. There are 24 recorded genera in Southeast Asia, of which 20 are present in Singapore (Walter Reed Biosystematics Unit 2018). This suggests that the diversity of mosquitoes in Singapore is fairly well represented across the Culicidae (Harbach 2007). The four genera which are not present in Singapore (*Bironella, Culiseta, Kimia*, and *Topomyia*) have been recorded in Malaysia and Indonesia, the two countries flanking Singapore geographically. These data highlight the importance of Singapore's mosquito research efforts because of its geographical position between Peninsular Malaysia to the north and the partially different mosquito fauna in the nearby Indonesian islands of Java and Sumatra to the south. This will advance our understanding of the biogeographical distribution of the mosquito fauna in Southeast Asia.

The high number of new records found in Tekong Island (12 species) may be in part due to the broad range of habitats present in its coastal and forested areas, and the regular mosquito surveillance program in place (Lee et al. 2010). Nonetheless, infrequent collections from forested areas in Bukit Timah, Sungei Buloh, and Mandai have resulted in new records of seven, five, and four species, respectively. It is likely that the mosquito fauna in those areas is under sampled, and more extensive sampling activities may yield additional species records.

During the preparation of this checklist, the identifications of several genus groups such as *Cx.* (*Lophoceraomyia*), *Ae.* (*Downsiomyia*), *Verrallina*, *Hodgesia,* and *Tripteroides* remained unresolved. They require further collection and examination of more specimens to describe larval and male genitalia morphology and utilization of molecular techniques to resolve some taxonomic problems in these groups.

While carrying out a complete literature review, we found a few species records that were erroneously included or excluded in previous checklists. This was partly due to many authors using the term 'Malaya' to encompass both Peninsular Malaysia and Singapore in many publications prior to Singapore's independence in 1965. After Singapore's independence, many of the species records listed under Malaya were not corroborated and were either excluded from Singapore or included erroneously (Notes and Excluded Species). In addition, several cryptic and morphologically similar species were misidentified, resulting in the incorrect reporting of their distributions (Notes and Excluded Species).

Mosquitoes of Public Health Importance

In Singapore, important arboviral diseases include dengue, chikungunya, Zika, and Japanese encephalitis (Table 3). *Aedes aegypti* is the primary vector of dengue in Singapore, whereas *Ae. albopictus* is a secondary vector (Chung and Pang 2002, Lee et al. 2013). Both species are also involved in the local transmission of chikungunya and Zika viruses (Ng et al. 2009, Tan et al. 2017, Ho et al. 2017). Mendenhall et al. (2017) reported that *Ae. malayensis* showed high susceptibility to dengue and chikungunya viruses and should be considered a potential vector. Through studies conducted in the 1960s, three malaria vectors have been identified in Singapore—*Anopheles maculatus* Theobald, *Anopheles epiroticus* Linton and Harbach, and *Anopheles letifer* Sandosham (Chan 1969, Chan et al. 1976, Goh 1983). *Anopheles sinensis,* an important malaria vector in China and South Korea (Rueda et al. 2005), was the predominant species in two localities (Mandai-Sungei Kadut and Sembawang) where local transmission of *Plasmodium vivax* was detected in 2009 (Ng et al. 2010). All dissected adults of *An. sinensis* and other *Anopheles* species, however, were found to be negative for sporozoites and oocysts. Nevertheless, recent infection experiments using blood from infected patients showed that *An. sinensis* is susceptible to *P. vivax* infection (Pang et al. 2017), thus implicating its role in earlier transmission (Ng et al. 2010).

Although transmission of *Plasmodium knowlesi* has been reported in Singapore (Ng et al. 2008), the vector has not been determined (Wong et al. 2011). Routine mosquito surveillance carried out in the affected areas found six species of *Anopheles*, including *An. kochi* Dönitz. It was suggested that *An. kochi* might be a potential vector as previous laboratory studies have shown it to be susceptible to *P. knowlesi* (Coatney

Table 2. New mosquito records in Singapore, including ecological information

No.	Species	First collection	Collection to date			
			Specimens	Collection method	Larval habitat	Locality (grid coordinates)
1	*Ae.* (*Dow.*) *mikrokopion* Knight and Harrison, 1988	29 Oct 1969	♀:2 ♂:0	Larval collection, human landing catch	Bamboo	Bukit Timah (forest) (1° 21′ 0″ N 103° 46′ 12″ E) Tekong Island (forest) (1° 25′ 12″ N 104° 2′ 24″ E)
2	*Ae.* (*Dow.*) *niveoides* Barraud, 1934	23 Jun 2014	♀:2 ♂:0	Human landing catch	N/A	Tekong Island (forest)
3	*Ae.* (*Edw.*) *imprimens* (Walker, 1860)	22 Dec 2006	♀:3 ♂:0	Human landing catch	N/A	Tekong Island (forest)
4	*Ae.* (*Fin.*) *poicilius* (Theobald, 1903)	20 Nov 2011	♀:1 ♂:0	Dry ice baited light trap	N/A	Ubin Island (forest) (1° 24′ 36″ N 103° 57′ 36″ E)
5	*Ae.* (*Och.*) *vigilax* (Skuse, 1889)	21 Dec 2006	♀:44 ♂:0	Human landing catch	N/A	Tekong Island (forest) Murai (forest) (1°23'24″ N 103°41'24″ E)
6	*Ae.* (*Phg.*) near *khazani* Edwards, 1922 (Note 4)	17 Jul 1968	♀:1 ♂:0	N/A	N/A	Bukit Timah (forest)
7	*Ae.* (*Stg.*) *annandalei* (Theobald, 1910)	06 May 2014	♀:6 ♂:0	BG-sentinel with octenol and CO_2, larval collection	Dried leaves	Tampines (urban) (1° 21′ 0″ N 103° 57′ 36″ E) Lim Chu Kang (forest) (1° 25′ 48″ N 103° 43′ 12″ E) Jurong West (forest/urban) (1° 21′ 0″ N 103° 42′ 36″ E)
8	*An.* (*Ano.*) *fragilis* (Theobald, 1903) (Note 7)	13 Jan 2011	♀:14 ♂:10	Larval collection	Earth stream, seepage, puddle	Woodlands (forest/urban) (1° 26′ 24″ N 103° 46′ 12″ E) Bukit Timah (forest)
9	*An.* (*Ano.*) *hodgkini* Reid, 1962	Jun-Jul 2009	♀:3 ♂:4	Human landing catch, and larvae (reared)	Swimming pool, puddle, catchment edge, disused well, pond	Mandai (forest) (1° 24′ 36″ N 103° 46′ 48″ E) Chestnut (forest/urban) (1° 22′ 12″ N 103° 46′ 48″ E) Ubin Island (forest) Tekong Island (forest) Woodlands (forest/urban)
10	*Ar.* (*Lei.*) *digitatus* (Edwards, 1914)	23 May 2007	♀:8 ♂:8	Larvae (reared)	Plastic bag	Tekong Island (forest)
11	*Cx.* (*Aca.*) *obscurus* (Leicester, 1908)	20 Jun 2016	♀:0 ♂:3	Larvae (reared)	Broken bottle, mess tin	Tekong Island (forest)
12	*Cx.* (*Eum.*) *malayi* (Leicester, 1908)	1 Nov 2011	♀:8 ♂:3	Larvae (reared)	Pond, quarry	Sungei Buloh (forest) (1° 26′ 60″ N 103° 43′ 12″E) Bukit Batok (forest/urban) (1° 21′ 36″ N 103° 45′ 36″ E)
13	*Cx.* (*Ocu.*) *infula* Theobald, 1901	10 Dec 2010	♀:2 ♂:0	Human landing catch, Larvae (reared)	Pond	Lorong Chencharu (forest/urban) (1° 25′ 12″ N 103° 49′ 48″ E) Murai (forest)
14	*Cx.* (*Ocu.*) *sinensis* Theobald, 1903	25 Apr 2012	♀:2 ♂:0	Human landing catch	N/A	Tekong Island (forest) East Coast (urban) (1° 19′ 12″ N 103° 57′ 36″ E)

Table 2. *Continued*

No.	Species	First collection	Collection to date			
			Specimens	Collection method	Larval habitat	Locality (grid coordinates)
15	*Hz.* (*Hez.*) *reidi* Mattingly, 1957	5 Jul 2005	♀:5 ♂:0	Dry ice baited light trap	N/A	Seletar (forest) (1° 25′ 12″ N 103° 52′ 12″ E) MacRitchie (forest) (1° 20′ 24″ N 103° 49′ 12″ E) Mandai (forest) Lower pierce (forest) (1° 22′ 12″ N 103° 49′ 48″ E)
16	*Hodgesia* sp.	5 Feb 1970	♀:1 ♂:0	Larvae (reared)	Seepage pool	MacRitchie (forest)
17	*Ma.* (*Mnd.*) *annulata* Leicester, 1908	Sep-Dec 2011	♀:18 ♂:0	Human landing catch	N/A	Tekong Island (forest)
18	*Mi.* (*Eto.*) *elegans* (Taylor, 1914)	9 Mar 2011	♀:3 ♂:0	Dry ice baited light trap	N/A	Sungei Buloh (forest)
19	*Tp.* (*Trp.*) *denticulatus* Delfinado and Hodges, 1968 (in NMNH)*	1969	♀:1 ♂:0	N/A	N/A	N/A
20	*Tp.* (*Trp.*) *mendacis* (Daniels, 1908) (in NMNH)*	1969	♀:0 ♂:3	N/A	N/A	N/A
21	*Tp.* (*Trp.*) *tarsalis* Delfinado and Hodges, 1968	09 Apr 2003	♀:2 ♂:5	Larvae (reared)	Tire, pail	Tekong Island (forest) Toa Payoh (urban) (1° 19′ 48″ N 103° 50′ 60″ E)
22	*Ud. argyrurus* (Edwards, 1934) (in NMNH)*	25 Apr 1968	♀:0 ♂:1	Larvae (reared)	Bamboo stump	Bukit Timah (forest)
23	*Ur.* (*Pfc.*) *bicolor* Leicester, 1908	14 May 2004	♀:8 ♂:11	Larvae (reared)	Puddle, pond	Ubin Island (forest) Bukit Timah (forest) Mandai (forest) Holland (urban) (1° 18′ 36″ N 103° 47′ 60″ E) Bukit Batok (forest/urban)
24	*Ur.* (*Pfc.*) *maculipleura* Leicester, 1908	24 Jun 16	♀:1 ♂:0	Hand caught	Foliage	Bukit Timah (forest)
25	*Ur.* (*Ura.*) *bimaculiala* Leicester, 1908	25 Mar 2003	♀:1 ♂:0	Larvae (reared)	Small stream	Bukit Timah (forest)
26	*Ur.* (*Ura.*) *campestris* Leicester, 1908	22 Apr 2003	♀:1 ♂:2	Dry ice baited light trap	Metal beam, ground depression	Tekong Island (forest) Sungei Kadut (forest/urban) (1° 24′ 36″ N 103° 45′ 36″ E) East Coast (urban)
27	*Ur.* (*Ura.*) *hebes* Barraud, 1931	10 Jan 2010	♀:2 ♂:0	Dry ice baited light trap	N/A	Sungei Buloh (forest)
28	*Ur.* (*Ura.*) *longirostris* Leicester, 1908	14 Dec 2010	♀:11 ♂:4	Dry ice baited light trap	N/A	Sungei Buloh (forest)
29	*Ur.* (*Ura.*) *macfarlanei* Edwards, 1914	9 Feb 2011	♀:9 ♂:5	Larvae (reared)	Puddle, seepage, concrete tank	Bukit Panjang (forest/urban) (1° 22′ 12″ N 103° 46′ 12″ E) Murai (forest) Sembawang (forest/urban) (1° 26′ 60″ N 103° 49′ 48″ E) Tekong Island (forest)
30	*Ur.* (*Ura.*) *micans* Leicester, 1908	15 Dec 2010	♀:8 ♂:4	Dry ice baited light trap	N/A	Sungei Buloh (forest)
31	*Ur.* (*Ura.*) *prajimi* Peyton and Rattanarithikul, 1970	13–20 Jan 2011	♀:2 ♂:4	Larvae (reared)	Puddle, seepage	Woodlands (forest/urban)
32	*Ur.* (*Ura.*) *trilineata* Leicester, 1908	17 Feb 2011	♀:2 ♂:3	Dry ice baited light trap, larvae collection	Seepage, grassy pool	Woodlands (forest/urban) Mandai (forest) Lower Pierce (forest)
33	*Ve.* (*Har.*) *consonensis* (Reinert, 1973)	22 Apr 2003	♀:1 ♂:1	Larvae (reared)	Puddle	East Coast (urban)

*Deposited in the National Museum of Natural History (NMNH), Washington, D.C.

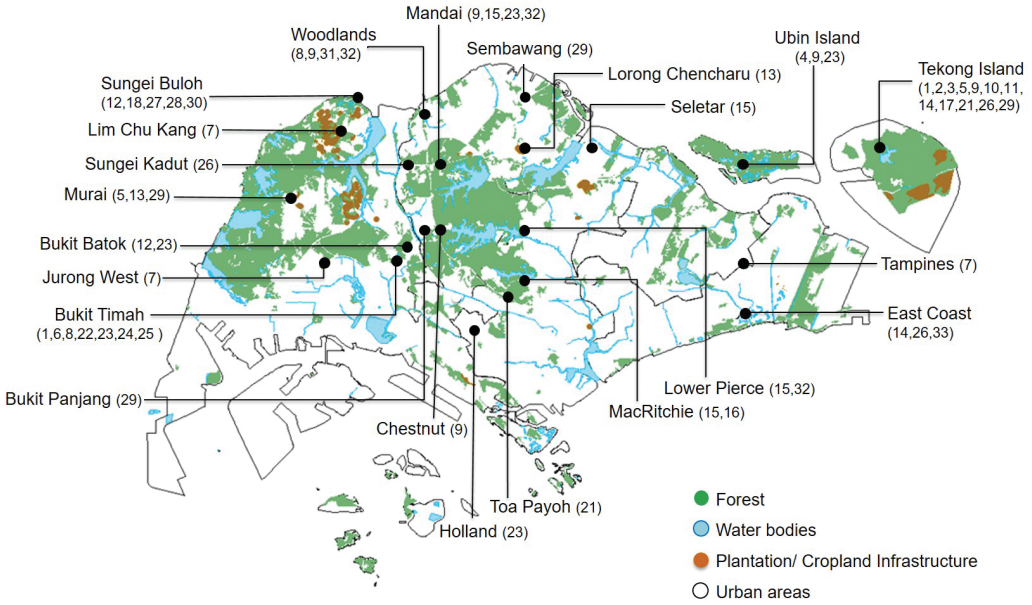

Fig. 2. Map of Singapore showing the locations of new species records. Numbers in parentheses indicate the new records in each location as shown in Table 2, first column.

et al. 1971). Species belonging to the *An. leucosphyrus* group have been incriminated as vectors of *P. knowlesi* (Wharton and Eyles 1961; Vythilingam et al. 2006, 2008; Tan et al. 2008). They were previously reported from Singapore (Colless 1956, Chew 1968), but have not been found since 1969, despite evidence of *P. knowlesi* transmission in Singapore (Ng et al. 2008). This could be due to the lack of sampling in the canopy as their natural monkey hosts are arboreal in nature (Faust and Dobson 2015). Hence, further epidemiological and entomological surveillance (including canopy sampling) needs to be done to incriminate the vector species for *P. knowlesi* in Singapore.

Concerning filariasis, *Culex quinquefasciatus* is incriminated as the primary vector of *Wuchereria bancrofti* in Singapore (Danaraj et al. 1958, as *Culex fatigans*, Colbourne and Ng 1972). There were also several local cases reported in the 1980s and the *Cx. quinquefasciatus* adults caught from the surroundings of patients' houses were positive for filarial worms (Lim and Phua 1997). Since then, there have been no further reports of local filarial disease, except for a recent imported asymptomatic microfilaremia in a relapsing *P. vivax* case (Chavatte and Jureen 2017).

As for Japanese encephalitis virus, *Culex tritaeniorhynchus* and *Culex gelidus* are considered vectors in Singapore, and field-caught samples have been found to be positive for the virus (Yin-Coggrave and Pong 1964). Japanese encephalitis virus was endemic in Singapore in the earlier years, but the incidence of reported cases has become very low since the complete phasing out of pig farming in 1992. In general, Japanese encephalitis virus is transmitted principally by *Cx. tritaeniorhynchus* (Koh et al. 2006) and less frequently by *Cx. gelidus* Theobald. In other countries, Japanese encephalitis virus has been detected in *Mansonia uniformis* (Theobald), *Culex bitaeniorhynchus* Giles, *Culex pseudovishnui* Colless, and *Culex vishnui* Theobald (Vythilingam et al. 1995).

Among the 25 vector species identified, nine species are recognized as vectors and two species have potential epidemiological importance in Singapore (Table 3). The remaining 14 species are known as vectors or potential vectors in neighboring countries, but have thus far not been implicated in disease transmission in Singapore. Nevertheless, their presence may pose risks to local transmission and should be assessed, in the event that their associated pathogens are introduced into the country.

This revised checklist provides the most updated species records in Singapore and should form the basis for future works, including the development of identification tools, research on mosquito bionomics and distribution, and risk assessment of mosquito–borne disease transmission.

Notes

1. *Aedes* (*Cancraedes*) *masculinus* Mattingly, 1958.
This species was initially reported in Singapore as *Aedes* (*Skusea*) *curtipes* Edwards, by Edwards (1928) and Edwards and Given (1928). Knight and Hull (1953) transferred *Ae. curtipes* from subgenus *Skusea* to subgenus *Cancaedes* of genus *Aedes*. Mattingly (1958) determined the species called *Ae. curtipes* in Singapore represented a new species, which he named and described *Ae. masculinus*.

2. *Aedes* (*Downsiomyia*) *leonis* Colless, 1958.
This species was originally reported from Singapore as *Aedes* (*Finlaya*) *niveus* ssp. *leonis* by Colless. Considering the recommendation of Dr. Kenneth L. Knight, who worked on the subgenus *Finlaya* species, including *Ae. niveus* for many years, Harrison et al. (1990) agreed with the recommendation and elevated this subspecies to species status. Subsequently, Wilkerson et al. (2015) placed it in subgenus *Downsiomyia* following the recognition of this group of species by Reinert et al. (2004).

3. *Aedes* (*Lorrainea*) *amesii* (Ludlow, 1903).
Edwards (1926) mistakenly described that larvae he thought were this species from Singapore. In 1928, he determined the larva figured in 1926 was actually a new species, which he described as *Aedes* (*Skusea*) *fumidus*. He also renamed the other specimens he described in 1926 as *Aedes* (*Skusea*) *furvus*, which was done because the first available synonym, *Stegomyia fusca* Leicester 1908, for *Ae. amesii*, was already occupied. Subsequently, *Ae. fusca* (Leicester)

Table 3. Mosquito species in Singapore and neighboring countries which are incriminated as vectors or with potential epidemiological importance in transmitting human diseases

Species	Pathogen[a]	Characteristics (Singapore)	Characteristics (neighboring countries)
Ae. (*Stg.*) *aegypti**	DENV	Naturally infected (Chan et al. 1971, Chung and Pang 2002, Lee et al. 2013)	Naturally infected in Malaysia (Ahmad et al.1997)
	CHIKV	Species found near patients (Ng et al. 2009) Susceptible to infection (Tan et al. 2017)	Naturally infected in Thailand (Thavara et al. 2009)
	ZIKV	Naturally infected (Ho et al. 2017)	Naturally infected in Malaysia (Marchette et al. 1969)
Ae. (*Stg.*) *albopictus**	DENV	Naturally infected (Chan et al. 1971, Chung and Pang 2002)	Naturally infected in Malaysia (Ahmad et al. 1997)
	CHIKV	Naturally infected (Ng et al. 2009)	
	ZIKV	Naturally infected (Ho et al. 2017)	Naturally infected in Thailand (Thavara et al. 2009)
Ae. (*Stg.*) *malayensis*	DENV	Local strain susceptible to infection (Mendenhall et al. 2017)	
	CHIKV	Local strain susceptible to infection (Mendenhall et al. 2017)	
An. (*Ano.*) *barbirostris* sensu lato	PF/PV		Naturally infected in Malaya and Thailand (Gater 1933, Rattanarithikul et al. 1996)
	BM, BT, WB		Possible vector in Indonesia (Lee et al. 1983)
An. (*Ano.*) *campestris*	PV		Naturally infected in Thailand (Coleman et al. 2002)
	BM		Naturally infected in Malaya (Reid 1968)
An. (*Ano.*) *hodgkini*	PF/PV		Naturally infected in Thailand (Coleman et al. 2002)
An. (*Ano.*) *letifer**	PF/PV/PM/PO	Species found near malaria patients (Chan et al. 1976)	Naturally infected by *Plasmodium* in Malaya (Reid 1968)
	BM		Naturally infected in Malaya (Reid 1968)
An. (*Ano.*) *sinensis**	PV	Species found near malaria patients (Ng et al., 2010); Local strain susceptible to infection (Pang et al. 2017)	
An. (*Cel.*) *annularis*	JEV		Naturally infected in Malaysia and Indonesia (Olson et al. 1985, Vythilingam et al. 1997)
An. (*Cel.*) *epiroticus**	PF/PV/PM/PO	Species found near malaria patients (Chan 1969); Dissection revealed only gametocytes (Goh 1983)	Naturally infected by *Plasmodium* in Malaya (Reid 1968)
An. (*Cel.*) *maculatus* sensu lato*	PF/PV/PM/PO	Species found near malaria patients (Chew 1968)	Naturally infected by *Plasmodium* in Malaysia (Reid, 1986, Kittayapong et al. 1992)
	BM		Vector in Malaysia (Cheong and Omar 1965)
	WB		Naturally infected in Malaysia (Reid 1968)
An. (*Cel.*) *kochi*	PK	Species found near malaria patients (Wong et al. 2011)	Susceptible to infection (Coatney et al. 1971)
An. (*Cel.*) *leucosphyrus* group[†]	PK		Naturally infected in Southeast Asia (Coatney et al. 1971)
An. (*Cel.*) *minimus*	PF/PV		Naturally infected in Thailand (Rattanarithikul et al. 1966, Coleman et al. 2002)
An. (*Cel.*) *tessellatus*	JEV		Susceptible to infection (Banerjee et al. 1977)
An. (*Cel.*) *vagus*	JEV		Naturally infected in Indonesia (Olson et al. 1985)
Ar. (*Arm.*) *subalbatus*	BP		Naturally infected in Malaysia (Muslim et al. 2013)
Cx. (*Cux.*) *fuscocephala*	JEV		Naturally infected in Thailand (Gould et al. 1974)
Cx. (*Cux.*) *gelidus**	JEV	Naturally infected (Yin-Coggrave and Pong 1964)	Naturally infected in Thailand (Gould et al. 1974, Gingrich et al. 1992)
Cx. (*Cux.*) *quinquefasciatus**	WB	Naturally infected (Lim and Phua 1997)	Local strain susceptible to infection in Malaysia (Vythilingam et al. 2005)
Cx. (*Cux.*) *tritaeniorhynchus**	JEV	Naturally infected (Yin-Coggrave and Pong 1964)	Naturally infected in Philippines and Indonesia (Olson et al. 1985)
Cx. (*Cux.*) *vishnui*	JEV		Naturally infected in Malaysia (Vythilingam et al. 1995)
Ma. (*Man.*) *annulata*	BM		Naturally infected in Malaya (Wharton 1962)
	BP		Naturally infected in Malaya (Muslim et al. 2013)
Ma. (*Man.*) *bonneae*	BM		Naturally infected in Malaya (Wharton 1962)
	DI		Naturally infected in Malaya (Wharton 1962)
Ma. (*Man.*) *uniformis*	BM		Naturally infected in Malaya (Wharton 1962)
	DI		Naturally infected in Malaya (Wharton 1962)

[a]Arboviral diseases: CHIKV (Chikungunya virus), DENV (Dengue virus), JEV (Japanese encephalitis virus), ZIKV (Zika virus). Filariasis: BM (*Brugia malayi*), BP (*Brugia pahangi*), BT (*B. timori*), DT (*Dirofilaria immitis*), WB (*Wuchereria bancrofti*). Malaria: PF (*Plasmodium falciparum*), PK (*Plasmodium knowlesi*), PM (*Plasmodium malariae*), PO (*Plasmodium ovale*), PV (*Plasmodium vivax*).

*Species which are recognized as vectors in Singapore based on previous studies; however, some species do not have available natural infection information or published records.

[†]Although there have been records of *An.* (*Cel.*) *leucosphyrus* group in Singapore (Colless 1956, Chew 1968), these were not identified to species and are not included in the checklist (Table 1). However, the group remains a probable vector of *P. knowlesi* in Singapore and is thus included in Table 3.

and *Ae. furvus* Edwards were both synonymized (Stone et al. 1959) under *Ae. amesii*. Fortunately, Mattingly (1959) was able to obtain sufficient specimens to determine that both *Ae. amesii* and *Ae. fumidus* occurred in Singapore. Thus, the first record of *Ae. amesii* collected in Singapore was the specimens mistakenly named *Ae. furvus* by Edwards (1928), and not the *Ae.* (*Lor.*) *amesii* specimens reported as a new record by Jeffery et al. (2010).

4. *Aedes* (*Phagomyia*) near *khazani* Edwards, 1922.
During this study, a single female of this species from Singapore was located and examined in the Lee Kong Chian Natural History Museum (LKCNHM), Singapore. Although this female is clearly similar to *Ae. khazani*, there are slight differences from the original description based on Indian specimens and also specimens from Thailand (Rattanarithikul et al. 2010).

5. *Aedes* (*Stegomyia*) *malayensis* Colless, 1962.
This species was initially recorded in Singapore as *Aedes* (*Stegomyia*) *hensilli* Farner, by Colless (1957c). Colless (1962) recognized that he misidentified those specimens, and that they were part of the *Aedes scutellaris* group. Consequently, he named them *Ae.* (*Stg.*) *scutellaris* ssp. *malayensis*. Huang (1972) elevated this subspecies to species status.

6. *Anopheles* (*Anopheles) barbirostris sensu lato*.
Colless (1959a) recorded this species (as *An. barbirostris*) collected in net-traps in Singapore. Recently, at least four new cryptic species have been described in the *An. barbirostris* complex (Townson et al. 2013, Taai and Harbach 2015) and one new species remains undescribed (Saeung et al. 2008). This raises the number of species in the *An. barbirostris* subgroup (Harbach 2013) to seven species. Currently, morphological identification of females of the *An. barbirostris* Subgroup is unreliable. Thus, the identity of the specimens that Colless collected is unknown, as is the identity of specimens recently collected by Lee et al. (2012) on Ubin Island.

7. *Anopheles* (*Anopheles*) *fragilis* (Theobald, 1903).
This species is recorded in Singapore for the first time in Table 2. The fine aciculae on the middle portion of larval seta 2-C are difficult to see without >50× magnification, but are diagnostic for *An. fragilis* regardless of the variable 2-C single to trifid branched stem illustrated in Reid (1968, p. 235) and Rattanarithikul et al. (2006a, p. 98). We suspect that Colless (1957a) did not see the minute aciculae on larval seta 2-C of the specimens he identified as *Ae. aitkenii* James, whose distribution has been restricted to the Indian Subregion (Harrison and Scanlon 1975) of the Oriental Region.

8. *Anopheles* (*Anopheles*) *paraliae* Sandosham, 1959.
This species was originally described as a subspecies in Malaya of *Anopheles* (*Ano.*) *lesteri* Baisas and Hu described from the Philippines. Harrison et al. (1990) elevated *An.* (*Ano.*) *lesteri* ssp. *paraliae* to species status based on its distribution in Southeast Asia and basic biological differences of this species from *An. lesteri*. *Anopheles paraliae* is a lowland coastal species whose larvae are usually found in brackish water, whereas *An. lesteri* from the Philippines extends north onto mainland Asia to northern China, Korea, and Japan. Larvae of the latter species are found in freshwater in the Philippines and far inland in China. Recently, Taai et al. (2013) provided evidence suggesting that these two taxa are very closely related or possibly conspecific; however, they refrained from synonymizing *An. paraliae* under *An. lesteri* until further work was conducted. Behavioral and biological differences play important roles in the process of speciation. Comparing two species from two very widely separated sites (thousands of miles in this case) does not prove that they will be compatible where they occur near to each other. We contend that crossing experiments and/or rDNA ITS2 molecular analysis should be conducted between *An. paraliae* from Malaysia, Thailand, or Vietnam and *An. lesteri* from near the type locality in the Philippines instead of comparing a strain of *An. paraliae* from southern Thailand and *An. lesteri* from South Korea. Thus, we will list this species in Singapore until this taxonomic problem is resolved.

9. *Anopheles* (*Anopheles*) *nitidus* Harrison, Scanlon, and Reid, 1973.
Colless (1957a) recorded this species in Singapore as *Anopheles* (*Ano.*) *indiensis* Theobald. Harrison et al. (1973) determined that *An. indiensis* of Reid (1953, 1968) did not occur in Madras, India, the type locality of *An. indiensis* Theobald. Furthermore, the type of *An. indiensis* is lost and no other specimens have been found. Thus, Harrison et al. (1973) synonymized *An. indiensis* with *Anopheles nigerrimus* Giles, 1900, and renamed *An. indiensis* of Reid in Malaysia, Singapore, and Thailand as *An. nitidus*. Additional information about this species is provided in Harrison and Scanlon (1975).

10. *Anopheles* (*Cellia*) *epiroticus* Linton and Harbach, 2005.
Initially, this species was reported to be common in Singapore by James and Stanton (1912, as *ludlowi* (sic) Theobald). Rodenwaldt (1925) determined that the name *ludlowi* should be applied to a Philippine species and the correct name for the species in Malaya (which included Singapore at that time) was actually *Anopheles sundaicus* (Rodenwaldt 1925). Reid (1968) briefly discussed differences he recognized between *An. sundaicus* from Peninsular Malaya and those from the Malay States on the Island of Borneo. Linton et al. (2005) designated a neotype for *An. sundaicus* from Sarawak, Borneo, and described a new species, *An. epiroticus* Linton and Harbach, based on those mainland specimens previously called *An. sundaicus* in Cambodia, Peninsular Malaysia, Thailand, and Vietnam. They also retained the name *An. sundaicus* for the species in East Malaysia. The accuracy of this identification was confirmed by the ITS2 sequences of Singapore specimens in the collections of the Natural History Museum, London (Linton, personal communication). Accordingly, we accept *An. epiroticus* as the species in Singapore, which is only 1.6 km from Peninsular Malaysia.

11. *Anopheles* (*Cellia*) *maculatus sensu lato*.
The importance of *An. maculatus* as a vector of malaria in Malaya was documented by Reid (1968). Reid (1970) suggested that *An. maculatus* may be a complex of species that could not be identified by morphology. Chan (1969) documented *An. maculatus* in Singapore, but by that time it was in low numbers. Green et al. (1985) discovered that at least three cryptic species were masquerading under the name *An. maculatus*. In that study, it was determined that Form B occurred primarily in Thailand, whereas Form E occurred primarily in Malaysia. Rattanarithikul and Green (1986) formally recognized and described two new species in the *An. maculatus* group. Kittayapong et al. (1992) conducted a malaria study in Perak, Malaysia, and the primary vector was Form E, with a high percentage of the studied specimens infected with one to three human malaria parasites. By 2007, eight species were recognized in the *An. maculatus* group (Walton et al. 2007), but species status for Form E remains unresolved. Although we suspect *An. maculatus* Form E is what occurs in Singapore, this has not been proven.

12. *Anopheles* (*Cellia*) *subpictus* Grassi, 1899.
This species was recorded in Singapore as *Anopheles rossii* Giles, by Leicester (1908). *Anopheles rossii* was recognized as a junior synonym of *An. subpictus* by Edwards (1932).

13. *Armigeres* (*Armigeres*) *subalbatus* (Coquillett, 1898).
Colless (1957a) reported *Armigeres obturbans* (Walker) as one of the two common species in Singapore. Macdonald (1958) listed "*Ar. obturbans* (= *subalbatus*)" ranging from India through the Malay Archipelago to New Guinea and northern Australia. Ramalingam (1987) and Jeffery et al. (2010) clarified the *Ar. obturbans* versus *Ar. subalbatus* records, pointing out that although Lee et al. (1988a) determined that *Ar. obturbans* is a valid species, it is restricted to the island of Sulawesi (= Celebes) and *Ar. subalbatus* is the correct name for the common Southeast Asian species previously called *Ar. obturbans*. Recently Lee et al. (2012) collected nine females of *Ar. subalbatus* on Ubin Island, Singapore.

14. *Coquillettidia* (*Coquillettidia*) *crassipes* (van der Wulp, 1881).
Edwards and Given (1928) illustrated the antenna of a larva collected in Singapore that they cautiously called *Taeniorhynchus* (*Coquillettidia*) sp., which they said was probably *Taeniorhynchus brevicellulus* Theobald or *Taeniorhynchus ochraceus* Theobald 'both of which were found to be common in Singapore'. Brug and Bonne-Wepster (1947) reported *Mansonia crassipes* in Singapore. Wharton (1962) determined that the unidentified larval description and illustration from Singapore (Edwards and Given 1928) was *Ma.* (*Coq.*) *crassipes*. *T. brevicellulus* is now recognized as a junior synonym of *Cq. crassipes* (Stone et al. 1959, Knight and Stone 1977). Lee et al. (2012) collected two females of *Cq. crassipes* on Ubin Island, Singapore.

15. *Culex* (*Culex*) *alis* Theobald, 1903.
Colless (1957b) first recorded this species in Singapore as *Culex* (*Culex*) *litoralis* Bohart. Sirivanakarn (1976) examined the specimens Colless identified from Pulau Hantu, Singapore and determined that they are *Culex alis*.

16. *Culex* (*Culex*) *quinquefasciatus* Say, 1823.
For years, *Culex* (*Culex*) *fatigans* Wiedemann was the name used for this species, particularly in the Orient, and Colless (1957b) considered this species common in Singapore. However, Sirivanakarn (1976) determined that *Cx. fatigans* is a junior synonym of *Cx. quinquefasciatus*. Danaraj et al. (1958) presented an overview of the importance of this vector species in the transmission of filariasis in Singapore. Lee et al. (2012) collected this species on Ubin Island, Singapore.

17. *Culex* (*Culex*) *vishnui* Theobald 1901.
Colless (1957a,b) recorded this species, as *Culex* (*Culex*) *annulus* Theobald as common in Singapore. Reuben (1969), after having the type specimens for these two species reexamined at the British Museum, determined that *Cx. annulus* is a junior synonym of *Cx. vishnui*, and Sirivanakarn (1976) agreed with this finding, but considered most of the females in the Vishnui Subgroup to be inseparable.

18. *Culex* (*Eumelanomyia*) *brevipalpis* (Giles, 1902).
Theobald (1901) first described this species as *Culex longipes*, with the type specimen from Singapore, but this name was preoccupied by *Cx. longipes* Fabricius, and not available for use. Thus, the next available name was *Stegomyia brevipalpis* Giles, which was corrected to *Cx. brevipalpis* by Theobald (1903). In the world catalogs of mosquitoes (Stone et al. 1959, Knight and Stone 1977), *Cx. longipes* is recognized as a junior synonym of *Cx. brevipalpis* and Theobald's type for *Cx. longipes* is located in the Natural History Museum, London (Sirivanakarn 1972). Five larvae of this species were recently collected on Ubin Island, Singapore by Lee et al. (2012).

19. *Culex* (*Lophoceraomyia*) *minor* (Leicester 1908).
Edwards (1928) and Edwards and Given (1928) recorded *Cx. minor* from rock pools in Singapore. More recently there has been a problem separating *Cx. minor* from *Culex bicornutus*. Colless (1965) examined 114 males and found *Cx. minor* specimens from Singapore, and said that *Cx. bicornutus* 'probably' occurred there. However, Sirivanakarn (1977) apparently overlooked the record of *Cx. minor* in Singapore by Colless (1965). Because of the larval habitat differences for these two species discussed in Colless (1965), we have decided to follow Colless and record *Cx. minor* from Singapore.

20. *Culex* (*Lophoceraomyia*) *reidi* Colless 1965.
Edwards and Given (1928) recorded this species in Singapore as *Culex quadripalpis* Edwards. Colless (1965) determined that the larval specimens identified as *Cx. quadripalpis* by Edwards and Given were actually a new species, which he described as *Cx. reidi* based on Singapore specimens.

21. *Heizmannia* (*Heizmannia*) *scintillans* Ludlow, 1905.
This species was first recorded in Singapore as a larva of *Heizmannia funerea* (Leicester) by Edwards and Given (1928). Mattingly (1957b) examined the larva and determined it was *Hz. scintillans*, not *Hz. funerea*. Also, Mattingly (1970) examined additional specimens of *Hz. scintillans* from Singapore.

22. *Mimomyia* (*Etorleptiomyia*) *luzonensis* (Ludlow, 1905).
Leicester (1908) established the first record of this species in Singapore when he described *Etorleptiomyia completiva*, which is now considered to be a junior synonym of *Mimomyia luzonensis*. Edwards and Given (1928) described a larva of this species, as *Mimomyia* species, but being uncertain they suspected it was *Ficalbia minima* (Theobald). Mattingly (1957a) provided an enhanced description for *Mi. luzonensis*.

23. *Orthopodomyia albipes* Leicester, 1904 (in Theobald, 1904).
The three species, *Orthopodomyia albipes*, *Orthopodomyia andamanensis* and *Orthopodomyia anopheloides*, are extremely difficult to distinguish without reared specimens that also have associated larval and pupal exuviae. Zavortink (1968) resolved some, but not all, of the identification problems and documented *Or. andamanensis* and *Or. anopheloides* in Singapore, but not *Or. albipes*. Finally, Zavortink (1971) found one larva that he identified as *Or. albipes* from Singapore.

24. *Orthopodomyia anopheloides* Giles, 1903 (in Thomson, 1903).
Zavortink (1968) determined that the Edwards (1926) record of *Orthopodomyia maculipes* Theobald in Singapore was a specimen of *Orthopodomyia anopheloides*.

25. *Toxorhynchites* (*Toxorhynchites*) *splendens* (Wiedemann, 1819).
Brunetti (1920) recorded this species in Singapore. However, Lee et al. (1988b) considered the record of *Toxorhynchites speciosus* (Skuse) in Singapore by Colless (1957a) a 'probable' misidentification of *Tx. splendens*.

26. *Tripteroides* (*Rachionotomyia*) *tenax* (de Meijere, 1910).

Edwards (1926) and Edwards and Given (1928) reported *Rachionotomyia aranoides* (Theobald) as very common in pitcher plants in Singapore. However, Mattingly (1981) determined that *Tripteroides aranoides* larvae were found in bamboo habitats, whereas *Tp. tenax*, a junior synonym of *Tp. aranoides*, was the species in pitcher plants in Singapore. Accordingly, he elevated *Tp. tenax* to species status. Based on these actions, *Tp. aranoides* has been replaced by *Tp. tenax* and is no longer recognized in Singapore.

27. *Uranotaenia* (*Pseudoficalbia) moultoni* Edwards, 1914.
Based on larvae collected by Dr. Given, Edwards (1926) and Edwards and Given (1928) recorded this species in Singapore as *Uranotaenia brevirostris* Edwards. Barr and Chellapah (1963) also recorded *Ur. brevirostris* in Singapore, in pitcher plants. However, Peyton (1972) synonymized *Ur. brevirostris* with *Ur. moultoni*.

28. *Verrallina* (*Verrallina*) *butleri* (Theobald 1901).
Edwards and Given (1928) collected larvae of this species in potholes and crab holes in an uncut mangrove area and identified them as *Aedes* (*Aedes*) *umbrosus* Brug. Knight and Hull (1953) synonymized *Ae. umbrosus* with *Ve. butleri*. Reinert (1974) recorded specimens of *Ve. butleri* from Singapore, and more recently Lee et al. (2012) collected this species on Ubin Island, Singapore.

Excluded Species

1. *Aedes* (*Cancraedes*) *curtipes* Edwards, 1915.
Apiwathnasorn (1986) recorded this species in Singapore. However, it was originally described based on a single female from Sarawak, Malaysia (as Borneo). Later, Edwards (1928) described a male from Singapore as *Ae. curtipes* and Edwards and Given (1928) identified larvae and pupae from Singapore as this species. Mattingly (1958) discovered the male identified as *Ae. curtipes* by Edwards was not the same species as the female holotype of *Ae. curtipes* from Sarawak, and the male Edwards identified, and the larvae and pupae identified by Edwards and Given, represented a new species which he described as *Aedes* (*Cancraedes*) *masculinus* (Note 1). Mattingly (1958) listed the distribution of *Ae. curtipes* as Sarawak (as Borneo), Sulawesi (as Celebes) and Luzon, Samar, and Mindanao in the Philippines. He also said this species 'is quite distinct and does not occur in Malaya or Singapore.' Therefore, we have deleted *Ae. curtipes* from the list of Singapore species.

2. *Aedes* (*Fredwardsius*) *vittatus* (Bigot, 1861).
Apiwathnasorn (1986) recorded this species in Singapore. It is widely distributed from France, throughout Africa, Aden, Yemen, India, across Southeast Asia to Vietnam, and in China. But according to Huang (1977) and Reinert (2000), it does not occur further south of northern Peninsular Malaysia (Penang and Langkawi Island) in Southeast Asia. Thus, we have deleted *Ae. vittatus* from the list of Singapore species.

3. *Aedes* (*Stegomyia*) *aegypti* var. queenslandensis (Theobald, 1901).
Aedes aegypti (L.) and *Aedes aegypti* var. queenslandensis were recorded in Singapore by Apiwathnasorn (1986). However, Lee et al. (1987) synonymized the varietal name queenslandensis under *Ae. aegypti,* and this change was entered into the world catalog of mosquitoes (Knight and Stone 1977, Ward 1992, p. 190). Accordingly, the name *queenslandensis* has no official status other than being a junior synonym of *Ae. aegypti*. Jeffery et al. (2010) adequately explained this, but it was overlooked by Chan et al. (2014) who again used *queenslandensis* as an official varietal name. We disagree with this use of the name because the name was not available for use without formal justification; thus, it is not included in the list of Singapore mosquito taxa.

4. *Aedes* (*Stegomyia*) *hensilli* Farner, 1945.
Apiwathnasorn (1986) did not record this species in Singapore, but Colless (1957c) reported it based on specimens from Pulau Hantu, Singapore. However, during revisionary work on the Scutellaris Group of Southeast Asia, Huang (1971) redescribed *Aedes scutellaris malayensis* and in 1972 discovered that Colless had misidentified *Ae. scutellaris malayensis* in Singapore as *Ae. hensilli* (Note 5). This discovery means *Ae. hensilli* is not found anywhere near Singapore, because Knight and Stone (1977) listed the distribution of *Ae. hensilli* as limited to the Caroline and Palau Islands in the South Pacific Region.

5. *Anopheles* (*Anopheles*) *aitkenii* James, 1903.
Apiwathnasorn (1986) did not list *An. aitkenii* in Singapore, but Colless (1957a) did. Although Harrison and Scanlon (1975) restricted the distribution of this species to the Indian Region of Asia, there are three other species of the Aitkenii Group in Peninsular Malaysia that might be misidentified as *An. aitkenii,* and also may possibly occur in Singapore: *Anopheles aberrans* Harrison and Scanlon, 1975; *Anopheles bengalensis* Puri, 1930; and *Anopheles fragilis* (Tables 1 and 2). Currently, we can vouch for only one member of the Aitkenii Group in Singapore, i.e., *An. fragilis*, which is a new record for Singapore (Tables 1 and 2). Although discussed earlier (Note 7), we suspect that *An. fragilis* was the species Colless misidentified, but this cannot be proven. Both *An. aberrans* and *An. bengalensis* lack the minute aciculae on larval seta 2-C, and both have variable branching of 2-C, i.e., *An. aberrans* (2–13 branches) and *An. bengalensis* (single to nine branches) (Harrison and Scanlon 1975). Thus, larval specimens of these two species with head seta 2-C bifid could be confused with *An. aitkenii*.

6. *Anopheles* (*Cellia*) *minimus*, Theobald, 1901.
Reid (1968) and Harrison (1980) agreed that on mainland Southeast Asia, this species does not extend further south than the northern state of Perlis in Peninsular Malaysia. Thus, Apiwathnasorn (1986) erred in recording *An. minimus* from the nonmainland countries of Indonesia, Singapore, Philippines, and the Island of Borneo (including Brunei, Kalimantan, Sabah, and Sarawak). Harrison (1980, pp. 19–20) determined that the species likely to occur in these last named areas is *Anopheles flavirostris* Ludlow, 1914; however, *An. flavirostris* has not been reported in Singapore. Also, we have not found a publication, other than Apiwathnasorn (1986) reporting *An. minimus* in Singapore. For these reasons, *An. minimus* is not included in the Singapore list of species.

7. *Armigeres* (*Armigeres*) *obturbans* (Walker, 1859).
Apiwathnasorn (1986) did not record this species in Singapore. *Ar. obturbans* was described from Sulawesi, and currently its distribution is restricted to Sulawesi. However, for many years, this species was considered the common peridomestic *Armigeres* species in the Australiasian and Oriental Regions, and was recorded in Singapore by Colless (1957a). Thurman (1959), Stone et al. (1959), and Knight and Stone (1977) considered this name a 'doubtful name' (= *nomen nudum*) because the type specimen was considered lost and a precise identification of the species was impossible. Ramalingam (1987) also considered this species a *nomen nudum*, and added that *Armigeres subalbatus* (Note 13) was the common peridomestic Oriental species extending from Japan, Pakistan, India, Sri Lanka, and through the Southeast Asian countries. Lee et al. (1988a) reported the female

holotype of *Ar. obturbans* had been found and they provided a character found on the holotype that is distinct from other known *Armigeres*, but they left it as a *nomen nudum*. We consider *Ar. obturbans* a valid species based on the distinguishing character described by Lee et al. (1988a). Regardless, *Ar. obturbans* is not included in the Singapore list of species and is restricted in distribution to Sulawesi, as suggested by Thurman (1959) and confirmed by Lee et al. (1988a).

8. *Culex* (*Culex*) *litoralis* Bohart and Ingram, 1946.
This species was recorded in Singapore by Colless (1957b) and added to the distribution of this species in the world catalog of mosquitoes (Knight and Stone 1977). After Colless established this record, it was determined that it was a misidentification of *Cx. alis* (Note 15). Determining that *Cx. litoralis* did not occur in Singapore solidified the Central and Western Pacific distribution of *Cx. litoralis*, i.e., Mariana Islands, New Guinea, Samoa Islands, and Society Islands. Thus, Apiwathnasorn (1986) erred in recording this species in Singapore.

9. *Culex* (*Culex*) *mimeticus* Noe, 1899.
Although Apiwathnasorn (1986) recorded this species in Singapore, we have been unable to find published information documenting this report. According to Sirivanakarn (1976), *Cx. mimeticus* is widely distributed from southern Europe and northern Africa across the Middle East and northern India, Tibet (up to 3,050 m), China, Taiwan, Japan, Korea, and to high elevations sites in Myanmar, Peninsular Malaysia, and Vietnam. The southern-most collection appears to be in Cameron Highlands, Pahang State, Peninsular Malaysia, in a rock pool at 1,450 m (Macdonald 1957). Sirivanakarn said 'it appears to be restricted to high elevations in India, Burma (Barraud 1934), Southeast Asia and other adjacent areas'.

According to Jeffery et al. (2010), the highest elevation in Singapore is 166 m. However, specimens of *Cx. mimeticus* from Singapore were located in the National Museum of Natural History, Smithsonian Institution, Washington, D.C. and their identification is questionable. Until their identification is confirmed using the recent key of Rattanarithikul (2005), *Cx. mimeticus* is not listed as a Singapore species.

10. *Culex* (*Culex*) *whitmorei* (Giles, 1904).
Apiwathnasorn (1986) recorded this species in Singapore, but we have been unable to verify this record. It was reported from Peninsular Malaya (Macdonald 1957), and this was included in the world catalog (Knight and Stone 1977). But, in Bram (1967) and the very thorough revision of *Culex* (*Culex*) in Southeast Asia (Sirivanakarn 1976), Singapore is not included in the distribution of this species. Thus, we consider the record of *Cx. whitmorei* in Singapore an error.

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