Aedes albopictus - (Asian) Tiger Mosquito

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Overview
*Aedes albopictus* is a mosquito (Culicidae) characterized by its stark black and white colouration. Also known as the forest mosquito or the tiger mosquito, it is so named for the black and white stripes on its body and legs, similar to a tiger.

This mosquito species is famous in Singapore for being the dreaded "dengue mosquito". There are many campaigns to limit the spread of dengue, many of which focus on vector control (i.e. limiting the spread of the tiger mosquito). Some of these campaigns include the 5-Step Mozzie Wipeout, as well as providing information about dengue clusters in Singapore or simply increasing awareness of how dengue spreads (via *Aedes* mosquitoes) and how to recognise the mosquito vector. More information is provided in the section "Campaigns against dengue".

There are a few closely related species that look superficially similar, however; care should be taken to ensure that species are properly distinguished when examining specimens. For example, Figures 2 and 3 show *Aedes albopictus* and *Aedes aegypti* respectively. Both mosquitoes look superficially similar without further inspection.

![Fig. 2: Aedes albopictus on human skin. Source: James Gathany, CDC. Public domain image](image1)

![Fig. 3: Aedes aegypti on human skin. Source: James Gathany, CDC. Public domain image](image2)
Native to Asia, this mosquito has spread rapidly all over the world in the past few decades. The spread was assisted mainly by increased transport of goods across the globe, although some evidence exists that it may outcompete native mosquitoes. Mosquitoes are well known for the itchiness that results after they bite; in this regard *Ae. albopictus* generally bites (and flies) in the daytime, as well as dusk and dawn. This is a nuisance, except that the Asian tiger mosquito is a vector for many pathogens. These include the viruses causing dengue, chikungunya and yellow fever, as well as the filarial nematodes responsible for heartworm.

Name and description

In 1894, Frederick A. Askew Skuse scientifically described this mosquito and named it *Culex albopictus* (Latin for "white painted") (Figure 4). It was later reassigned to the genus *Aedes* in 1920, although recent phylogenetic analyses may result in reclassification as *Stegomyia albopicta*. Systematicists continue to debate the reclassification.
THE BANDED MOSQUITO OF BENGAL.

BY P. A. A. SKUSE, ENTOMOLOGIST TO THE AUSTRALIAN MUSEUM, SYDNEY.

*Culex albopticus*, Skuse, Sp. nov.

*Female.*—Length of antennae 1·50 mm.; expanse of wings 2·60 x 0·50 mm.; length of body 8·3·50 mm.

Black with silvery-white markings. Antenna somewhat shorter than the proboscis, joints of the scapus with silvery scales. Head with silvery-white scales on the front and sides. Proboscis five times the length of the palpi, the latter tipped with silvery scales. Thorax traversed by a line of silvery scales for rather more than its anterior half; pleurs spotted with silvery white; scutellum with minute silvery hairs. Abdomen twice the length of the thorax, the segments bordered with a narrow band of silvery scales, and with lateral silvery spots. Legs: femora with a silvery line beneath and slightly tipped with silvery scales; tarsi, the first two joints in the fore and intermediate legs with a narrow silvery-white ring at the base; broad rings at the base of all the joints of the tarsi in the hind legs, the last joint entirely white. In the hind-legs the tibia about one-third longer than the metatarsus. Wings the length of the abdomen, pellucid, iriscent, the veins clothed with linear black scales. Auxiliary vein joining the costa at a point a little before the posterior branch of the fifth longitudinal vein; middle cross-vein indistinct, shorter than the posterior cross-vein, situated beyond it scarcely a distance equal to twice the length of the latter; first sub-marginal cell longer and narrower than the second posterior cell, their bases opposite or almost opposite; anterior branch of the fifth longitudinal vein originating about midway between the origin of the second longitudinal vein and the tip of the sixth longitudinal.

*Hab.*—Bengal.

*Type in Australian Museum.*

Three specimens received from Mr. E. C. Cotes, who informs me that this insect is a great nuisance in Calcutta. The species is allied to *C. nosteripta*, Sk., from New South Wales, and *C. bancrofti*, Sk., from Queensland, but the silvery ornamentation of the thorax in the latter is of an elaborate pattern ([Proc. Linn. Soc. N. S. W.], Vol. III (Ser. 2), 1888, pp. 1738, 1749).
Aedes albopictus was first described in Bengal, although it was accepted to be present in the general South-East Asian area as well. A highly invasive species, Ae. albopictus has since spread almost worldwide. This was facilitated at least in part by the used tire trade; as a floodwater species, rainwater collecting in the tires provide prime breeding grounds, and eggs laid on tires could easily escape notice. Climate change is also predicted to further increase the ability of Ae. albopictus to invade new areas.

Ae. albopictus can be found in a wide range of habitats. While it is commonly known as a forest mosquito, Ae. albopictus has adapted to occurring in suburban and even dense, urban areas like Rome. In fact, compared to rural and suburban areas, urban locations had shorter larval development time, increased density of larval habitats. Mosquito adults in urban areas also had a longer lifespan as well as higher emergence rates. In a Singaporean context, mosquito breeding sites were mostly artificial, with one study finding 96% of breeding habitats being "domestic containers".

Mosquitoes are famous for biting and feeding on human blood. Most mosquito species are obligatory blood feeders, although in these species it is the female who is responsible for seeking a host to feed off. Males are generally thought to feed on nectar or plant juices and water before mating and dying. Ae. albopictus females require a blood meal for eggs to develop. Thus, females have to seek out a viable host to bite. Although blood contains various chemicals and substances, protein is the most important substance in the blood for the mosquito. Ae. aegypti.

Ae. albopictus is highly anthropophilic; given equal availability of five hosts (calf, dog, chicken, goat and human), females still preferred human blood. Larvae feed on detritus in water bodies; small pieces of algae or leaf litter.

Females display non-specific searching behaviour until host specific substances are detected, such as carbon dioxide, octenol and L-lactic acid. The mosquito then targets the host more specifically, using the host specific cues to locate its next blood meal.

Fig. 4: The original description of Aedes albopictus, (first named as Culex albopictus) by Skuse in 1894). The banded mosquito of Bengal. Indian Museum Notes 3(5):20. Public domain image
*Ae. albopictus* is primarily active in the daytime, with peak activity around dusk and dawn. Females are mainly exophilic (rest outdoors) and exophagic (feed outdoors). In regions with seasonal changes, *Ae. albopictus* displays significant seasonal variances in bite rates. Mosquitoes feed by piercing the skin of the host, probing for a suitable capillary and extracting blood from it. The mosquito starts by pushing its proboscis into the skin, anchoring the tip of the feeding fascicle (structures in the proboscis used to feed). Two microsawtoothed maxillas are next used to saw deeper into the skin, with the frequency of oscillations of the maxillas decreasing as depth of penetration decreased. This process is usually complete within 10-20 seconds, with the mosquito drawing blood for about 2-3 minutes under laboratory conditions. While mosquito saliva is known as the itch-causing agent, it actually plays a few roles in assisting mosquitoes in getting a successful blood meal. Mosquito saliva contains various anticouagulants, apyrases and enzyme-glucosidase. Mosquito saliva also acts as a way to locate blood vessels; compounds in saliva may promote haematoma formation, and increased amounts of blood in that area may lead to increased blood feeding success.

Video 1 shows the probing action of *Anopheles gambiae*, as it searched for a suitable capillary under the skin to feed from.

**Vid. 1: Video showing Anopheles gambiae probing and feeding from a capillary.** Obtained from YouTube under fair use. Credit: Choumet et al, PLOS 2012

*Ae. albopictus* larvae feed on organic detritus, and play a part in leaf litter breakdown and decay. They feed by gathering detritus into their mouthparts (Video 2). *Ae. albopictus* larvae are classified as "shredders" and "collector-gatherers". Pupae do not feed.

**Vid. 2: Video showing Ae. albopictus larvae feeding on organic detritus.** Obtained from YouTube under fair use. Credit: Sean McCann

Mating Behaviour and Oviposition

Newly emerged *Ae. albopictus* mosquitoes are ready to mate after 24 hours. Prior to mating, the male chases the female, from behind, lateral or even from the front. Females reject males by kicking or simply flying away. If genital contact is allowed, copulation occurs. If mating is successful (usually if copulation lasts longer than 30s), sperm will be transferred from the male to the female. Sperm is stored in the spermathecae of the female; eggs are only fertilized as they are laid. Dissection of the spermathecae can be performed to investigate if successful sperm transfer has occurred; if so, spermatozoa can be seen in the spermathecae (Figure 5).
Ae. albopictus is a floodwater species; females lay eggs just above the waterline. These eggs, when first laid, are white, but slowly turn black as they dry and harden (Figure 6 & 7). Eggs laid this way can be viable for almost 6 months. The eggs stay dormant in this state until the water level rises, usually due to rains or floodwaters covering the eggs. Low oxygen levels are a hatching stimulus for the eggs. In some temperate countries, combinations of short light periods and low temperatures may result in Ae. albopictus females laying diapausing eggs. These eggs are able to survive winters and stay viable until spring.

Development

The entire life cycle of Ae. albopictus potentially takes as little as 7-9 days: while development is dependent on temperature, larvae usually pupate in about 5-10 days, and the pupal stage lasts about 2 days. The lifespan for adults is about 3 weeks.

About 150 to 250 eggs may be laid per oviposition, with about 1-4 ovipositions for each female. The eggs do not all hatch at the same time; Ae. albopictus eggs display scattered, or installment hatching. This phenomenon in Aedes eggs was first described by Gillett in 1955, and it was subsequently shown that bacteria density on the surface of egg affects the egg hatching process. The more the bacteria, the smaller the stimulus required to hatch the egg; similarly, eggs laid in clumps were much more likely to hatch together due to the generally higher bacterial density. Even larvae from earlier hatched eggs feeding on bacteria growth of unhatched eggs was enough to delay hatching. The results have been recently reproduced; unfortunately, the process of how bacteria affect hatching of Aedes eggs is still unclear, and warrants more study.
Predation & Parasitism

The larvae of mosquitoes are commonly predated upon by various fish. In fact, guppies (*Poecilia reticulata*) have been studied as a potential way to control mosquito populations [40]. Copepods have also been studied as potential biological controls (Video 3) [41], as well as other, predatory species of mosquitoes like *Toxorhynchites splendens* [42]. (F
Odonate nymphs also predate on mosquito larvae. As adults, mosquitoes face predation from insectivorous birds and bats. However, most of these predators are not specific to *Ae. albopictus*, but to the general type of prey (“wrigglers” or “flies”).

![Figure 8](image.png)

**Fig. 8:** Toxorhynchites splendens feeding on a captured 4th instar larvae of *Ae. albopictus*. Image by: Theodore Lee

**Vid 3:** Macrocylops albidus (a copepod) preying on first instar larvae

Obtained from YouTube under fair use. Credit: David Whittall and ecotippingpoints.org

### Defensive Adaptations
The larvae and pupae of *Ae. albopictus* thrash downwards, away from the surface of the water when they are disturbed. This behaviour can be seen in Video 4; although the tray is shallow, as a shadow falls over the water the larvae start thrash in an effort to swim away from the surface and lower in the water column.

**Vid. 4:** Video of larvae/pupae swimming down (away from the surface) when disturbed.

Obtained from YouTube under fair use.

### Significance
As vectors of disease

*Aedes albopictus* is a known vector for chikungunya [46][47], dengue fever [48][49], yellow fever [10][19][37]. These diseases are not only painful, but they carry an economic cost in lost time and medical expenditures. While Singapore has strong epidemiological control and healthcare systems, some countries do not. Studies have been done to estimate the cost of only dengue on the economy, and estimates run as high as USD1.11bn (~SGD 1.58bn) in India [46]. Similarly, the economic cost of dengue fever to the Philippines is estimated at USD345 million (USD3.26 per capita) [57]. In South-East Asia, costs of dengue in 12 countries were estimated to run close to USD1b (~USD1.65 per capita) [48]. While no statistics for the other diseases are presented, it is easy to see why the spread of the tiger mosquito worldwide is a cause for concern.

Such a high economic cost drives many attempts to find a solution; while dengue vaccines are being developed, most countries focus on vector control. This involves studying the biology and physiology of the vector, in this case, *Ae.*
*albopictus*, in the hopes of understanding ways to control or limit the spread of the vector, and hence, any associated zoonotic diseases. In Singapore, many studies have been funded to understand *Ae. albopictus*. This increased understanding of the various mosquito vectors in our environment in turn enables better policy-making, to better combat this public health issue. However, this is not a process that is close to completion. New emerging infectious diseases are always on the horizon; zika virus (ZIKV) is one of these potential new arboviruses. While zika virus is usually spread by *Ae. aegypti*, *Ae. albopictus* has recently been proven to have potential to spread ZIKV. Dengue control plans already in place in Singapore may mitigate the threat of these new problems.

All 3 species (*Ae. albopictus*, *Ae. malayensis* and *Ae. aegypti*) can be found in Singapore.

### Campaigns against dengue

In Singapore, there are several campaigns against dengue. Most of these campaigns focus on vector control of *Ae. albopictus* and *Ae. aegypti*, as it is something that can be done by the community and does not require specialized training. Some of the campaigns are as follows:

- A website (run by the National Environment Agency, NEA) providing public information about the dengue virus and the vectors that spread it. ([http://www.dengue.gov.sg](http://www.dengue.gov.sg))
- The website also has latest information about dengue clusters in Singapore. ([Dengue clusters in Singapore](http://www.dengue.gov.sg))
- The 5-Step Mozzie Wipeout campaign to stop mosquito breeding
- Various social media initiatives to remind Singaporeans to perform the 5-Step Mozzie Wipeout regularly.
  - Facebook
  - Twitter (link is a general NEA announcement board; used for haze updates as well)
- TV advertisements and Youtube videos (Video 5 & 6)
- Even home-made videos by comedy personality mrbrown (Video 7)

_Vid. 5: Mozzie Wipeout Day campaign. Obtained from YouTube under fair use._
_Vid. 6: The 5-Step Mozzie Wipeout advertisement Obtained from YouTube under fair use._
_Vid. 7: Mozzie Wipeout song Obtained from YouTube under fair use._

### Conservation

As a pest species, *Aedes albopictus* does not have many supporters. As an invasive species almost globally, much money has been spent eradicating this mosquito, but its reach continues to spread into various countries.

*Ae. albopictus* has a wide range and is hence unlikely to face global extinction.

### Morphology and Identification

#### General Anatomy and Characteristics
Fig. 9: Generalized diagram of a female mosquito. Image from Rattanarithikul, R. et al. (2005).
ADULT

HEAD

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<th>Description</th>
<th>Abbreviation</th>
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<td>Ant</td>
<td>antenna</td>
<td>C</td>
<td>costa</td>
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<tr>
<td>CE</td>
<td>compound eye</td>
<td>CuA</td>
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<td>CuP</td>
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<td>flagellum</td>
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<td>maxillary palpus</td>
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<td>mcu</td>
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<td>vertex</td>
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<td></td>
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THORAX

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<td>Stm</td>
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LEG

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<td>hindcoxa</td>
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ABDOMEN

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<tr>
<td>Te</td>
<td>tergum</td>
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<tr>
<td>S</td>
<td>sternum</td>
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<tr>
<td>1-VIII</td>
<td>abdominal segments</td>
</tr>
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Fig. 10: Abbreviations for features used in Fig. 9. Image from Rattanarithikul, R. et al. (2005).
Adult Description

The main features of *Ae. albopictus* are laid out in the table below.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Property</th>
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<tbody>
<tr>
<td>Antennae</td>
<td>Plumose in males; comparatively less plumose in females. (cf Fig. 12 &amp; 13)</td>
</tr>
</tbody>
</table>
| Head | Proboscis dark scaled  
Palpus longer than proboscis |
| Thorax | Scutum with narrow, dark scales  
Scutum with prominent median stripe of white scales |
| Abdomen | Abdominal segment I has white scales on laterotergite  
Terga III-VI has a basal white band, which widens laterally. Includes lateral white spots  
Terga II and VII only has lateral white spots.  
Sternum VIII mostly covered with white scales |
| Legs | Coxae with patches of white scales  
Fore and mid femur dark anteriorly, lighter posteriorly  
White apical scale patches |

*Ae. albopictus* is often confused with another, very similar species: *Ae. malayensis*.

Fig. 11: Female *Aedes albopictus* on the right, female *Aedes malayensis* on the left. Image by: Theodore Lee

Note the apical scales on terga IV-VI. In *Ae. malayensis* (on the left of Figure 11), the apical scales are dark, with the white scales forming a U-shaped pattern through the middle of the tergum. For *Ae. albopictus* (on the right of Figure 11), each terga has white apical scales. This is one of the easiest methods to differentiate between *Ae. malayensis* and *Ae. albopictus*. 
Sexual Dimorphism

*Ae. albopictus* males are generally smaller than females; when developing as pupae, they can actually be sorted as females tend to be larger and emerge slightly later. As adults, genitalia is of course different, but the most obvious difference is that males have bushier antennae compared to females (compare Figures 11 and 12).

Fig. 12: *Aedes albopictus* female, lateral view. Image by: Theodore Lee

Fig. 13: *Aedes albopictus* male, lateral view. Image by: Theodore Lee
Rearing & Breeding

BEWARE!

It is ILLEGAL to rear/culture/keep mosquitoes without a permit from NEA in Singapore. All information here is strictly for educational purposes only. Under the Control of Vectors and Pesticides Act Part IV Section 15: "No person shall create or cause of permit to be created any condition favourable to the propagation or harbouring of vectors." and Section 16: "No person shall breed, keep, collect, distribute, sell, import or export any vectors without the permission in writing of the Director-General". Please do not try this at home.

Aedes mosquitoes are easily bred in lab conditions. Adults are stored at room temperature (25°C ± 1°C), at 70% ± 5% relative humidity (RH), with equal photoperiods of light and dark (12h:12h). Adults had free access to 10% sucrose solution and water. Blood meals were given to females three times a week, and all mosquitoes within a holding cage are free to mate for maintenance cultures. Germ paper was used as a substrate to allow females to lay eggs.

Eggs were removed and incubated for 3 days to allow complete embryogenesis. When properly stored (sealed from excess moisture and heat), these eggs are viable for up to 6 months, although mortality rises sharply in the last few months.

As needed, germ papers containing eggs were hatched by placing them in a plastic tray of Milli-Q water (Figure 14). First-instar larvae usually emerge within the hour.

![Fig. 14: Hatching Ae. albopictus eggs. Germ papers containing eggs placed in water in plastic trays. Image by: Theodore Lee](image)

Trapping wild mosquitoes

While rearing mosquitoes in an insectary is useful for in-house studies, sometimes wild mosquitoes are required to add genetic diversity to insectary cultures. Instead of catching flying adults, oviposition traps (Figure 15) are used to collect eggs. The traps are small black plastic buckets about 12cm in diameter, with a hole punched through the side to allow excess water to drain out (Figure 15).
Germ paper is then placed into the traps. This allows a substrate for the mosquitoes to lay eggs on. Traps are next placed in areas where there are known populations of *Ae. albopictus* (or even other floodwater species). Usually, traps are placed near the ground, amongst vegetation and between tree roots that create a semi-enclosed space (Figure 16). Note the germ paper lining the inside of the trap; it should not block the overflow hole. Finally, water is added into the trap up to the overflow line.

The traps work by providing a ready source of water for mosquito females to lay eggs. Eggs laid on the germ paper can be collected and hatched in single containers, then identified and sorted by species. Traps are collected every 2-3 days to avoid eggs hatching into the water.
Taxonomy and Systematics

Synonym

*Culex albopictus* (Skuse, 1895) (Original description)

*Culex albopictus* was first described as *Culex albopictus*, but has since been transferred into genus *Aedes*. It has 3 other synonyms. New classification as *Stegomyia albopicta* was proposed by Reinert et al. in 2004, but it is not universally accepted.

Type Information

The U.S. National Museum houses the neotype of *Aedes albopictus* (1 specimen).

Subspecies

No subspecies rank.

Classification

The Taxo-navigation system below is provided by and referenced to UniProt Taxonomy. This is the classification of *Aedes albopictus* above species level.

Subclass Eumetazoa
  - Phylum Bilateria
    - Subphylum Protostomia
      - Superclass Ecdysozoa
        - Class Panarthropoda
          - Subclass Mandibulata
            - Class Pancrustacea
              - Order Hexapoda
                - Suborder Insecta
                  - Superfamily Dicondylia
                    - Family Neoptera
                      - Subfamily Endopterygota
                        - Superfamily Diptera
                          - Class Nematocera
                            - Superfamily Culicidae

Phylogeny
Mosquito phylogeny is currently still being reassessed and several proposed reclassifications are under contention. The introduction of new molecular methods (DNA barcoding via next-gen sequencing) and the discovery of various new species also lends itself to some of the confusion seen in mosquito phylogeny. One of the studies by Reinert et al. (2004) was based on 172 character states in 119 exemplar species representing most of the genera and subgenera within tribe Aedini. The study found that genus Aedes was polyphyletic; the solution proposed was to reorganise the generic classification of Aedini, resulting in the promotion of many subgenera to genus, including Stegomyia.

A further study in 2009 built on this idea; this time, a cladistic analysis of 336 characters from all life stages of mosquitoes was conducted. These characters include both male and female genitalia, various scales and setae on adults and larvae, and even spots on pupae. As defined by Reinert et al. (2009), Stegomyia is a monophyletic group, but the study showed that the two Stegomyia clades were poorly supported. While the terminal group was moderately supported, the branch supports (where “Stegomyia albopicta” is placed) leading to the terminal group are quite poorly supported (Figure 17). Much more work has to be done to resolve the proposed tree.

Fig. 17: Proposed phylogeny of Aedes albopictus (here reclassified as Stegomyia albopicta). Notice the low/moderate support for the branch St. albopicta is on. Tree obtained from Reinert et al., 2009. Phylogeny and classification of tribe Aedini (Diptera: Culicidae). Obtained and accredited under fair use.

References

Contact Me

Theodore Lee is contactable here

This page was authored by Theodore Lee

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