Literature Survey: Dengue conditions in Singapore

April 17, 2017

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9. Which is the peak period and/or season of the year for dengue mosquito breeding and subsequent dengue hotspot/cluster emergence?
10. Which man-made locations are possible mosquito breeding sites? (E.g. Construction site, Sewage system, food hawker centres etc.)
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15. Is it possible to convert a favourable breeding spot to unfavourable spot to stop the possible mosquito breeding?

16. What if all the mosquitoes in the world are extinguished? Will there be a missing link in the food chain? What would be the possible implications of this situation?

Dengue numbers in Singapore.

17. Which are the dengue hotspots in Singapore?

18. How many positive dengue cases are recorded in each district of Singapore?

19. How many deaths are recorded due to dengue in each year? What is the death rate due to dengue?

20. What is the duration of positive dengue condition and complete recovery from dengue? What are further precautions to be taken in order prevent getting infected with dengue again?

21. What treatments are used to treat a dengue patient? What is the cost of treatment and medication?

1. **Which animal causes maximum number of human deaths in a year?**
   Answer:

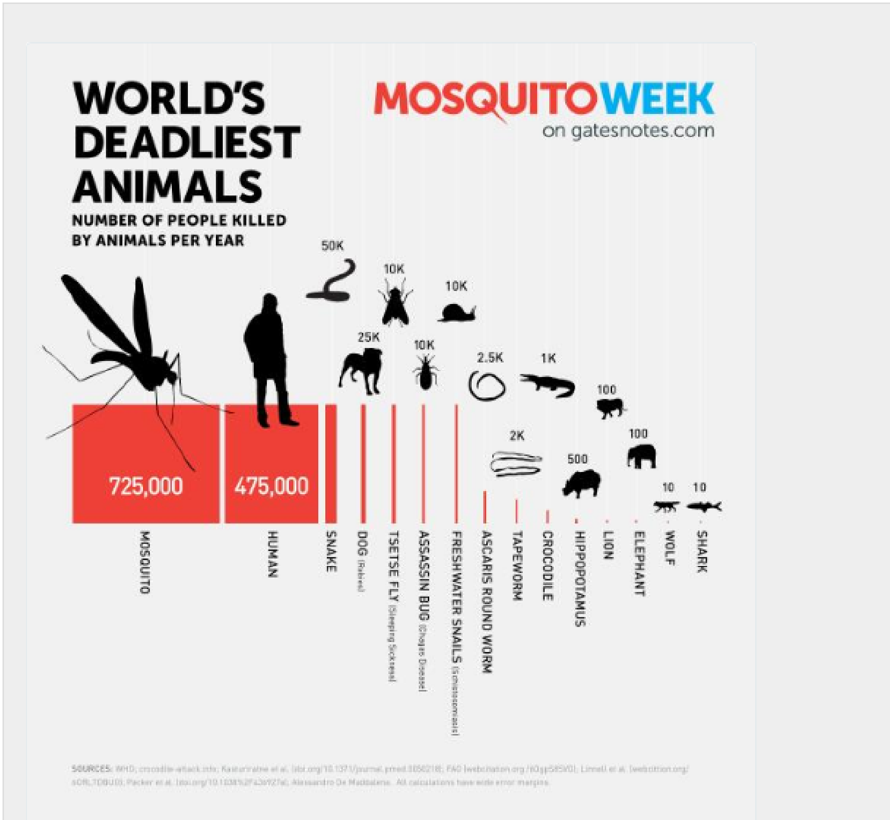


Figure 1: World's deadliest animals[1].

- According to WHO report, every year more than one billion people are infected with vector-borne diseases and more than one million people die from vector-borne diseases including malaria,dengue, yellow fever, lymphatic filariasis etc.
  Vectors are any living organisms that transmits infectious diseases between people or from animal to people.

- Many of these vectors are blood sucking insects that ingest disease-causing micro-organisms from the infected(virus carrying) host during a blood meal and later inject it into new host during their next blood meal.
  Mosquitoes are best know disease vectors. There are around 3500 species of mosquitoes. Some of these species have ability to carry many different diseases.
  Among these species, *Aedes Aegypti (Ae. aegypti)* is a primary vector that spreads dengue, Zika, chikungunya, and yellow fever[2].

- **Mosquitoes are effective transmitters:** Mosquitoes feed on blood. When feeding they pierce the skin like a needle and inject a saliva into a person's skin. This transmits the disease causing agents into the site. As mosquitoes fly, they can spread diseases more quickly than any contagious disease like Ebola[3].
  One sixth of the illness and disability suffered worldwide is due to vector-borne diseases

with more than half the world's population currently estimated to be at the risk of these diseases[2]. Nearly 700 million people get mosquito-borne illness each year and more than one million of them result in death[4].

Summary:

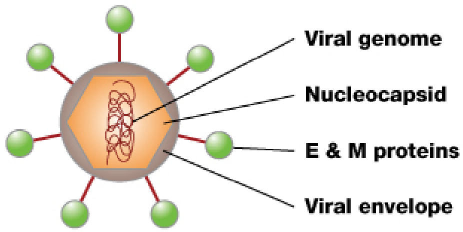
1. Mosquito being an effective transmitter of vector-borne diseases, is the deadliest insect causing around 1 million deaths per year by transmitting diseases like dengue, Zika, yellow fever, chikungunya etc.
2. There are around 3500 species of mosquitoes.
3. Nearly 700 million people get mosquito-borne illness each year.

2. **What is dengue? How lethal is it?**
   Answer:

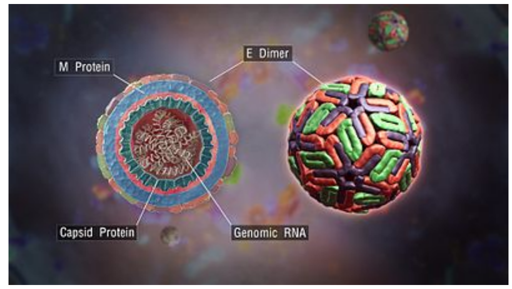
   - Dengue is a mosquito-borne viral infection that affects infants, young children and adults. It is caused by four closely related viruses (DEN-1, DEN-2, DEN-3 or DEN-4). This illness causes flue-like illness and occasionally develops into potentially lethal complication called *severe dengue*[5].The two most severe forms of dengue are Dengue Haemorraghic Fever (DHF) and Dengue Shock Syndrome (DSS).
     There is no specific treatment for dengue fever but early clinical diagnosis and careful clinical management often save lives.
   - The incidence of dengue has grown dramatically around the world in recent decades. The actual numbers of dengue cases are under reported and many cases are misclassified. One recent estimate indicates **390 million dengue infections per year** (95% credible interval 284–528 million), of which **96 million (67–136 million) manifest clinically** (with any severity of disease).
     Another study, of the prevalence of dengue, estimates that 3.9 billion people, in 128 countries, are at risk of infection with dengue viruses.
     Member States in 3 WHO regions regularly report the annual number of cases. The number of cases reported increased from 2.2 million in 2010 to 3.2 million in 2015. Although the full global burden of the disease is uncertain, the initiation of activities to record all dengue cases partly explains the sharp increase in the number of cases reported in recent years[5].

   About Dengue Virus :

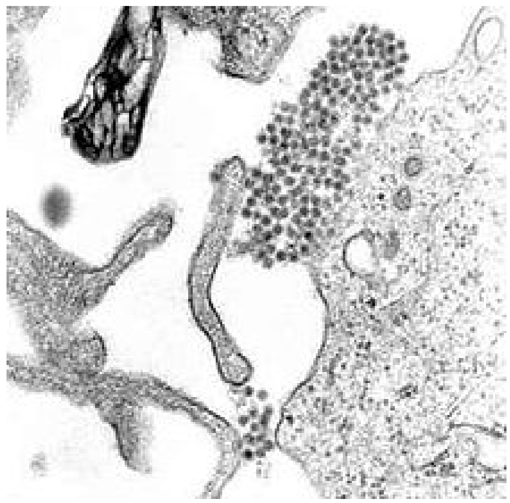
   - Dengue virus (DENV) is a tiny structure that cause the most common arthropod-borne viral disease in man with 50–100 million infections per year.
     It is a mosquito-borne single positive-stranded RNA virus of the family Flaviviridae; genus Flavivirus. Four serotypes of the virus have been found, all of which can cause the full spectrum of disease. All four DENV serotypes have emerged from sylvatic strains in the forests of South-East Asia.
     DENV infection can be asymptomatic or a self-limited, acute febrile disease ranging in severity[22].



(a) Dengue virus structure



(b) Structural components in Cross-section view of DNV



(c) TEM Micrograph showing DNV virions cluster

Figure 2: Dengue virus

- The dengue virus can only replicate inside a host organism. It is a roughly spherical structure composed of the viral genome and capsid proteins surrounded by an envelope and a shell of proteins. The envelope is a lipid bilayer that is taken from the host. Embedded in the viral envelope are E and M proteins that span through the lipid bilayer. These proteins form a protective outer layer that controls the entry of the virus into human cells.
  After infecting a host cell, the dengue virus hijacks the host cell's machinery to replicate the viral RNA genome and viral proteins. After maturing, the newly synthesized dengue viruses are released and go on to infect other host cells[23].

Summary:

1. Dengue is one of the most lethal disease.
2. Around 2.5 to 3.9 billion people worldwide are at risk of dengue infection.
3. 390 million dengue infections per year.
4. Increased number of 3.2 million dengue cases reported in 2015 as compared to 2.2 million in 2010.

3. **What causes Dengue?**
   Answer: *Aedes aegypti* mosquito is the primary vector of the dengue virus. The virus is transmitted to humans through the bites of female mosquitoes.
   Vector-borne diseases like dengue are the illnesses caused by parasites and pathogens in human populations. Infected humans are the main carriers and multipliers of the virus, serving as a source of the virus for uninfected mosquitoes. Patients who are already infected with the dengue virus can transmit the infection (for 4–5 days; maximum 12) via Aedes mosquitoes once their first symptoms appear.

(a) Aedes Aegypti

(b) Aedes Albopictus

Figure 3: Dengue vectors

Aedes albopictus also called as *Asian tiger mosquito*, is a secondary dengue vector in Asia, has spread to North America and more than 25 countries in the European Region, largely due to the international trade in used tyres (a breeding habitat) and other goods (e.g. lucky bamboo). Ae. albopictus is highly adaptive and, therefore, can survive in cooler temperate regions of Europe. Its spread is due to its tolerance to temperatures below freezing, hibernation, and ability to shelter in microhabitats.

Summary:

1. Two types of mosquitoes from same genus namely, Aedes aegypti and Aedes albopictus carry dengue virus from an infected person to another uninfected person.
2. These mosquitoes transmit dengue virus by injecting virus into the uninfected person's body through saliva during their blood meal.

4. **How does a mosquito carry a dengue virus?**
   Answer:

   1. 'Typically, both male and female mosquitoes feed on nectar and plant juices. But in many species, to lay eggs, female mosquito needs to obtain protein from a blood meal. For this, in many species the mouthparts of the females are adapted for piercing the skin of animal hosts and sucking their blood[7].'

   2. 'The mosquito becomes infective approximately seven days after it has bitten a person carrying the virus. This is the extrinsic incubation period, during which time the virus replicates in the mosquito and reaches the salivary glands[8].'

   3. 'Mosquitoes carrying such arboviruses(any virus that is transmitted by an arthropod.) stay healthy because their immune systems recognizes the virions as foreign particles and "chop off" the virus's genetic coding, rendering it inert. Human infection with a mosquito-borne virus occurs when a female mosquito bites someone while its immune system is still in the process of destroying the virus's harmful coding.
   It is not completely known how mosquitoes handle eukaryotic parasites to carry them without being harmed. Data has shown that the malaria parasite Plasmodium falciparum alters the mosquito vector's feeding behaviour by increasing frequency of biting in infected mosquitoes, thus increasing the chance of transmitting the parasite[7].'

   Summary:

   1. Only female mosquitoes need protein in the blood for laying eggs. Hence, only female mosquitoes carry dengue virus from infected person during their blood meal.
   2. These mosquitoes become infective approximately seven days after their infected blood meal. During this incubation period virus replicates in the mosquitoes and reaches the salivary glands.
   3. Mosquitoes carrying these viruses are immune to those foreign particles.

5. **How do mosquitoes transmit dengue to a person?**
   Answer:
   'Once an infected mosquito has incubated the virus for 4–10 days, it can transmit the virus for the rest of its life[5].'
   'Prior to and during blood feeding, blood-sucking mosquitoes inject saliva into the bodies of their source(s) of blood. This saliva serves as an anticoagulant and the main route by which mosquito physiology offers passenger pathogens access to the hosts' interior. The salivary glands are a major target to most pathogens, whence they find their way into the host via the stream of saliva[7].'

   Interesting facts about mosquito feed and hunt for blood hosts:

   1. 'All adult mosquitoes feed on the nectar or honey dew of plants to get sugar, and that provides enough nourishment for both males and females to live. Both plant materials and blood are useful sources of energy in the form of sugars, and blood also supplies more concentrated nutrients, such as lipids, but the most important function of blood meals is to obtain proteins as materials for egg production.
   2. A mosquito has a variety of ways of finding its prey, including chemical, visual, and heat sensors.
   3. **Feeding preferences of mosquitoes:** Those with type O blood, heavy breathers, those with a lot of skin bacteria, people with a lot of body heat, and the pregnant.
   4. When a female reproduces with such parasitic meals, this reproduction is termed as **anautogenous**('anautogeny' is the condition found in many insects, where a gravid female has to feed before laying eggs in order for the eggs to mature.), as occurs in mosquito species that serve as disease vectors, particularly Anopheles and **Aedes**.
   5. **Hunting for host location:** female mosquitoes hunt their blood host by detecting organic substances such as carbon dioxide (CO_2) and 1-octen-3-ol (octenol for short and also known as mushroom alcohol, is a chemical that attracts biting insects such as mosquitoes.) produced from the host, and through optical recognition. Mosquitoes prefer some people over others. The preferred victim's sweat simply smells better than others' because of the proportions of the carbon dioxide, octenol and other compounds that make up body odor.
      Another compound identified in human blood that attracts mosquitoes is sulcatone or 6-methyl-5-hepten-2-one, especially for **Aedes aegypti** mosquitoes with the odor receptor gene Or4.
      A large part of the mosquito's sense of smell, or olfactory system, is devoted to sniffing out blood sources. Of 72 types of odor receptors on its antennae, at least 27 are tuned to detect chemicals found in perspiration.
      In **Aedes**, the search for a host takes place in two phases. First, the mosquito exhibits a nonspecific searching behavior until the perception of host stimulants, then it follows a targeted approach[7].'

6. Both dengue vectors Ae aegypti and Ae. Albopictus are daytime feeders: The peak biting periods are early in the morning and in the evening before dusk.

(a) Mosquito before feeding.

(b) Mosquito after feeding.

Figure 4: Mosquito before and after feeding.

Summary:

1. Once the mosquito has incubated the dengue virus, it can transmit the virus for rest of its life.
2. During the blood meal on uninfected person's body, mosquito carrying dengue virus injects saliva into the person's body. This saliva serves the main route by which pathogens find their way into the host's interior.
3. **Feeding preferences**: Those with type O blood, heavy breathers, those with a lot of skin bacteria, people with a lot of body heat, and the pregnant.
4. **Hunting for host location**: By detecting organic substances like carbon dioxide, octenol, and sulcatone produced from the host and through optical recognition.
5. Peak biting period of dengue vector mosquitoes is daylight; approximately two hours after sunrise and several hours before sunset.

6. **What is the life cycle of Aedes Aegypti?**
   Answer:
   Aedes Aegypti is a so-called holometabolous insect. This means that the insects goes through a complete metamorphosis with an egg, larvae, pupae, and adult stage. The life cycle of Aedes aegypti can be completed within one-and-a-half to three weeks.

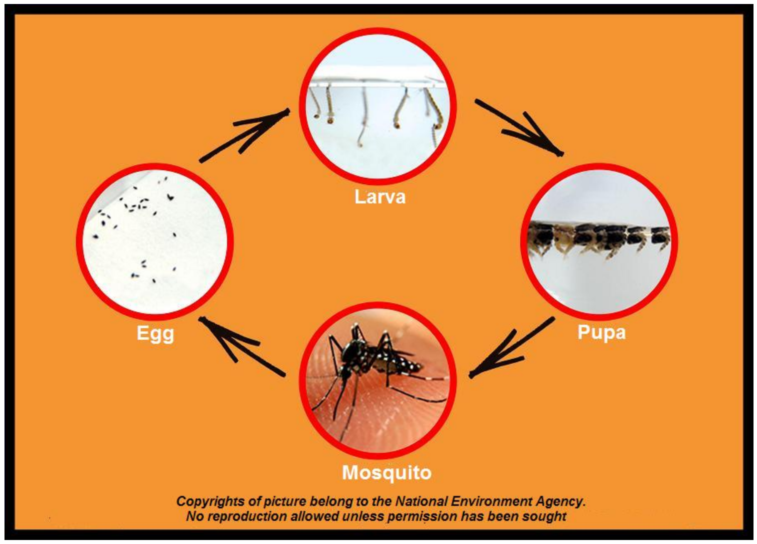


Figure 5: Mosquito life cycle[10].

1. ′**Egg:** After taking a blood meal, female Aedes aegypti mosquitos produce on average 100 to 200 eggs per batch. The females can produce up to five batches of eggs during a lifetime.
   Eggs are laid on damp surfaces in areas likely to temporarily flood, such as tree holes and man-made containers and a lot more places where rain-water collects or is stored.
   The female Aedes aegypti lays her eggs separately unlike most species. Not all eggs are laid at once, but they can be spread out over hours or days, depending on the availability of suitable substrates. Eggs will most often be placed at varying distances above the water line. The female mosquito will not lay the entire clutch at a single site, but rather spread out the eggs over several sites.
   The eggs of Aedes aegypti are smooth, long, ovoid shaped, and roughly one millimeter long. When first laid, eggs appear white but within minutes turn a shiny black. In warm climates eggs may develop in as little as two days, whereas in cooler temperate climates, development can take up to a week. Laid eggs can survive for very long periods in a dry state, often for more than a year. However, they hatch immediately once submerged in water. This makes the control of the dengue virus mosquito very difficult.

2. **Larvae:** After hatching of the eggs, the larvae feed on organic particulate matter in the water, such as algae and other microscopic organisms. Most of the larval stage is spent at the water's surface. Larvae are often found around the home in puddles, tires, or within any object holding water.
   Larval development is temperature dependent. Males develop faster than females, so males generally pupate earlier. If temperatures are cool, Aedes aegypti can remain in the

larval stage for months so long as the water supply is sufficient.
The larvae pass through four instars, spending a short amount of time in the first three, and up to three days in the fourth instar. Fourth instar larvae are approximately eight millimeters long. Males develop faster than females, so males generally pupate earlier. If temperatures are cool, Aedes aegypti can remain in the larval stage for months so long as the water supply is sufficient.

(a) Ae.aegypti larvae stage

(b) Ae.aegypti pupae stage.

Figure 6: Aedes aegypti larvae and pupae stage.

7. **Pupae:** After the fourth instar, the larvae enters the pupal stage. Mosquito pupae are mobile and respond to stimuli. Pupae do not feed and take approximately two days to develop. Adults emerge by ingesting air to expand the abdomen thus splitting open the pupal case and emerge head first[11].'

8. Adult mosquitoes usually mate within a few days after emerging from the pupal stage. In most species, the males form large swarms, usually around dusk, and the females fly into the swarms to mate. Males typically live for about 5–7 days, feeding on nectar and other sources of sugar. After obtaining a full blood meal, the female will rest for a few days while the blood is digested and eggs are developed. This process depends on the temperature, but usually takes two to three days in tropical conditions. Once the eggs are fully developed, the female lays them and resumes host-seeking.

   Summary:

1. Aedes Aegypti goes through a complete metamorphosis with an egg, larvae, pupae, and adult stage.

2. After a blood meal,female Ae. aegypti mosquitoes lay upto five batches of 100 to 200 eggs. The eggs are laid on damped surface areas over several sites. The eggs can lie dormant in dry conditions for up to about nine months, after which they can hatch if exposed to favourable conditions, i.e. water and food[10].

3. Larval stage is temperature dependant. It passes through 4 instars. Males develop faster than females. If temperatures are cool, it remains in the larval stage for months as long as the water supply is sufficient.

4. Pupae do not feed and take approximately two days to develop into adult mosquito. The adult life span can range from two weeks to a month depending on environmental conditions.

9. **What are the symptoms of dengue infection? What is the duration of mosquito bite to positive dengue condition? What are the intermediate stages of mosquito bite and positive dengue conditions?**
Answer:

   1. '**Incubation period:** (Time between mosquito's bite to onset of symptoms) After the infective bite, the dengue virus circulates in the blood. The incubation period for Dengue Fever and Dengue Haemorrhagic Fever lasts from 3 to 14 days. The average incubation period is 4-6 days.

   2. **Symptoms of dengue infection:** The signs and symptoms of dengue fever vary according to the age of the patient. The principal symptoms of dengue are high fever, severe headache, backache, joint pains, nausea and vomiting, eye pain and rash.
   Infants and young children may have a fever and a rash. They have milder illness compared to other older children and adults[12].'
   Thereafter symptoms appear such as a high fever (40°C/104°F) accompanied by 2 of the following symptoms: severe headache, pain behind the eyes, muscle and joint pains, nausea, vomiting, swollen glands or rash. These symptoms usually last for 2–7 days[5].

   3. **Dengue Haemorrhagic Fever (DHF) and Dengue Shock Syndrome (DSS):** These are characterised by a sudden onset of fever, as high as 40-41ºC, lasting about 2-7 days with similar signs and symptoms of dengue fever. This is followed by "leaky" capillaries allowing fluid component to escape from the blood vessels causing shock and hemorrhagic manifestations such as bleeding nose or gums, and possibly internal bleeding. Platelet counts will fall to less than 100,000/mm3. The course of DHF is 7-10 days.
   During the acute phase of dengue, it is difficult to distinguish DHF/DSS from Dengue fever and other viral illnesses. The critical stage of DHF/DSS occurs most frequently from 24 hours after the temperature falls to or below normal. If Dengue Haemorrhagic Fever is not treated, it can lead to Dengue Shock Syndrome.

Summary:

1. After the infective bite, the average incubation period of dengue virus is 3-6 days.
2. The principal symptoms of dengue are high fever, severe headache, backache, joint pains, nausea and vomiting, eye pain and rash.
3. Severe dengue or Dengue Haemorrhagic Fever (DHF) is a potentially deadly complication due to plasma leaking, fluid accumulation, respiratory distress, severe bleeding, or organ impairment.

10. **Which conditions are favourable for dengue mosquito breeding?**
Answer:

1. ' Aedes aegypti originated from Africa, is now present globally in tropical and subtropical regions (see also Epidemiology). The mosquito has a so-called cosmo-tropical distribution annually, and spreads to more temperate regions during the summer.
   Living near man Aedes aegypti has become largely dependent on and adapted to humans. For instance, the mosquito has greatly reduced the 'humming' sound it makes with their wings. Humans nearly hear Aedes aegypti, unlike other species whose humming is extremely irritating and awakens the deepest sleeper. The insect is very fast in flight unless gorged with blood. Other types of mosquito even fly into your face and can be easily caught or killed, not Aedes aegypti.

2. Aedes aegypti is adapted to breed around human dwellings and prefers to lay its eggs in clean water which contains no other living species.
   The mosquito Aedes aegypti comes in three polytypic forms: domestic, sylvan, and peridomestic.

   - The domestic form breeds in urban habitat, often around or inside houses.
   - The sylvan form is a more rural form, and breeds in tree holes, generally in forests.
   - The peridomestic form thrives in environmentally modified areas such as coconut groves and farms.

3. Mosquitoes prefer stagnant water within which to lay their eggs. They most commonly infest ponds, marshes, swamps and other wetland habitats. However, they are capable of thriving in a variety of locations and can successfully grow in numbers even when not in their natural habitat. Many species of mosquitoes use containers of water as egg-deposit sites. Hot, humid environments are most amenable to mosquito growth and survival. Infestations can occur easily in tropical areas.
   The aedes mosquito goes into hibernation when the temperature dips. The favourable condition for mosquito breeding is a humidity level of 60% and an atmospheric temperature between 21 and 23 degrees celsius[15].'

   Mosquito larvae can be found in various habitats. Some larvae are active in transient waters such as floodwater, ditches and woodland pools. The Anopheles, Culex, Culiseta, Coquillettidia and Uranotaenia species breed in permanent bodies of water and can survive in polluted water as well as freshwater, acid water and brackish water swamps. Other mosquito larvae may be present in container water sources such as puddles upon leaves and stagnant water within small pools.

4. **Relationship Between Mosquitoes and Water**
   'Mosquitoes live in water but must make periodic trips to the water's surface in order to eliminate carbon dioxide and inhale a fresh supply of oxygen.
   Water provides mosquitoes with a place to lay eggs, grow and develop through their water stages (egg, larval and pupal). After the airborne portion of their lifecycle, females return to water to lay a new batch of fertile eggs. Female mosquitoes usually lay their

eggs on the surface of water or in areas where water can rise, flood the eggs, and stimulate them to hatch. Even as adult mosquitoes leave the pupal stage and become adults, water still plays a role because adult mosquitoes exit the pupal case on the water's surface and "dry out" before taking flight[14].'

5. National Environmental Agency, Singapore has listed following places at potential sites for mosquito breeding[8].
   Usual mosquito breeding sites:
   1. Flower pot and flower pot plates.
   2. Hardened soil of potted plants .
   3. Corner of the toilet bowl.
   4. Gully trap.
   5. Roof gutter.
   6. Roadside drain.
   7. Scuppar drain.

   Unsual mosquito breeding sites:
   1. Tree hole.
   2. Plant axil.
   3. Aircon-tray.
   4. BBQ pit.
   5. Canvas sheets.
   6. Discarded receptacles
   7. Planted box.

Table 1:Top 5 breeding habitats of Aedes Aegypti.

Top 5 breeding habitats of Aedes Aegypti	
Breeding habitats in homes	Breeding habitats in public places
1. Domestic Containers 2. Flower Pot Plates / Trays 3. Ornamental Containers 4. Plants (Hardened Soil and Plant Axils) 5. Toilet Bowl / Cistern	1. Closed Perimeter Drains 2. Discarded Receptacles 3. Gully Traps 4. Opened Perimeter Drains 5. HDB Corridor Scupper / Gullies

11. **What are the preventive measures that can be implemented in order to avoid creating possible mosquito breeding site?**
Answer:
As per the WHO recommendation, the main method to control or prevent the transmission of dengue virus is to combat vector mosquitoes through:

Preventing mosquitoes from accessing egg-laying habitats by environmental management and modification.
Disposing of solid waste properly and removing artificial man-made habitats.
Covering, emptying and cleaning of domestic water storage containers on a weekly basis.
Applying appropriate insecticides to water storage outdoor containers.
Using of personal household protection such as window screens, long-sleeved clothes, insecticide treated materials, coils and vaporizers.
Improving community participation and mobilization for sustained vector control.
Applying insecticides as space spraying during outbreaks as one of the emergency vector-control measures.
Active monitoring and surveillance of vectors should be carried out to determine effectiveness of control interventions.

12. **Is it possible to make dengue mosquitoes harmless at any stage of their life cycle before they spread virus? If yes, what are the possible ways?**
Answer: Wolbachia-Aedes Mosquito Suppression Strategy.

NEA's Environmental Health Institute (EHI) has studied various novel mosquito control methods over the past six years, and has focused on the Wolbachia method over the last four years. Wolbachia's potential to reduce the Aedes aegypti mosquito population has been demonstrated in our laboratories[27].

Wolbachia technology is considered a biological control method. Wolbachia are naturally occurring bacteria found in more than 60 per cent of insects around us, including butterflies, dragonflies, fruit flies, and various mosquito species such as Aedes albopictus, but not in the primary dengue vector mosquito Aedes aegypti. Wolbachia have not been shown to infect humans or other mammals, even when carried by biting insects.

The World Health Organization (WHO) Vector Control Advisory Group (VCAG) recommends carefully planned pilot deployment under operational conditions accompanied by rigorous independent monitoring and evaluation that builds entomological capacity to support operational use, for the use of Wolbachia against Aedes-borne diseases.

The Dengue Expert Advisory Panel (DEAP), comprising experts from Singapore, Australia, the United Kingdom (UK) and the United States of America (USA), recommends that Singapore explores the use of Wolbachia-carrying Aedes males to help suppress the Aedes mosquito population in Singapore, for further reduction of the risk of dengue[26].

How does Wolbachia-Aedes suppression strategy works?

1. When male Wolbachia-carrying Aedes aegypti mosquitoes mate with female Aedes aegypti without Wolbachia, their resulting eggs do not hatch. This is because such matings are biologically incompatible. Thus release of male Wolbachia-Aedes aegypti will lead to a decline in the Aedes aegypti population in the field over time.
2. The outcome of this approach is consistent with our current emphasis on source reduction (removal of breeding habitats).
3. This mosquito suppression strategy is species-specific. Release of male Wolbachia-Aedes aegypti will only impact the Aedes aegypti population in the field, and not other insects [28].

Dengue numbers in Singapore.

The incidence of dengue in Singapore exhibits a distinct seasonality. It typically rises in the warmer months. Usually starting from April, the incidence reaches a peak in July or August, and declines in September or October[16]. WHO report mention that in Asia, Singapore has reported an increase in cases after a lapse of several years[5].

13. **How many positive dengue cases are recorded in each district of Singapore?**
Answer:

1. In Singapore, there are around 4,000 to 5,000 reported cases of dengue or dengue haemorrhagic fever every year. Since 1980s, more than 50% of deaths in the country have occurred in adults (individuals older than 15 years)[25]. 'MOH-NEA's quarterly dengue surveillance data mentions following information:

2. **No. of cases reported**:
   (a) Jul to Sept 2016 (03/07/2016 - 1/10/2016), = 2,888 dengue cases (4 DHF cases); an increase of 2.7% as compared to the previous quarter from April to Jun 2016.
   (b) Oct to Dec 2016 (02/10/2016 - 31/12/2016), = 1084 dengue cases (1 DHF cases); a decrease of 62.5% as compared to the previous quarter from Jul to Sep 2016.
   In 2016 (03/01/2016-31/12/2016), a cumulative total of **13,115** dengue cases were notified to Ministry of Health (MOH).

3. **No. of deaths:**
   (a) Jan to Jun 2016 : 6
   (b) Jul to Sept 2016 : 2
   (c) Oct to Dec 2016 : 1
   This brings the annual number of deaths in the year 2016 to 9[19].'

4. **Serotype Distribution:** Preliminary results of the positive dengue samples serotyped in Jul to Dec 2016 have indicated that DEN-1 accounted for majority of the typed samples, followed by DEN-2, DEN-3 and DEN-4.

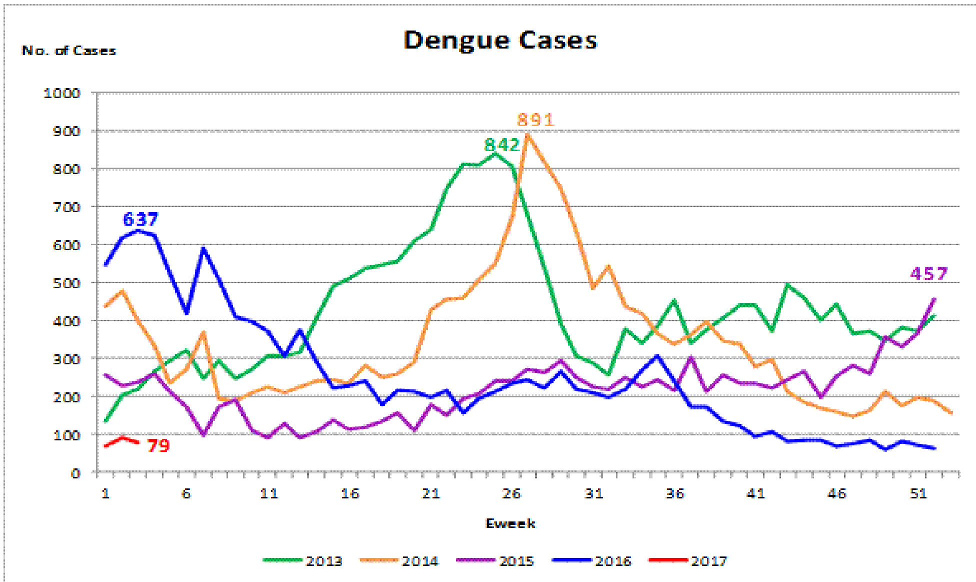


Figure 7: Dengue Cases(Year 2013-2016)[21].

Number of Dengue cases

It is important to note that day-to-day numbers fluctuates as they depend on the number of notification received. Therefore, weekly numbers are a better reflection of actual trends.

No. of Reported Cases*

19-Jan	20-Jan	21-Jan	22-Jan	23-Jan	24-Jan	25-Jan at 3pm
14	10	11	7	14	16	5

*provisional

No. of Reported Cases by E-week (from Sun 0000hrs to Sat 2359hrs)

E-week 50 (11-17Dec16)	E-week 51 (18-24Dec16)	E-week 52 (25-31Dec16)	E-week 01 (01-07Jan17)	E-week 02 (08-14Jan17)	E-week 03 (15-21Jan17)	E-week 04 (22-25Jan17 at 3pm)
81	72	64	70	91	79	42

Cumulative No. of cases for 2017 (First 3 weeks): 240

Compiled by Communicable Diseases Division, Ministry of Health

Figure 8: Dengue Cases reported by E-week[21].

14. **Which are the dengue clusters in Singapore?**
Answers:

1. Operationally, a dengue cluster indicates a locality with active transmission where intervention is targeted. It is formed when two or more cases have onset within 14 days and are located within 150m of each other (based on residential and workplace addresses as well as movement history). The clusters are categorised according to their current status. There are 3 alert levels:

Definition	Alert Level
High-risk area with 10 or more cases	Red
High-risk area with less than 10 cases	Yellow
No new cases, under surveillance for the next 21 days	Green

Figure 9: Categories of dengue clusters[17].

2. Following map shows the high-risk dengue clusters in Singapore.

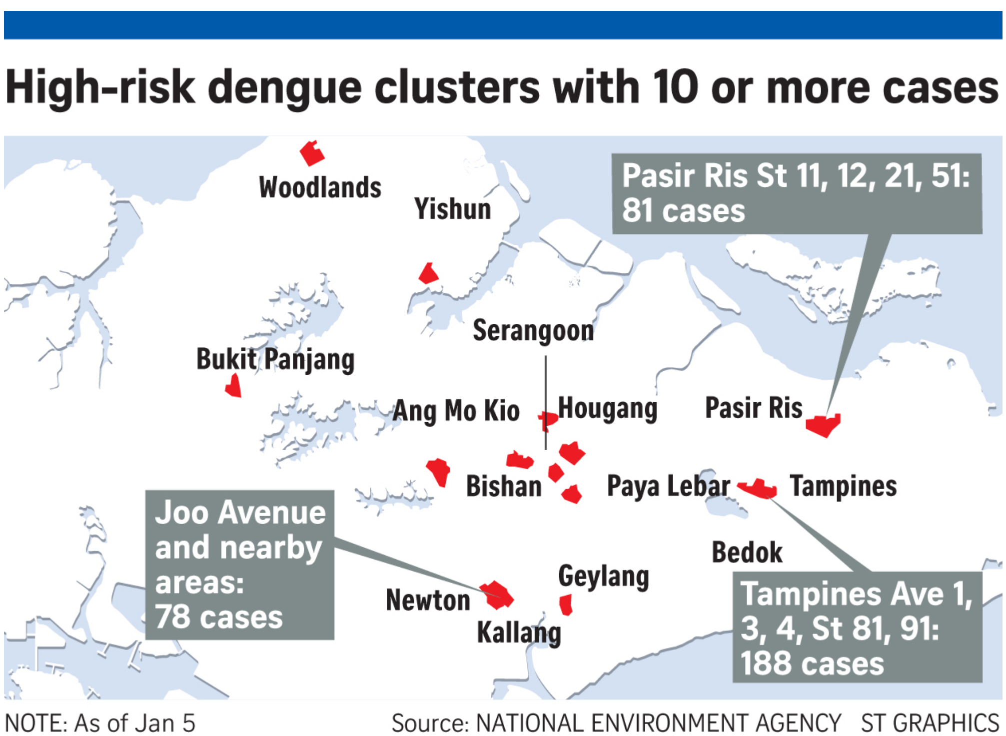


Figure 10: High-risk dengue clusters[18].

3. For 2016, about 17,000 mosquito breeding have been detected and destroyed. The breakdown of breeding found at various premises types are found in Table 2. The largest proportion of breeding is still being found in homes.

Table 2: No. of breeding detected from Jan to Dec 2016*

Mosquito habitats	2016
Residential premises	About 7,800 (46%)
Public areas About	4,900 (30%)
Construction sites	About 870 (5%)
Others About	3,200 (19%)
Total About	17,000

*Provisional; generated as of 9 Jan 2017.

More about Dengue clusters in Singapore:

1. **Dengue Clusters 1990 to 2015.**

Dengue clusters identified, 1990 – 2015

Year	No. of indigenous cases	No. of clusters*	No. of cases in cluster area (% total cases)	No. of clusters with >=10 cases (% total clusters)	Median no. of cases per cluster	Median duration of transmission (days)
1990	1,640	40	270 (16.5)	11 (27.5)	4.5	10
1991	2,062	74	414 (20.1)	9 (12.2)	3.5	6
1992	2,741	134	733 (26.7)	13 (9.7)	3	5
1993	794	33	183 (23.0)	4 (12.1)	3	8
1994	1,084	75	424 (39.1)	8 (10.7)	3	7
1995	1,756	118	679 (38.7)	16 (13.6)	3	7
1996	2,877	143	1,088 (37.8)	27 (18.9)	3	6
1997	4,039	198	1,124 (27.8)	24 (12.1)	3	5
1998	5,105	239	1,197 (23.4)	23 (9.6)	2	7
1999	1,138	54	230 (20.2)	6 (11.1)	3	11
2000	402	9	40 (10.0)	1 (11.1)	4	15
2001	2,064	93	531 (25.7)	15 (16.1)	3	8
2002	3,560	73	725 (20.4)	30 (41.1)	7	20
2003	4,542	180	1,405 (30.9)	38 (21.1)	4.5	12
2004	9,297	559	2,434 (26.2)	34 (6.1)	3	4
2005	14,032	1,190	5,362 (37.7)	93 (7.8)	3	5
2006	2,844	172	871 (30.6)	19 (11.0)	3	5
2007	8,287	949	3,877 (46.8)	58 (6.1)	3	10
2008	6,631	576	2,267 (34.2)	34 (5.9)	2	7
2009	4,187	392	1,456 (34.8)	17 (4.3)	3	7
2010	4,978	406	1,858 (37.3)	29 (7.1)	3	7
2011	5,099	433	1,904 (37.3)	32 (7.4)	3	7
2012	4,369	328	1,403 (30.9)	21 (6.4)	3	6
2013	21,863	1,475	10,256(46.3)	188 (12.7)	3	9
2014	17,812	1,418	9,474 (51.7)	137 (9.7)	3	9
2015	10,856	1,114	5,744 (50.9)	108 (9.7)	3	10

*A cluster is defined as two or more cases epidemiologically linked by place [within 150m (200m till 2002)] and time (within 14 days)

Figure 11: Dengue Clusters identified during 1990 to 2015[29].

2. **Premises Percentage of Aedes breeding habitat.**

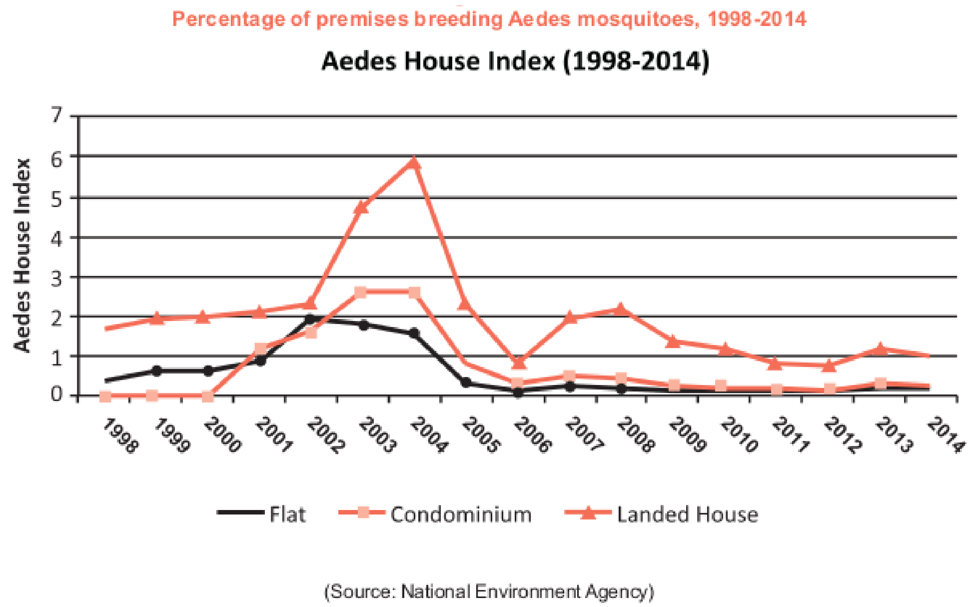


Figure 12: Percentage of Premises breeding of Aedes Mosquitoes from 1998 to 2014[30].

Vector Surveillance

'Surveillance on Ae. aegypti density is important in determining factors related to dengue transmission, in order to prioritize areas and seasons for vector control. Selection of appropriate surveillance strategies are based upon outcome/objective, also taking into consideration time, resources, and infestation levels.

Additionally, vector surveillance is required to sustain the control measures and detect any increase in vector density [45].'

Following are the most used indices in dengue vector surveillance.

(a) '**House Index or Aedes Index (HI):**Percentage of houses infested with larvae and/or pupae. It is measured as,

$$HI = \frac{No. of houses with positive Aedes Larvae}{No. of houses inspected} \times 100$$

HI has been widely used to calculate the presence and distribution of Aedes population in a given locality. For epidemiological purposes, the HI is extremely important and indicates potential spread of virus through an area once an infected case becomes established.

Generally HI greater than 5% for any locality is an indication that the locality is dengue-sensitive.

(b) **Container Index (CI):**Percentage of water holding containers infested with larvae or pupae. It is measured as,

$$CI = \frac{No. of positive containers}{No. of containers inspected} \times 100$$

CI only provides information on the proportion of water-holding containers that are positive.

(c) **Breteau Index (BI):**Number of positive containers per 100 houses inspected in a specific location. It is measured as,

$BI = \frac{No.of positivecontainers}{No.of housesinspected} \times 100$

BI establishes a relationship between the positive containers and number of houses. Hence the BI is considered as the most useful single index for estimating Aedes density in a location.
BI and HI are commonly used for the determination of priority(risk) areas for control measures. BI greater than 20 for any locality is an indication that the locality is dengue-sensitive.

(d) **Pupal Index (PI):**Number of pupae per 100 houses inspected. It is measured as,

$PI = \frac{No.of pupae}{No.of housesinspected} \times 100$

The emergence of adult mosquito population can be estimated by the pupal count in each container.

(e) **Adult landing/ Biting rate :** Aedes mosquito can be collected on a human bait and landing rate/bait/hour is calculated.
Mosquitoes thus collected can be used for the virus isolations. The males should not be counted while calculating the landing/Biting rate.[46].'

Table 2: Dengue vector surveillance indices and their respective risk markers[46].

Top 5 breeding habitats of Aedes Aegypti		
Indices	High risk of transmissions	Low risk of transmission
House Index	>10%	<1%
Breteau Index	>50	<5
Landing or Biting rate	>2 per man hour	<0.2 per man hour

3. **Dengue cases incidence rates by housing type.**

Incidence rates of reported indigenous DF/DHF cases by housing type, 2000

Housing types	Cases (%)	Incidence rates per 100,000 population*
Compound house	104 (25.9)	43.6
HDB flat	215 (53.5)	8.8
Condominium	42 (10.4)	21.6
Bangsals, containers/workers' quarters	41 (10.2)	45.0
Total	402 (100)	13.5

*Rates are based on 2000 census population
(Source: Department of Statistics, Singapore)

Figure 13: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2000[44].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2001

Housing types	Cases (%)	Incidence rates per 100,000 population*
Compound house	629 (30.5)	275.4
HDB flat	1049 (50.8)	38.0
Condominium	181 (8.8)	135.3
Bangsals, containers/workers' quarters and others	205 (9.9)	146.1
Total	2064 (100.0)	63.3

*Rates are based on 2000 census population
(Source: Department of Statistics, Singapore)

Figure 14: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2001[43].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2002

Housing types	Cases (%)	Incidence rates per 100,000 population*
Compound house	855 (24.0)	358.9
HDB flat	2042 (57.4)	84.0
Condominium	410 (11.5)	211.2
Bangsals, containers/workers' quarters and others	253 (7.1)	292.4
Total	3560(100)	119.2

*Rates are based on 2000 census population
(Source: Department of Statistics, Singapore)

Figure 15: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2002[42].

Incidence rates of reported indigenous DF/DHF cases
(Singaporeans and Permanent Residents) by housing type, 2003

Housing Types	Cases	%	Incidence rate per 100,000 population
Compound houses (including shophouses)	1124	31.9	633.7
HDB flats	1937	55.0	63.9
Condominiums	453	12.9	220.4
Bangsals, containers/workers' quarters and others	7	0.2	-
Total	3521	100.0	102.9

Figure 16: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2003[41].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2004

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	1,877	20.2	586.7
HDB Flats	5,951	64.0	192.3
Condominiums	846	9.1	292.6
Bangsals, containers/workers' quarters and others	623	6.7	116.1
Total	9,297	100.0	219.3

*Rates are based on census of population 2000.
(Source: Singapore Department of Statistics)

Figure 17: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2004[40].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2005

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	2,333	16.6	710.7
HDB Flats	10,545	75.2	332.1
Condominiums	860	6.1	289.8
Others	294	2.1	53.4
Total	14,032	100.0	322.5

*Rates are based on census of population 2000.
(Source: Singapore Department of Statistics)

Figure 18: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2005[39].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2006

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	578	20.3	170.9
HDB Flats	1,878	66.0	57.4
Condominiums	318	11.2	104.0
Others	70	2.5	12.3
Total	2,844	100.0	63.4

*Rates are based on census of population 2000.
(Source: Singapore Department of Statistics)

Figure 19: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2006[38].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2007

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	1,217	14.7	351.5
HDB Flats	5,242	63.2	156.5
Condominiums	1,420	17.2	453.8
Others	408	4.9	70.2
Total	8,287	100.0	180.6

*Rates are based on census of population 2000.
(Source: Singapore Department of Statistics)

Figure 20: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2007[37].

Incidence rates of reported indigenous# DF/DHF cases by housing type, 2008

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	1,363	20.5	373.3
HDB Flats	3,540	53.4	100.2
Condominiums	927	14.0	280.9
Others	801	12.1	130.7
Total	6,631	100.0	137.0

#Cases acquired locally among Singaporeans, permanent and temporary residents.
*Rates are based on 2008 estimated mid-year population.
(Source: Singapore Department of Statistics)

Figure 21: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2008[36].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2009

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	856	20.4	227.9
HDB Flats	2,830	67.6	77.8
Condominiums	410	9.8	120.6
Others	91	2.2	14.4
Total	4,187	100.0	83.9

*Rates are based on census of population 2000.
(Source: Singapore Department of Statistics)

Figure 22: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2009[35].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2010

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	1,614	32.4	484.9
HDB Flats	2,615	52.5	76.3
Condominiums	672	13.5	130.4
Others	77	1.5	232.6
Total	4,978	100	115.5

*Rates are based on census of population 2010.
(Source: Singapore Department of Statistics)

Figure 23: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2010[34].

Incidence rates of reported indigenous DF/DHF cases by housing type, 2011

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	668	18.7	200.7
HDB Flats	2,514	70.3	73.3
Condominiums	381	10.6	73.9
Others	13	0.4	39.2
Total	3,576	100.0	83.0

*Rates are based on census of population 2010.
(Source: Singapore Department of Statistics)

Figure 24: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2011[33].

Incidence rates of reported indigenous DF/DHF cases by housing type for Singapore residents, 2012

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	533	18.6	160.1
HDB Flats	1,992	69.6	58.1
Condominiums	284	9.9	55.1
Others	52	1.8	156.7
Total	2,861	100.0	66.4

*Rates are based on census of population 2010.
(Source: Singapore Department of Statistics)

Figure 25: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2012[32].

Incidence rates of reported indigenous DF/DHF cases by housing type for Singapore residents, 2013

Housing Type	No.	%	Incidence rate per 100,000 population*
Compound houses (including shophouses)	568	6.3	6845.0
HDB Flats	11539	85.4	1222.5
Condominiums	1098	6.0	852.1
Others	309	2.3	476.1
Total	**13514**	**100.0**	**1179.3**

*Rates are based on census of population 2010.
(Source: Singapore Department of Statistics)

Figure 26: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2013[31].

Incidence rates of reported indigenous DF/DHF cases by housing type for Singapore residents, 2014

Housing Type	No.	%	Incidence rate per 100,000 population*
HDB Flats	7,117	67.5	225.6
Landed Properties (including shophouses)	2,266	21.5	896.3
Condominiums and Other Apartments	1,139	10.8	267.4
Others	16	0.2	43.0
Total	**10,538**	**100.0**	**272.2**

*Rates are based on census of population 2014.
(Source: Singapore Department of Statistics)

Figure 27: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2014[30].

Incidence rates of reported indigenous DF/DHF cases by housing type for Singapore residents, 2015

Housing Type	No.	%	Incidence rate per 100,000 population*
HDB Flats	6,914	63.7	218.6
Landed Properties (including shophouses)	1,688	15.6	672.3
Condominiums and Other Apartments	2,253	20.7	497.4
Total	**10,855**	**100.0**	**185.3**

*Rates are based on census of population 2015.
(Source: Singapore Department of Statistics)

Figure 28: Incidence rates of reported indigenous DF/DHF cases By Housing type, 2015[29].

4. **Geographical Distribution of DF/DHF Clusters from 2000 to 2015.**

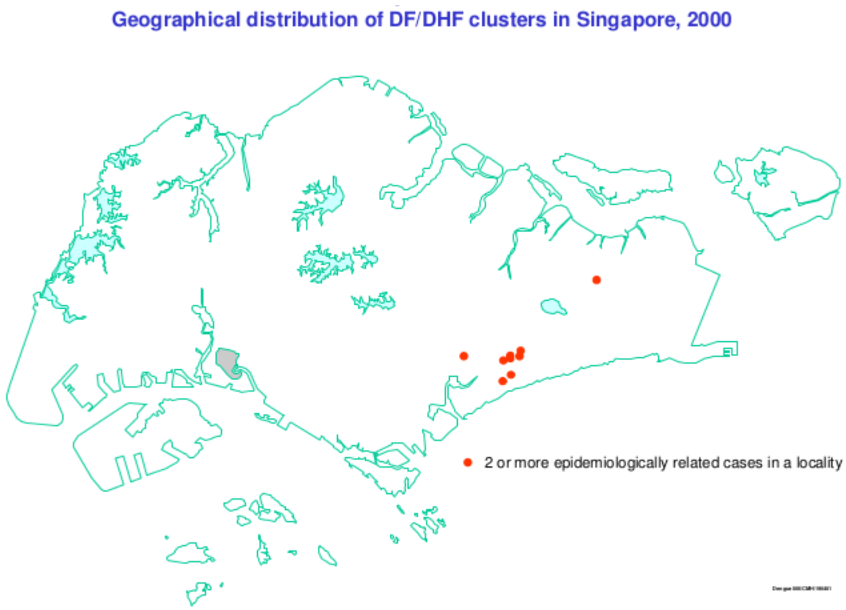


Figure 29: Geographical Distribution of DF/DHF Clusters in 2000[44].

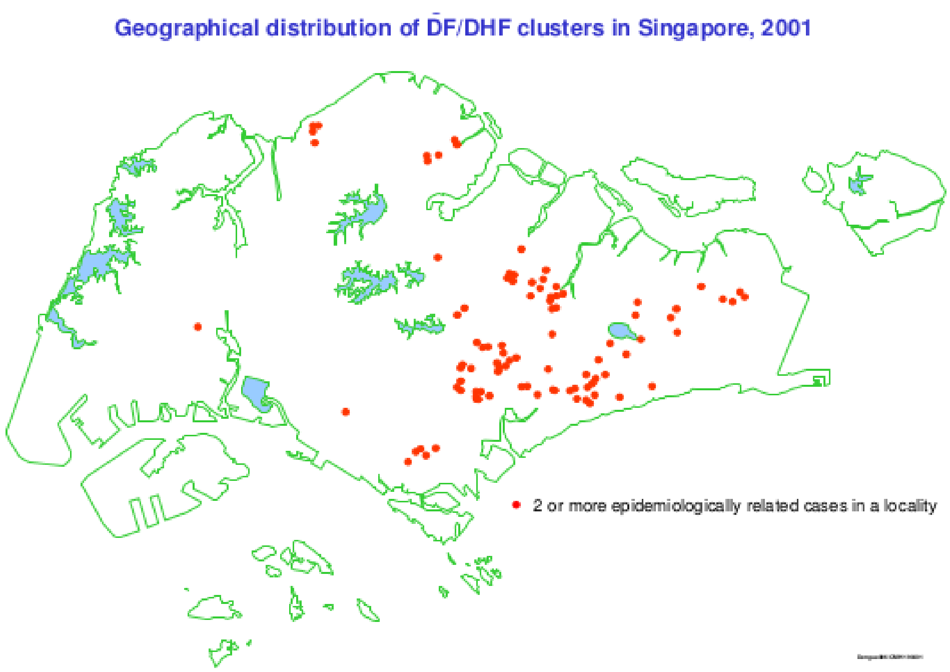


Figure 30: Geographical Distribution of DF/DHF Clusters in 2001[43].

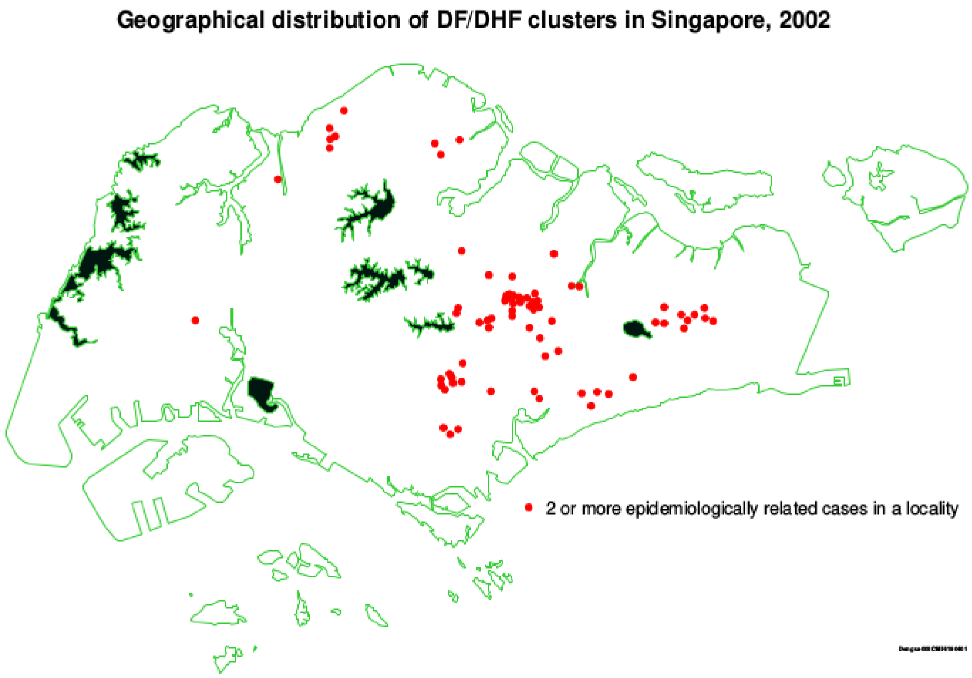


Figure 31: Geographical Distribution of DF/DHF Clusters in 2002[42].

5. **Geographical Distribution of DF/DHF cases from 2003 to 2014.**

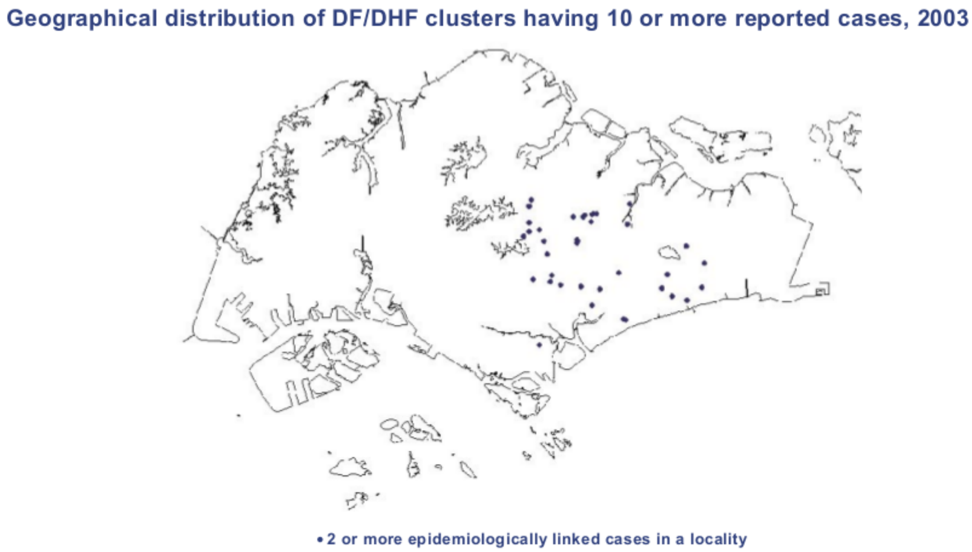


Figure 32: Geographical Distribution of DF/DHF cases in 2003[41].

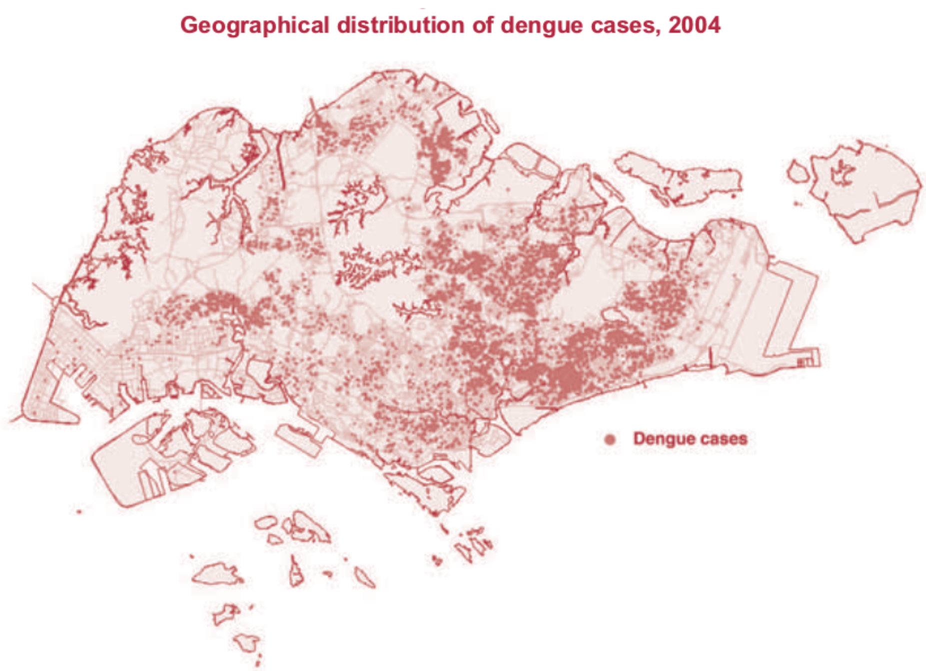


Figure 33: Geographical Distribution of DF/DHF cases in 2004[40].

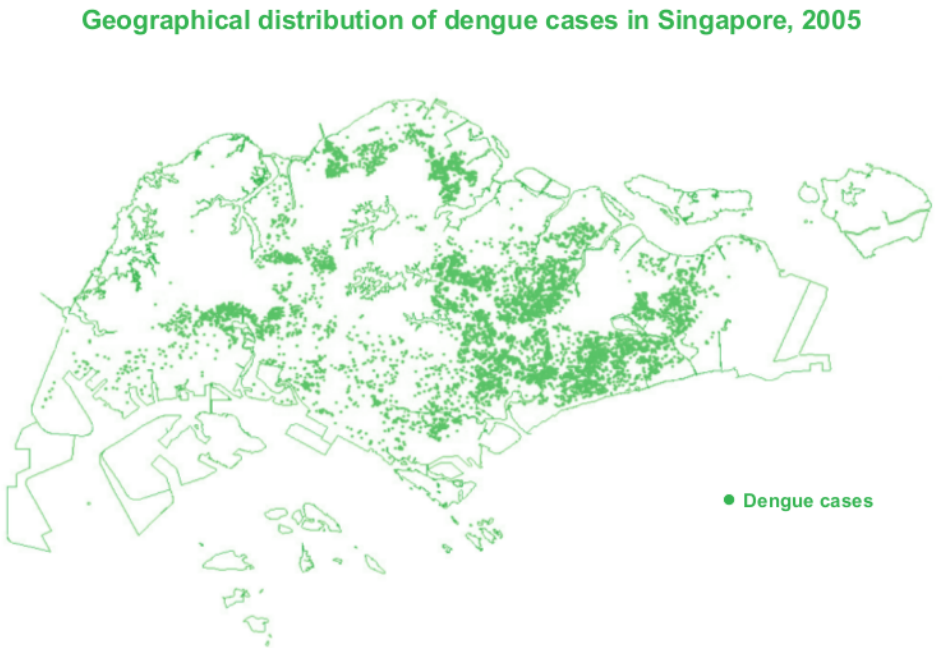


Figure 34: Geographical Distribution of DF/DHF cases in 2005[39].

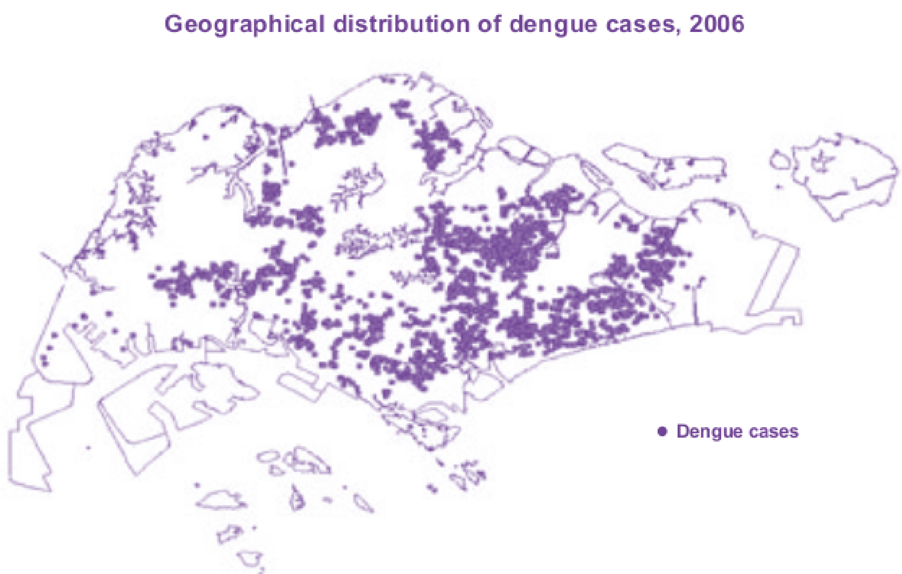


Figure 35: Geographical Distribution of DF/DHF cases in 2006[38].

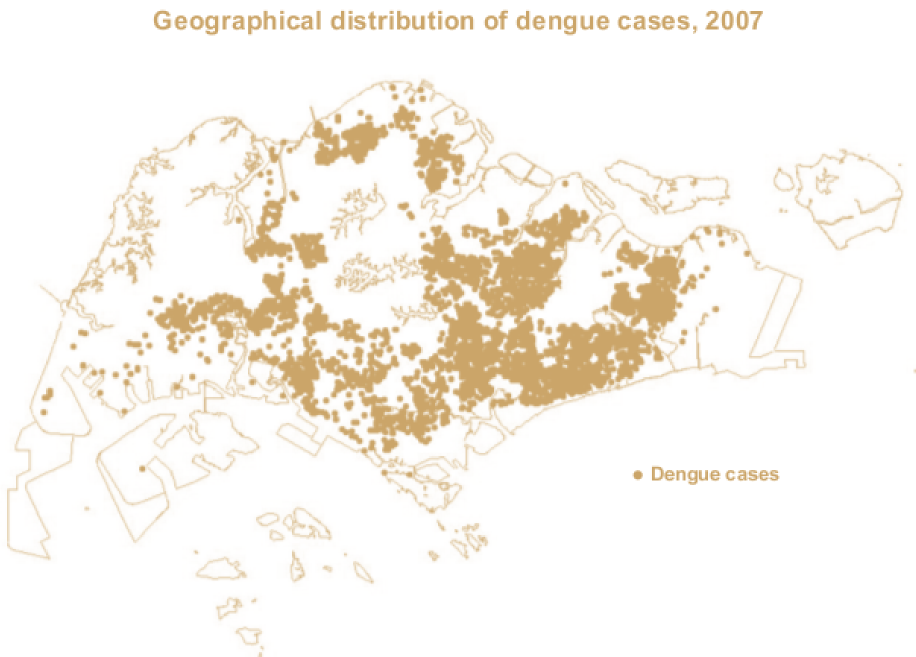


Figure 36: Geographical Distribution of DF/DHF cases in 2007[37].

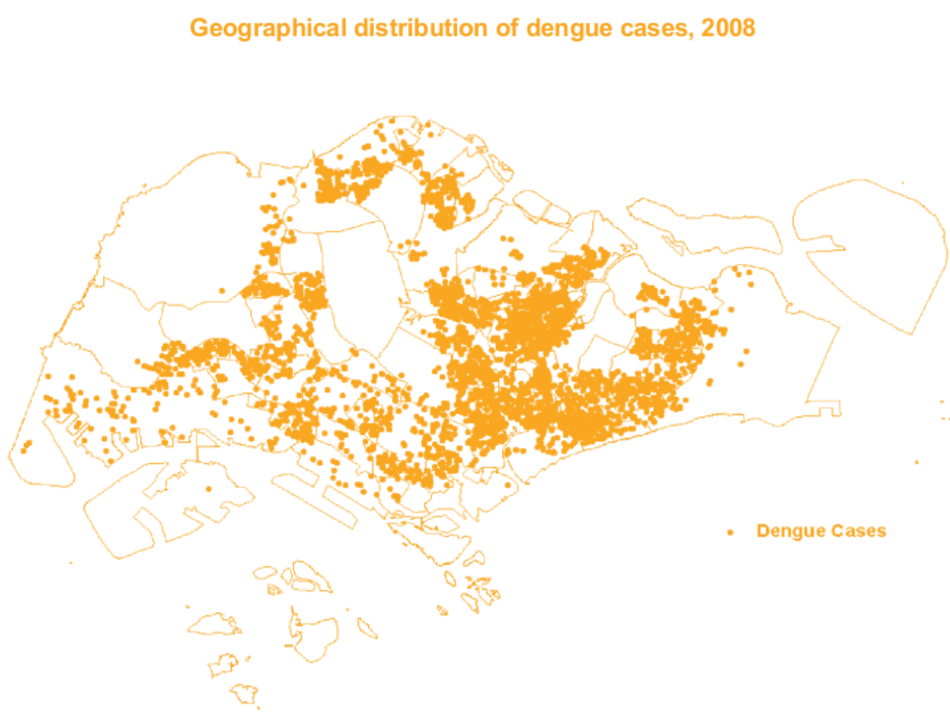


Figure 37: Geographical Distribution of DF/DHF cases in 2008[36].

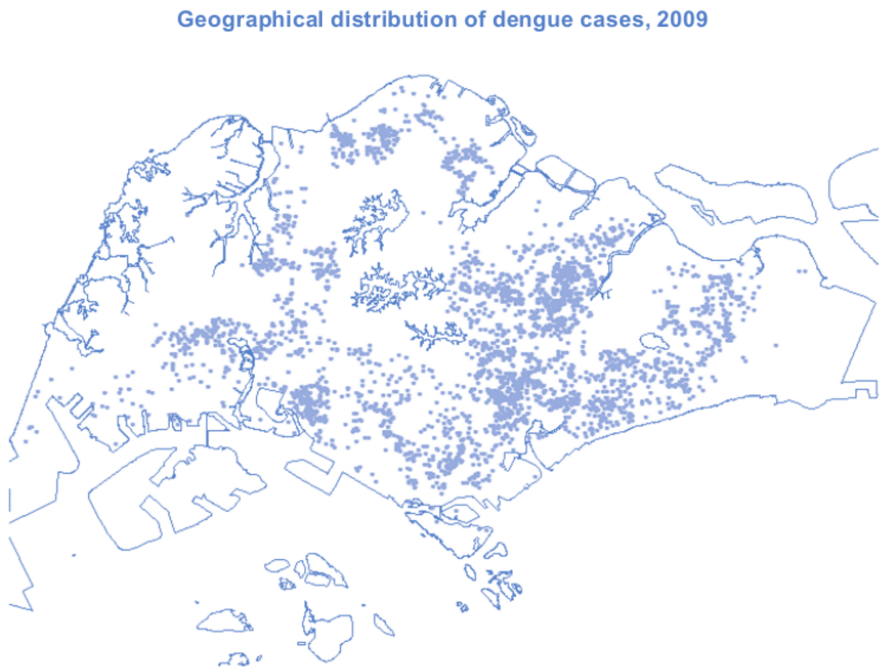


Figure 38: Geographical Distribution of DF/DHF cases in 2009[35].

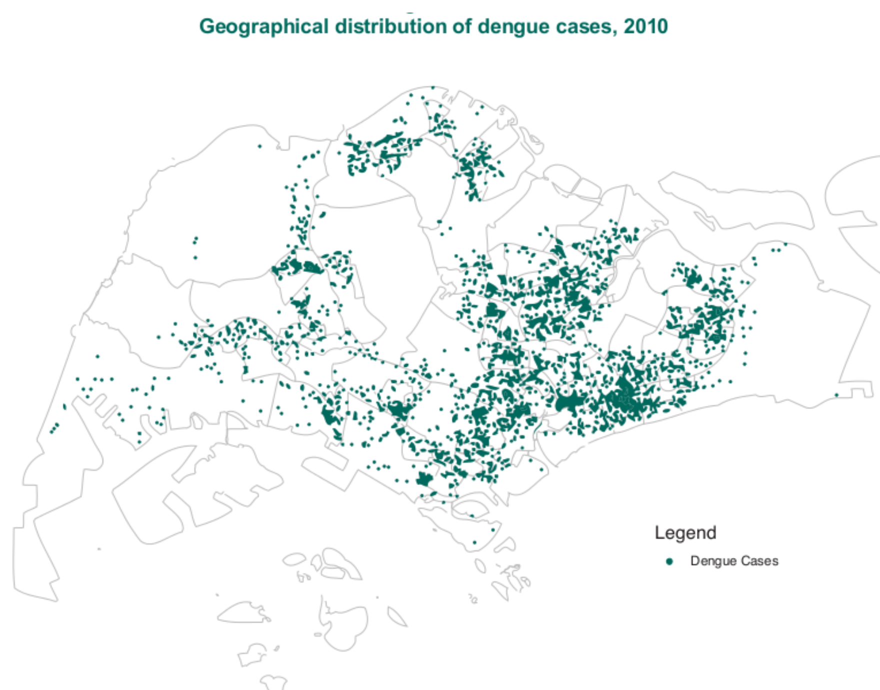


Figure 39: Geographical Distribution of DF/DHF cases in 2010[34].

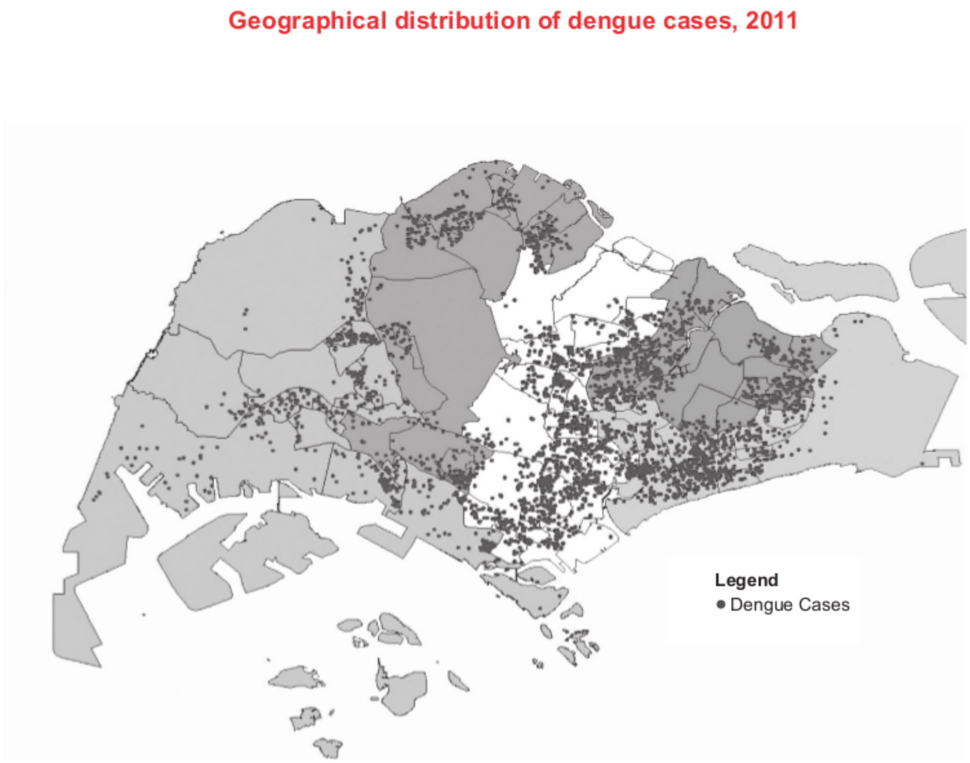


Figure 40: Geographical Distribution of DF/DHF cases in 2011[33].

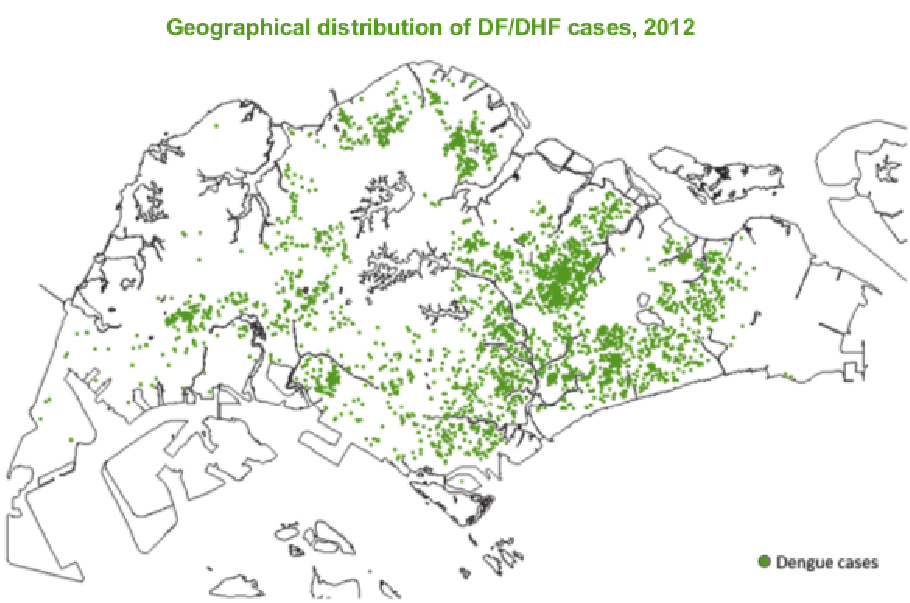


Figure 41: Geographical Distribution of DF/DHF cases in 2012[32].

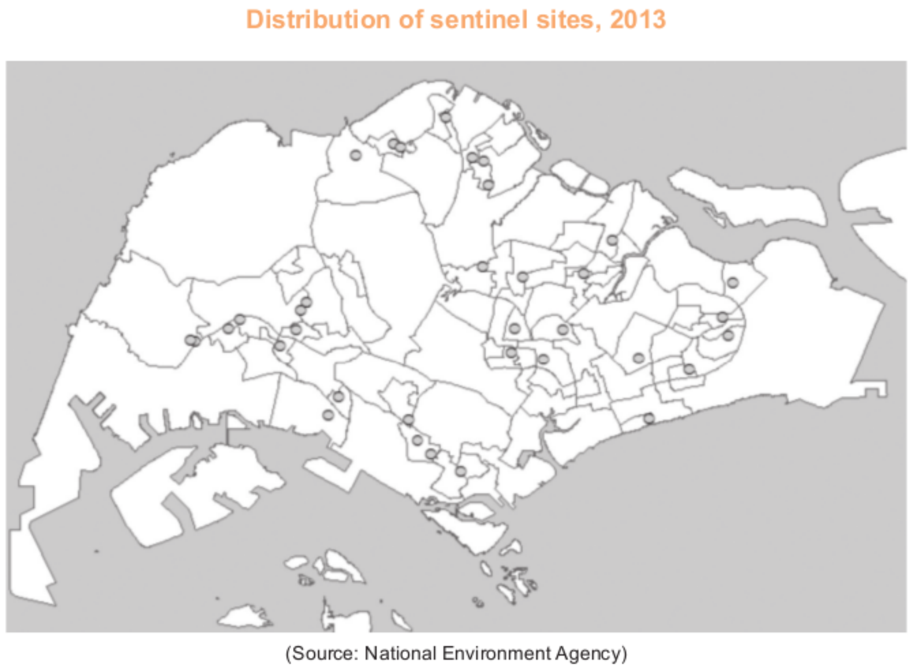


Figure 42: Sentinel Site Distribution in 2013[31].

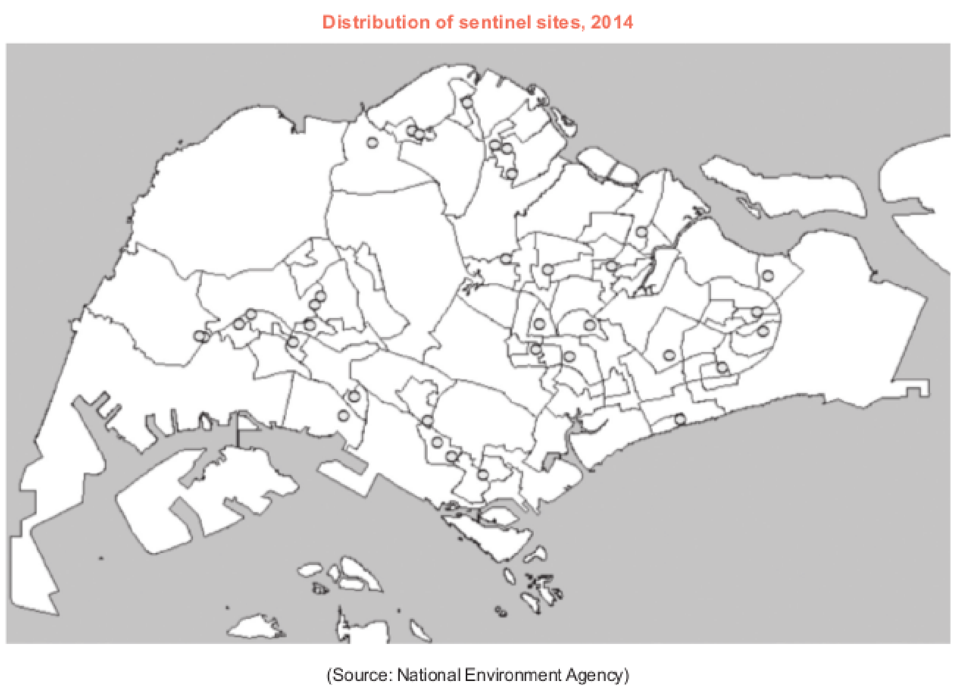


Figure 43: Sentinel site Distribution in 2014[30].

What are Sentinel sites?
World Health organization has defined surveillance systems in two categories.

(a) Active surveillance system/ Sentinel surveillance system.
(b) Passive surveillance system.

'**Sentinel Surveillance system:**

- A sentinel surveillance system is used when high-quality data are needed about a particular disease that cannot be obtained through a passive system. Selected reporting units, with a high probability of seeing cases of the disease in question, good laboratory facilities and experienced well-qualified staff, identify and notify on certain diseases.
- Data collected in a well-designed sentinel system can be used to signal trends, identify outbreaks and monitor the burden of disease in a community, providing a rapid, economical alternative to other surveillance methods.
- A sentinel system deliberately involves only a limited network of carefully selected reporting sites. For example, a network of large hospitals might be used to collect high-quality data on various diseases and their causative organisms, such as invasive bacterial disease caused by Haemophilus influenzae type b, meningococcus or pneumococcus.
- Because sentinel surveillance is conducted only in selected locations, however, it may not be as effective for detecting rare diseases or diseases that occur outside the catchment areas of the sentinel sites.

Passive surveillance system:

- Most passive surveillance systems receive data from as many health workers or health facilities as possible[45].'

6. **Breeding Habitats of Aedes Aegypti and Aedes Albopictus.**

Distribution of *Aedes aegypti* breeding habitats by type of premises, 2000

Type of premises	Total no. checked	No. of premises breeding (%)	Number of breeding habitats																			
			Ornamental container	Domestic container	Discarded receptacle	Perimeter drain	Toilet bowl/cistern	Roof-top water tank	Puddle/ground depression	Canvas/plastic sheet	Roof gutter	Pond/swimming pool	Water stopcock pit/valve chamber	Roof-top	Plant	Sumpit	Inspection chamber cover	Lightning conductor pit	Gully trap	Others	Total
Flat	321,874	1,163 (0.36)	549	360	47	13	15	1	21	8	5	9	0	25	5	0	1	0	4	172	1,235
Compound house	146,726	1,134 (0.77)	283	431	80	46	19	1	18	56	106	44	0	4	6	1	4	1	5	126	1,231
Slum	175	4 (2.28)	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4
Shophouse	35,123	203 (0.58)	15	106	19	2	12	1	16	8	12	0	1	3	1	0	1	0	3	23	223
Factory	4,692	37 (0.79)	3	18	3	1	1	0	5	3	0	0	0	0	0	0	0	0	0	7	41
School	1,297	14 (1.08)	1	3	3	0	0	0	1	0	2	1	0	1	0	0	0	0	0	2	14
Hospital	48	1 (2.08)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Construction site	8,145	221 (2.71)	9	48	30	5	13	0	83	23	3	2	0	5	0	4	0	0	0	51	276
Vacant premises	26,605	136 (0.51)	1	45	28	1	29	0	8	10	4	4	0	2	0	0	1	0	15	16	164
Others	39,231	352 (0.90)	78	81	65	17	8	3	24	19	12	3	1	3	2	1	0	0	6	68	391
Total	583,916	3,265 (0.56)	939	1,095	276	85	97	6	176	127	144	63	2	43	14	6	7	1	33	466	3,580
Total no. of larvae			19,108	38,222	13,282	4,136	2,715	309	15,499	7,794	11,591	3,757	40	13,464	263	910	69	100	521	14,765	146,545
Average no. of larvae/habitats			20	35	48	49	28	52	88	61	80	60	20	313	19	152	10	100	16	32	41

Source: Vector Control & Research Department, Ministry of the Environment

Figure 44: Breeding habitats of Aedes Aegypti in 2000[44].

Distribution of *Aedes albopictus* breeding habitats by type of premises, 2000

Type of premises	Total no. checked	No. of premises breeding (%)	Number of breeding habitats																			
			Ornamental container	Domestic container	Discarded receptacle	Perimeter drain	Toilet bowl/cistern	Roof-top water tank	Puddle/ground depression	Canvas/plastic sheet	Roof gutter	Pond/swimming pool	Water stopcock pit/valve chamber	Roof-top	Plant	Sumpit	Inspection chamber cover	Lightning conductor pit	Gully trap	Others	Total
Flat	321,874	688 (0.21)	197	170	81	10	7	1	20	16	29	6	8	7	13	2	2	3	35	142	749
Compound house	146,726	1,863 (1.27)	584	638	197	45	19	1	23	130	89	36	5	2	53	3	28	1	62	166	2,082
Slum	175	4 (2.29)	0	5	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	7
Shophouse	35,123	113 (0.32)	7	42	23	1	0	0	1	24	3	0	2	1	2	0	0	0	2	13	121
Factory	4,692	452 (9.63)	27	133	121	13	3	0	14	208	19	2	2	2	5	2	0	3	5	108	667
School	1,297	110 (8.49)	14	26	32	4	3	0	3	9	5	2	6	3	13	3	0	0	3	17	143
Hospital	48	7 (14.58)	1	1	3	0	0	0	2	0	1	0	0	0	0	0	0	0	1	1	10
Construction site	8,145	562 (6.90)	25	98	169	17	10	0	170	94	6	1	4	6	4	6	6	0	5	145	766
Vacant premises	26,605	59 (0.22)	20	87	134	15	22	0	18	31	6	4	0	8	18	0	4	0	71	35	473
Others	39,231	691 (1.76)	64	157	259	40	10	2	22	123	43	8	7	1	43	2	8	4	31	149	973
Total	583,916	4,549 (0.78)	939	1,357	1,020	145	74	4	273	636	201	59	34	30	151	18	48	11	215	776	5,991
Total no. of larvae			23,157	45,010	42,099	6,904	3,016	43	17,761	30,581	32,122	2,607	1,488	4,634	5,294	995	808	425	4,883	30,215	252,042
Average no. of larvae/habitats			25	33	41	48	41	11	65	40	160	44	44	154	35	55	17	39	23	39	42

Figure 45: Breeding habitats of Aedes Albopictus in 2000[44].

Distribution of *Aedes aegypti* breeding habitats by type of premises, 2001

Type of premises	Total no. checked	No. of premises breeding (%)	Number of breeding habitats: Ornamental container	Domestic container	Discarded receptacle	Perimeter drain	Toilet bowl/cistern	Roof-top water tank/roof top	Puddle/ground depression	Canvas/plastic sheet	Roof gutter	Pond/swimming pool	Water stopcock pit/valve chamber	Plant	Sumpit	Inspection chamber cover	Lightning conductor pit	Gully trap	Others	Total
Flat	218,418	1,410 (0.65)	729	402	34	6	18	10	18	8	8	7	0	5	0	2	0	5	158	1,410
Compound house	130,491	1,238 (0.95)	337	365	49	38	12	7	9	50	163	34	0	4	0	6	0	7	157	1,238
Slum	204	6 (2.94)	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Shophouse	26,809	244 (0.91)	44	107	17	1	4	1	7	9	20	0	0	0	0	0	0	4	30	244
Factory	3,259	37 (1.14)	2	5	1	0	0	0	0	10	5	2	0	1	0	0	0	1	7	37
School	800	24 (3.00)	4	3	3	1	0	2	1	0	1	0	0	1	0	0	0	0	8	24
Hospital	58	3 (5.17)	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Construction site	7,547	306 (4.05)	7	38	40	4	7	8	76	28	0	1	2	0	1	0	0	5	89	306
Vacant premises	6,573	82 (1.25)	1	20	13	3	12	5	9	4	3	3	0	0	0	0	0	4	5	82
Others	52,723	317 (0.60)	88	60	21	13	6	4	8	21	18	3	1	1	2	0	0	7	64	317
Total no. of larvae			10,231	13,703	14,411	2,490	335	3,023	1,661	2,485	2,995	150	328	330	0	682	82	545	10,577	64,028
Average no. of larvae/habitats			8	14	81	38	6	82	13	19	14	3	109	28	152	85	100	17	20	17

Figure 46: Breeding habitats of Aedes Aegypti in 2001[43].

Distribution of *Aedes albopictus* breeding habitats by type of premises, 2001

Type of premises	Total no. checked	No. of premises breeding (%)	Number of breeding habitats: Ornamental container	Domestic container	Discarded receptacle	Perimeter drain	Toilet bowl/cistern	Roof-top water tank/roof top	Puddle/ground depression	Canvas/plastic sheet	Roof gutter	Pond/swimming pool	Water stopcock pit/valve chamber	Plant	Sumpit	Inspection chamber cover	Lightning conductor pit	Gully trap	Others	Total
Flat	218,418	592 (0.27)	231	131	67	11	3	3	8	13	10	3	3	3	2	0	1	14	89	592
Compound house	130,491	1,748 (1.34)	548	475	104	30	19	10	11	93	116	31	1	30	3	18	5	24	230	1,748
Slum	204	2 (0.98)	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Shophouse	26,809	110 (0.41)	17	40	14	1	1	0	3	5	5	1	0	3	0	0	0	1	19	110
Factory	3,259	239 (7.33)	16	42	27	8	0	0	4	61	7	2	1	3	2	0	4	4	58	239
School	800	123 (15.38)	13	14	17	7	3	2	4	6	3	0	2	8	5	1	0	5	33	123
Hospital	58	9 (15.52)	0	2	3	0	0	0	0	2	0	0	0	0	0	0	0	0	2	9
Construction site	7,547	699 (9.26)	15	66	144	16	14	16	117	93	3	5	2	4	6	3	0	7	188	699
Vacant premises	6,573	318 (4.84)	18	58	91	7	18	2	8	16	7	3	0	12	0	1	0	43	34	318
Others	52,723	724 (1.37)	82	95	161	21	17	6	25	73	29	4	4	27	3	10	2	25	140	724
Total	446,882	4,564 (1.02)	940	924	629	101	75	39	180	362	180	49	13	90	21	33	12	123	793	4,564
Total no. of larvae			12,177	16,475	60,074	6,930	560	1946	3,234	9,092	7,069	520	1,342	9,284	0	3,164	3,329	5,771	33,922	174,889
Average no. of larvae/habitats			13	18	96	69	7	50	18	25	39	11	103	103		96	227	47	43	38

Figure 47: Breeding habitats of Aedes Albopictus in 2001[43].

Distribution of *Aedes aegypti* breeding habitats by type of premises, 2002

Type of premises	Total no. checked	No. of premises breeding (%)	Larvae count in breeding habitat																			
			Ornamental container	Domestic container	Discarded receptacle	Perimeter drain	Toilet bowl/cistern	Roof-top water tank	Puddle/ground depression	Canvas/plastic sheet	Roof gutter	Pond/swimming pool	Water stopcock pit / valve chamber	Roof-top	Plants	Sump pit	Inspection chamber cover	Lightning conductor pit	Gully traps	Others	Total
Flat	190782	2543(1.33)	1343	968	26	0	31	0	2	8	2	10	0	2	6	0	0	0	3	335	2736
Compound house	119803	1427(1.19)	526	448	36	64	9	1	7	30	156	34	2	4	6	0	6	0	10	275	1614
Apart & Condo	45571	452(0.99)	214	106	7	16	9	10	9	7	13	1	1	9	4	0	0	0	5	91	502
Shophouse	22805	126(0.55)	26	54	4	2	4	0	2	7	8	0	0	2	0	0	0	0	1	36	146
Factory	3868	32(0.82)	0	9	3	1	2	1	1	5	3	0	0	2	0	0	0	0	0	15	42
School	825	14(1.69)	0	1	0	2	1	0	1	1	2	0	0	1	1	0	0	0	0	4	14
Hospital	219	2(0.91)	1	0	0	0	0	0	0	0	2	0	0	2	1	0	0	0	2	1	9
Construction site	7381	199(2.69)	7	22	16	2	11	4	55	23	2	3	0	2	1	0	2	1	1	152	304
Vacant premises	7612	83(1.09)	2	17	9	5	18	0	5	2	5	3	1	0	1	0	0	0	11	20	99
Others	15547	253(1.62)	88	75	56	14	11	2	29	16	28	6	1	12	2	0	4	0	14	103	461
Total	414413	5208(1.25)	2207	1700	157	106	96	18	111	99	221	57	5	36	22	0	12	1	47	1032	5927
Total no. of larvae			42631	50769	4494	2429	3295	1450	5685	5208	15321	3928	265	3518	320	0	181	10	1085	30599	171188
Average no. of larvae/habitats			19	30	29	23	34	81	51	53	69	69	53	98	15	0	15	10	23	30	29

Figure 48: Breeding habitats of Aedes Aegypti in 2002[42].

Distribution of *Aedes albopictus* breeding habitats by type of premises, 2002

Type of premises	Total no. checked	No. of premises breeding (%)	Larvae count in breeding habitat																			
			Ornamental container	Domestic container	Discarded receptacle	Perimeter drain	Toilet bowl/cistern	Roof-top water tank	Puddle/ground depression	Canvas/plastic sheet	Roof gutter	Pond/swimming pool	Water stopcock pit / valve chamber	Roof-top	Plants	Sump pit	Inspection chamber cover	Lightning conductor pit	Gully traps	Others	Total
Flat	190782	970(0.51)	509	339	18	1	8	0	0	5	3	0	0	0	6	0	1	1	1	149	1041
Compound house	119803	1616(1.35)	620	456	89	16	12	3	8	69	106	11	1	3	34	0	14	5	20	370	1837
Apart & Condo	45571	316(0.69)	149	55	15	9	1	1	1	10	15	1	3	1	18	0	2	2	5	80	368
Shophouse	22805	67(0.29)	13	28	2	0	0	0	2	7	2	0	0	0	0	0	0	0	0	17	71
Factory	3868	164(4.23)	5	38	33	6	2	0	7	51	4	3	1	2	1	0	1	0	3	102	259
School	825	33(4.00)	7	8	4	1	0	0	0	2	2	0	1	2	2	0	1	0	1	21	52
Hospital	219	11(5.02)	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	4	10	19
Construction site	7381	270(3.66)	3	29	80	4	10	5	42	62	2	1	0	0	6	0	6	0	3	183	436
Vacant premises	7612	175(2.3)	16	21	51	5	22	1	3	7	4	4	0	0	12	0	0	0	45	33	224
Others	15547	444(2.85)	91	122	164	19	39	3	15	94	46	9	4	6	31	0	12	3	72	300	1030
Total	414413	4066(0.98)	1413	1096	456	61	94	13	78	307	189	29	10	14	110	0	37	11	154	1265	5337
Total no. of larvae			39910	33387	17403	3072	2282	1884	4643	16268	20949	3049	130	3225	3201	0	2204	684	3928	43779	199998
Average no. of larvae/habitats			28	30	38	50	24	145	60	53	111	105	13	230	29	0	60	62	26	35	37

Source: Vector Control & Research Department, National Environment Agency

Figure 49: Breeding habitats of Aedes Albopictus in 2002[42].

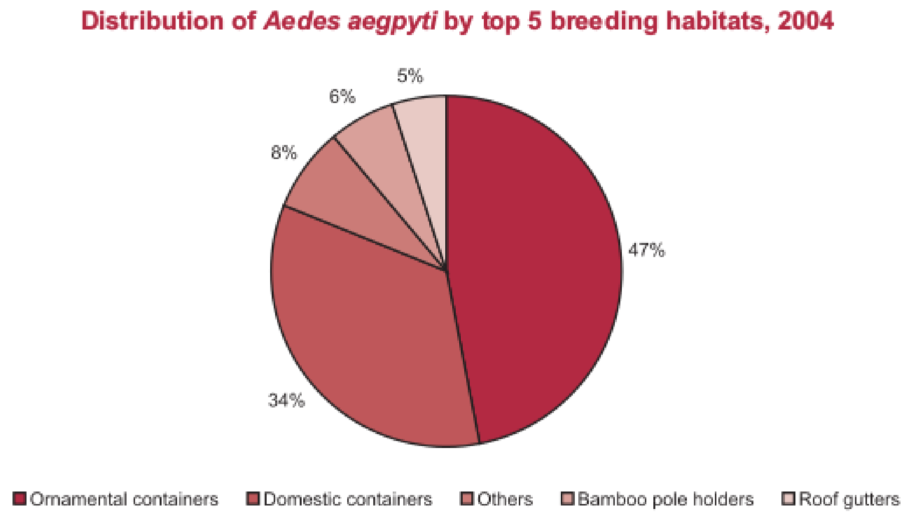


Figure 50: Breeding habitats of Aedes Aegypti in 2004[40].

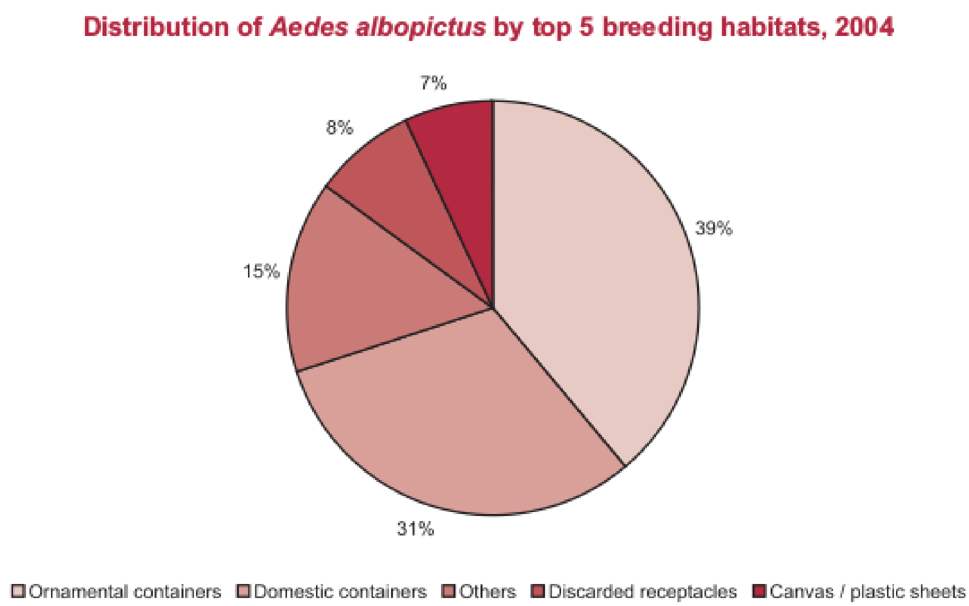


Figure 51: Breeding habitats of Aedes Albopictus in 2004[40].

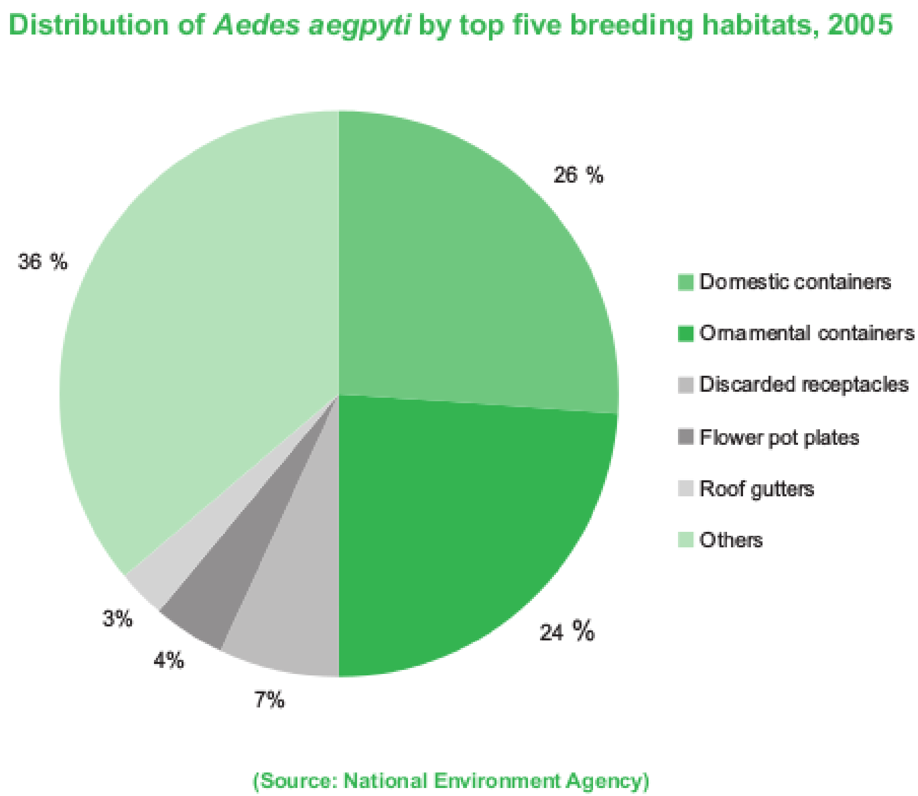


Figure 52: Breeding habitats of Aedes Aegypti in 2005[39].

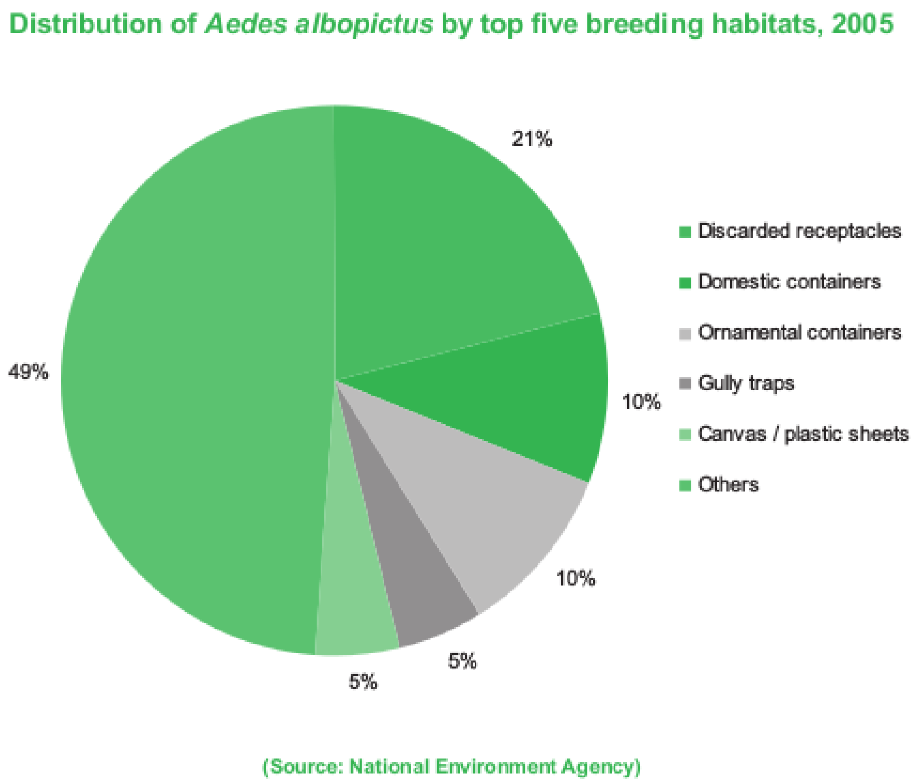


Figure 53: Breeding habitats of Aedes Albopictus in 2005[39].

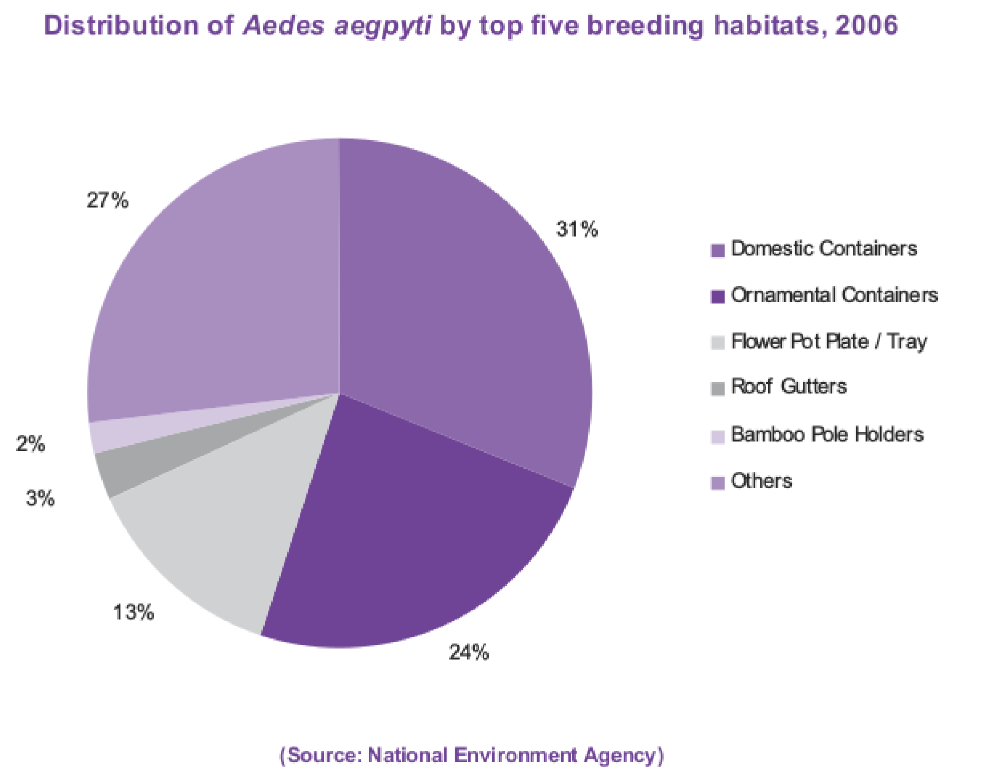


Figure 54: Breeding habitats of Aedes Aegypti in 2006[38].

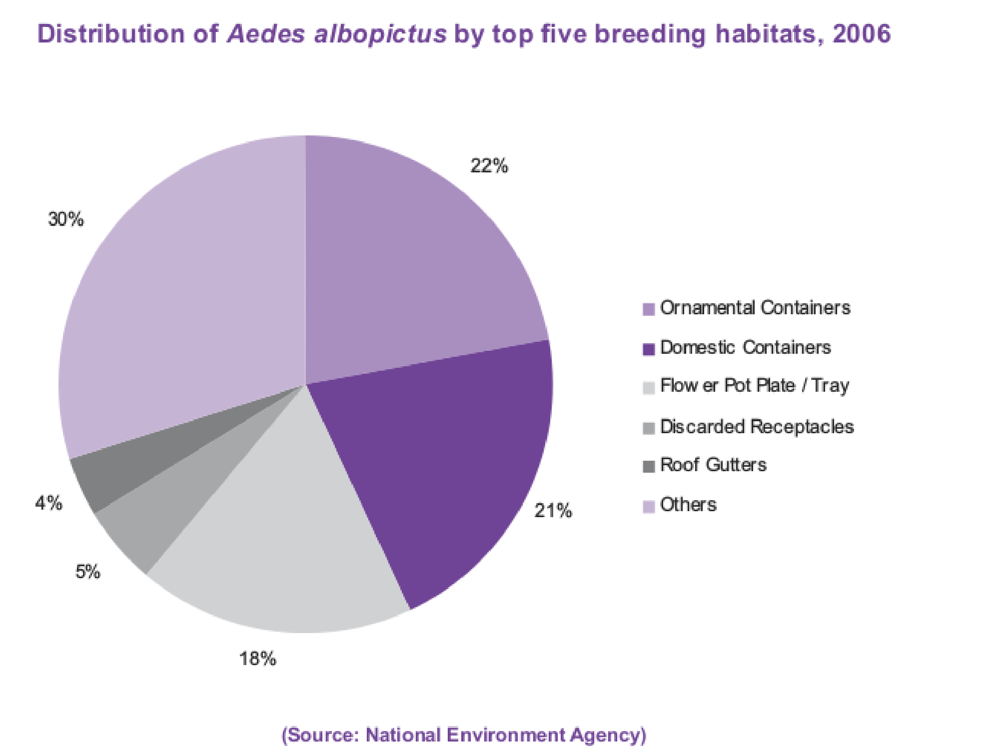


Figure 55: Breeding habitats of Aedes Albopictus in 2006[38].

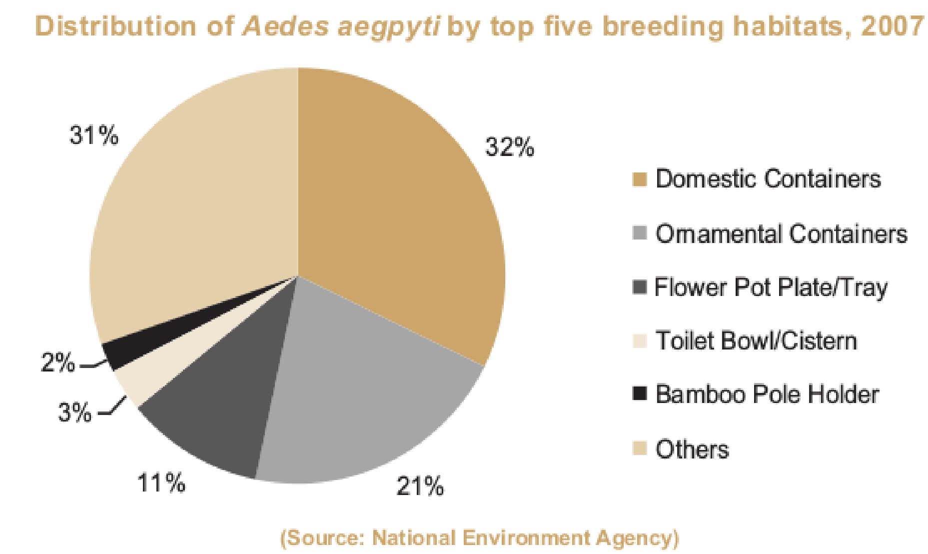


Figure 56: Breeding habitats of Aedes Aegypti in 2007[37].

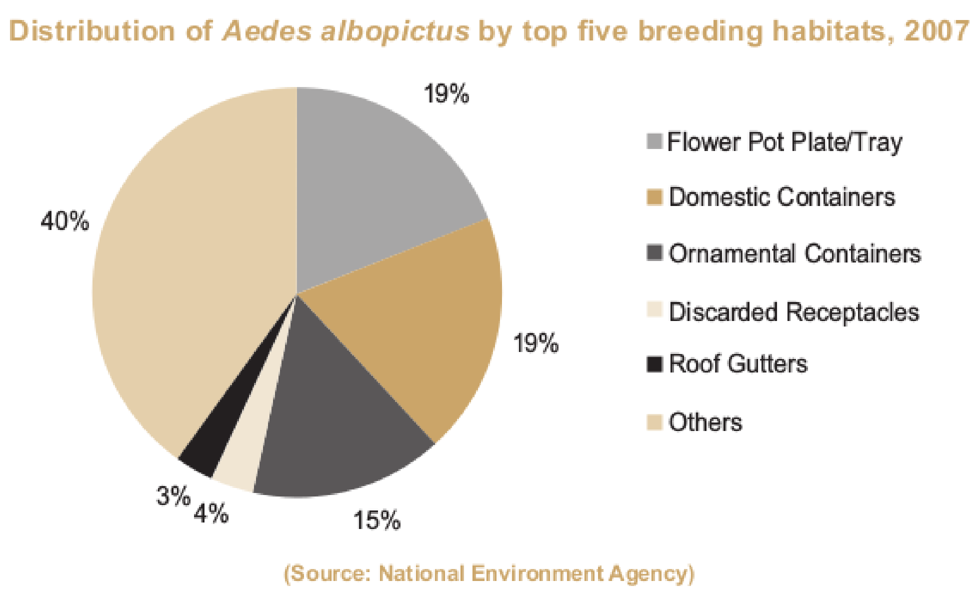


Figure 57: Breeding habitats of Aedes Albopictus in 2007[37].

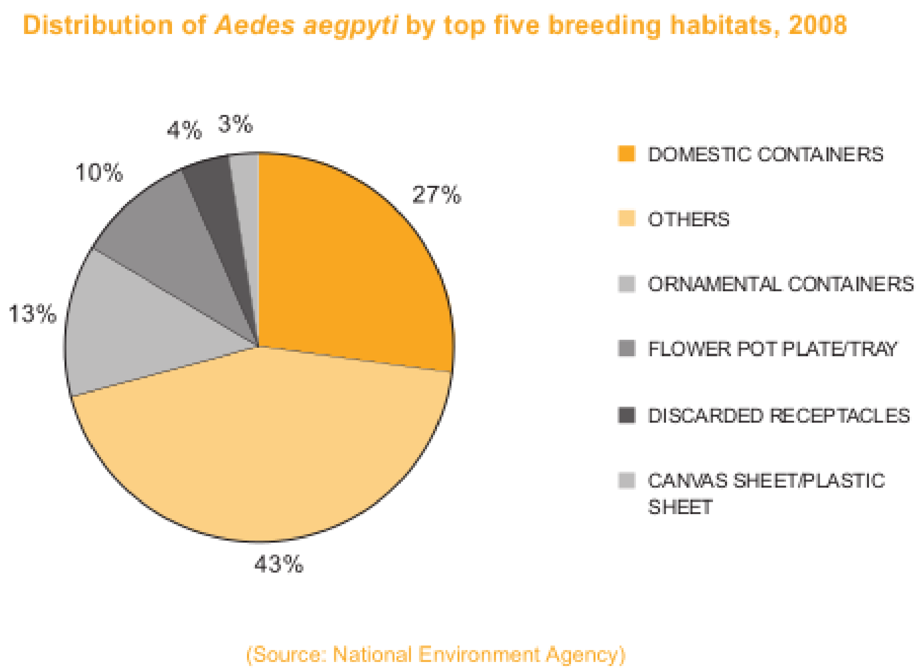


Figure 58: Breeding habitats of Aedes Aegypti in 2008[36].

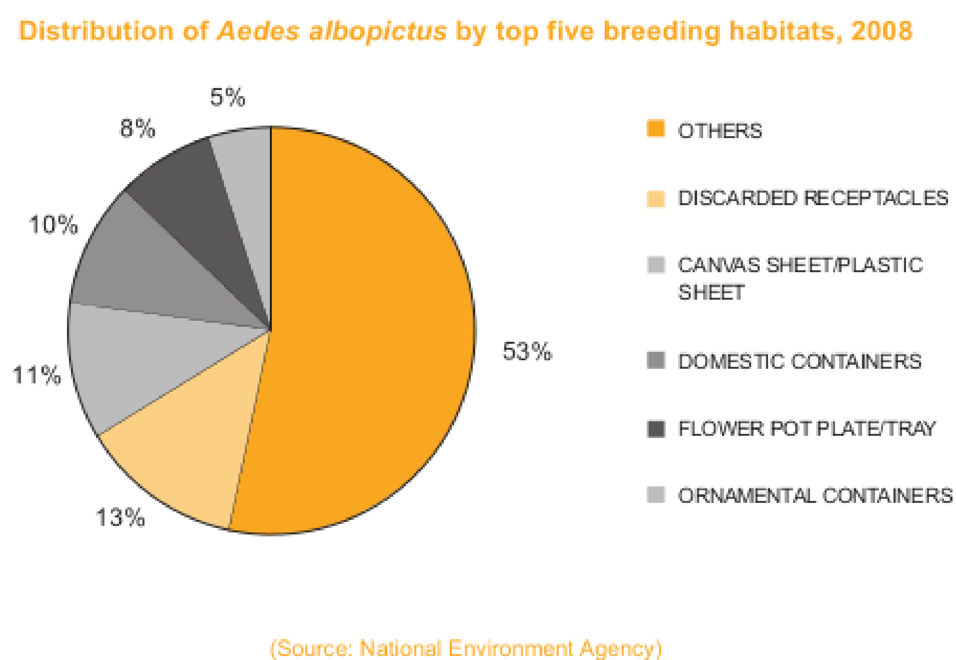


Figure 59: Breeding habitats of Aedes Albopictus in 2008[36].

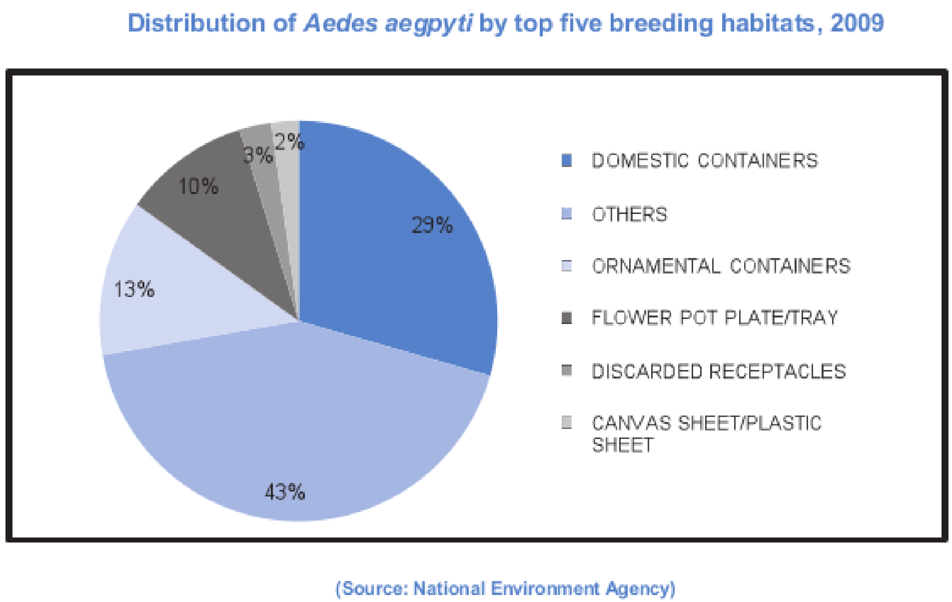


Figure 60: Breeding habitats of Aedes Aegypti in 2009[35].

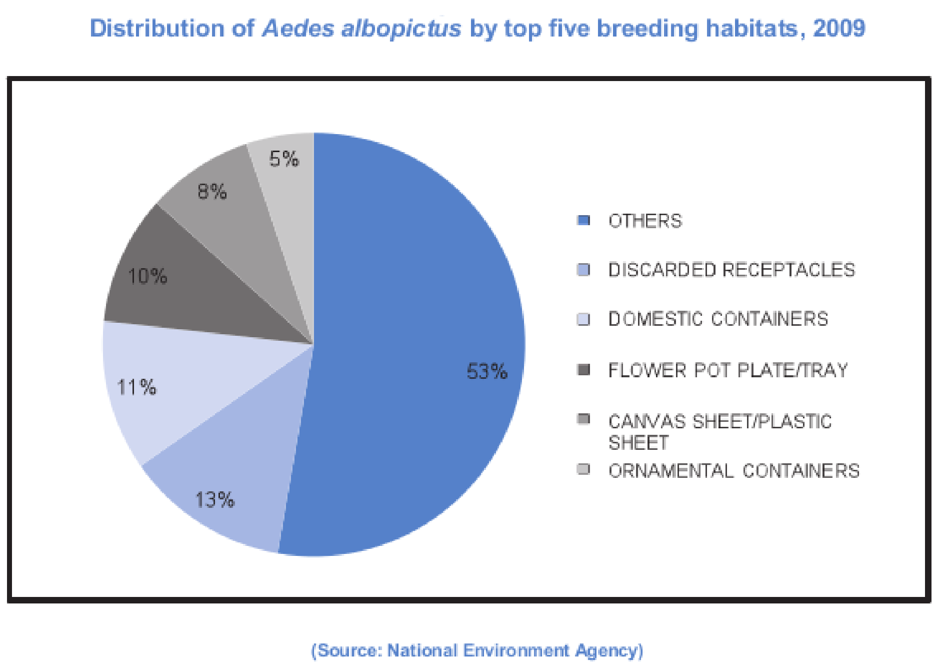


Figure 61: Breeding habitats of Aedes Albopictus in 2009[35].

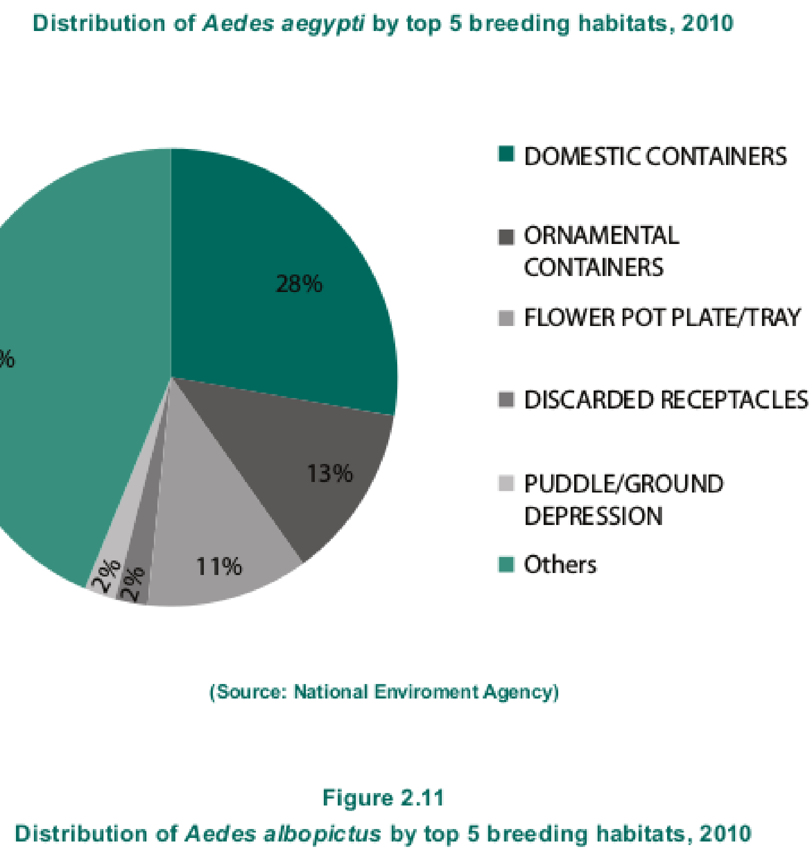


Figure 62: Breeding habitats of Aedes Aegypti in 2010[34].

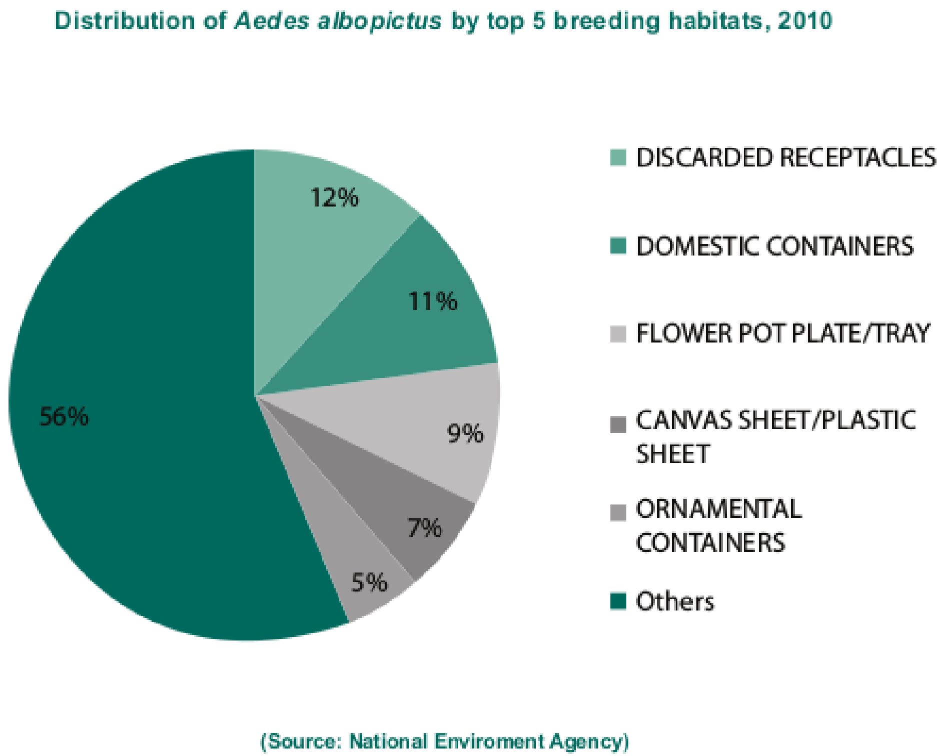


Figure 63: Breeding habitats of Aedes Albopictus in 2010[34].

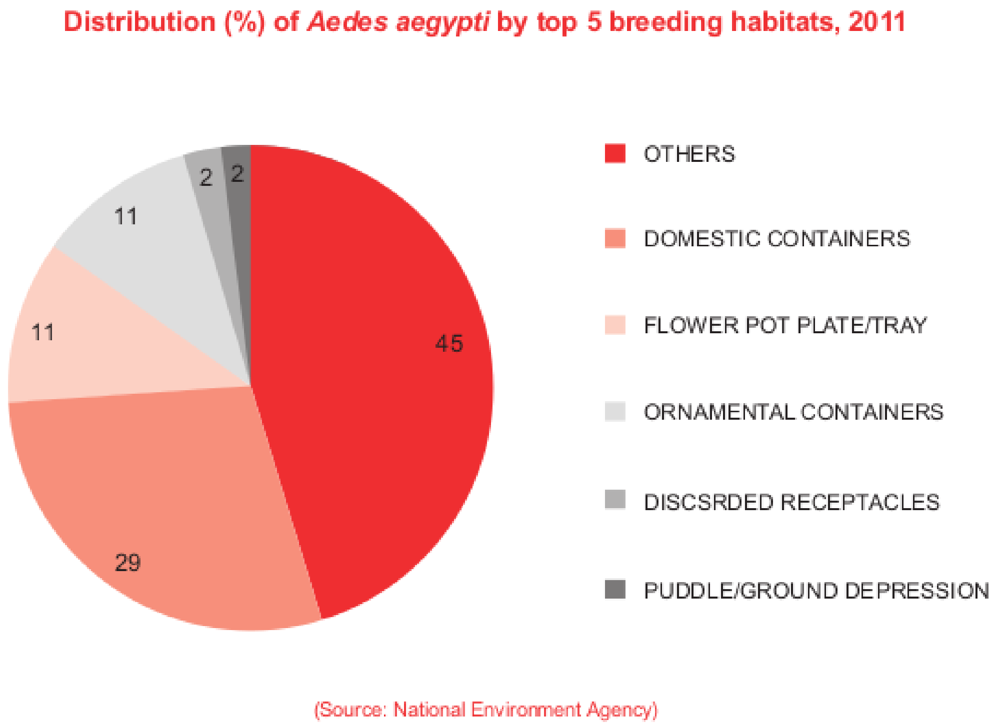


Figure 64: Breeding habitats of Aedes Aegypti in 2011[33].

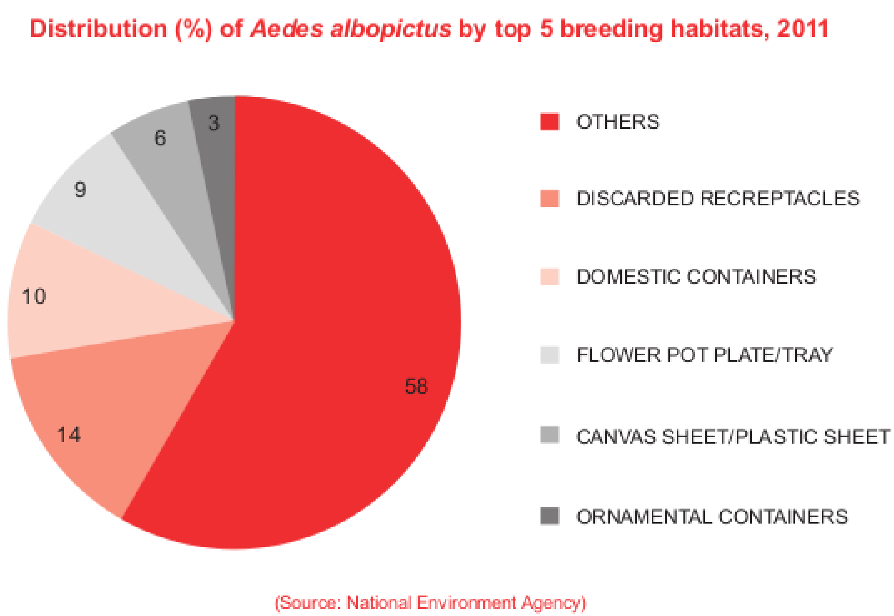


Figure 65: Breeding habitats of Aedes Albopictus in 2011[33].

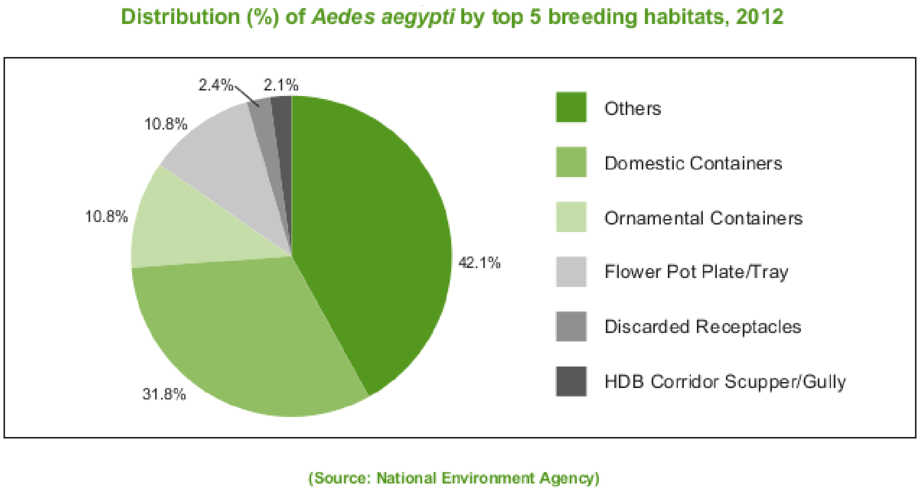


Figure 66: Breeding habitats of Aedes Aegypti in 2012[32].

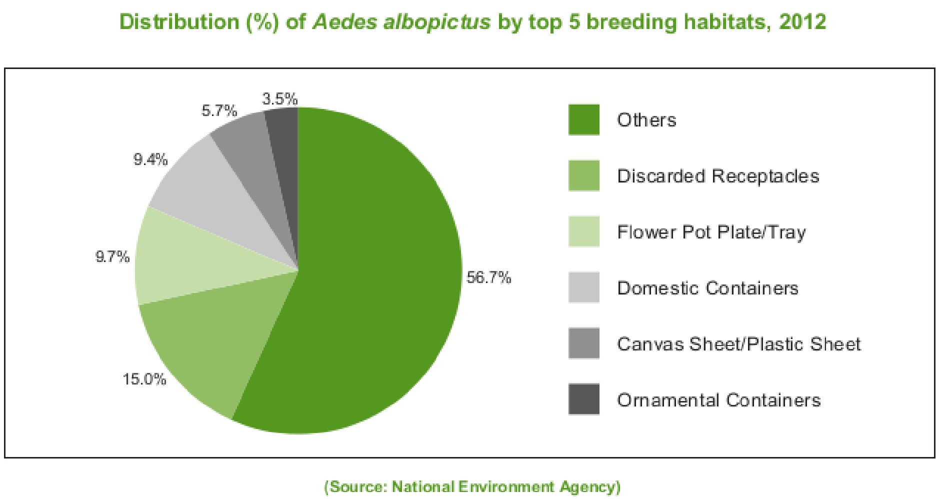


Figure 67: Breeding habitats of Aedes Albopictus in 2012[32].

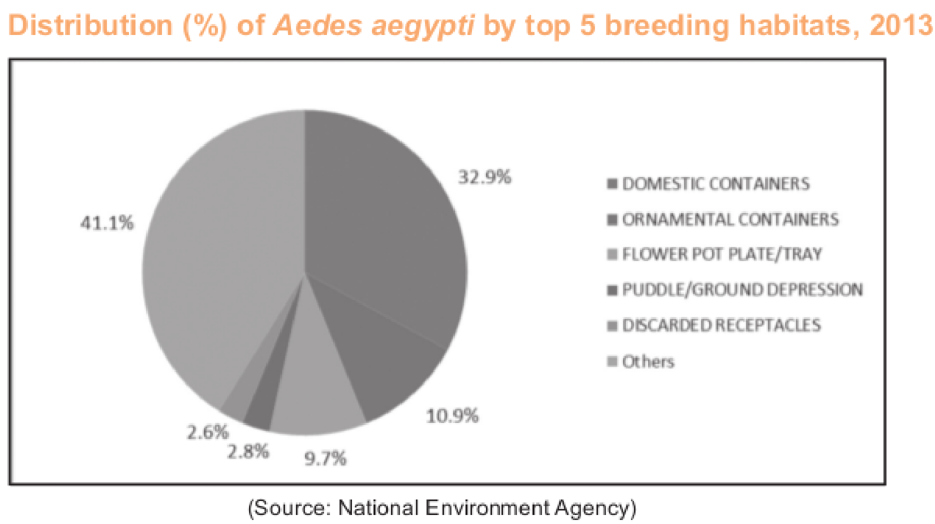


Figure 68: Breeding habitats of Aedes Aegypti in 2013[31].

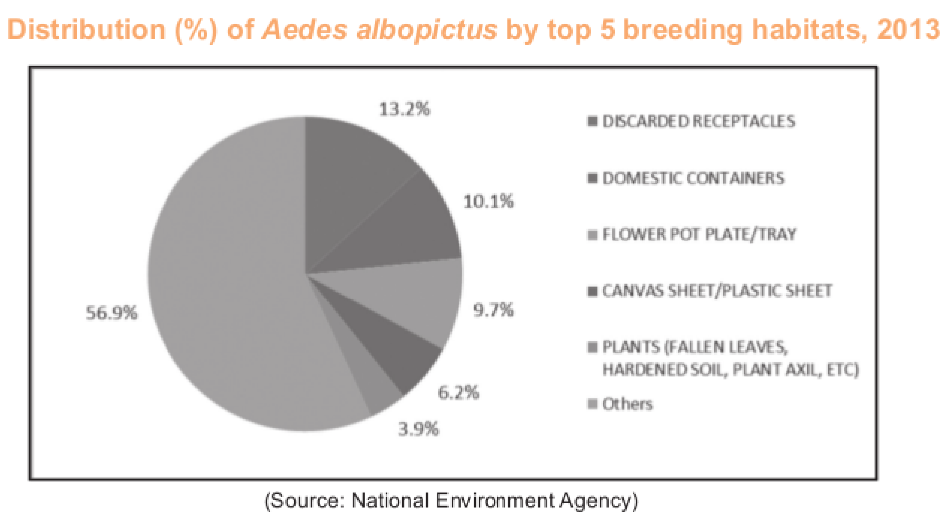


Figure 69: Breeding habitats of Aedes Albopictus in 2013[31].

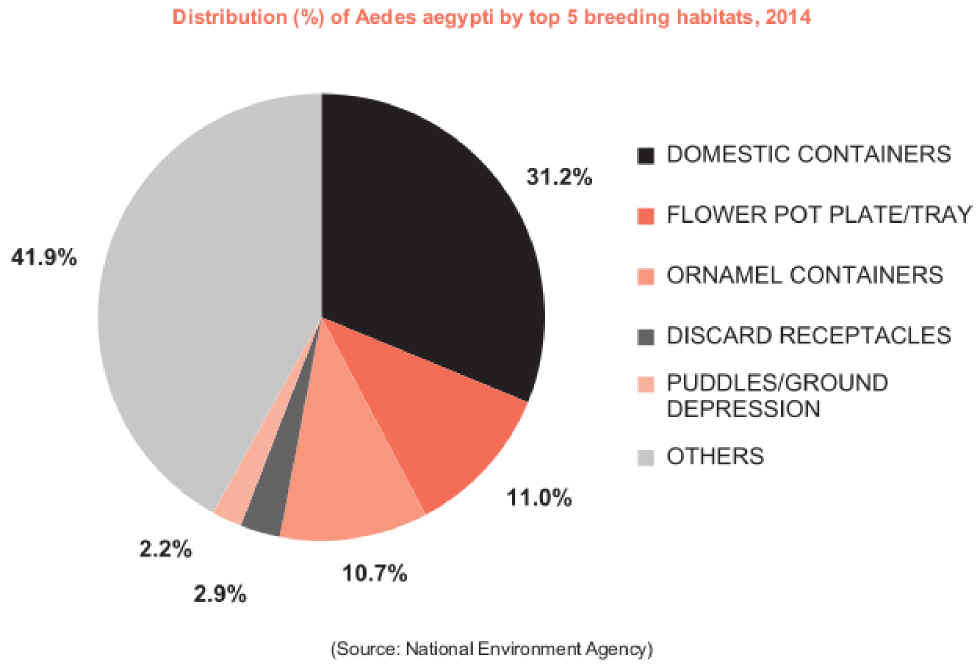


Figure 70: Breeding habitats of Aedes Aegypti in 2014[30].

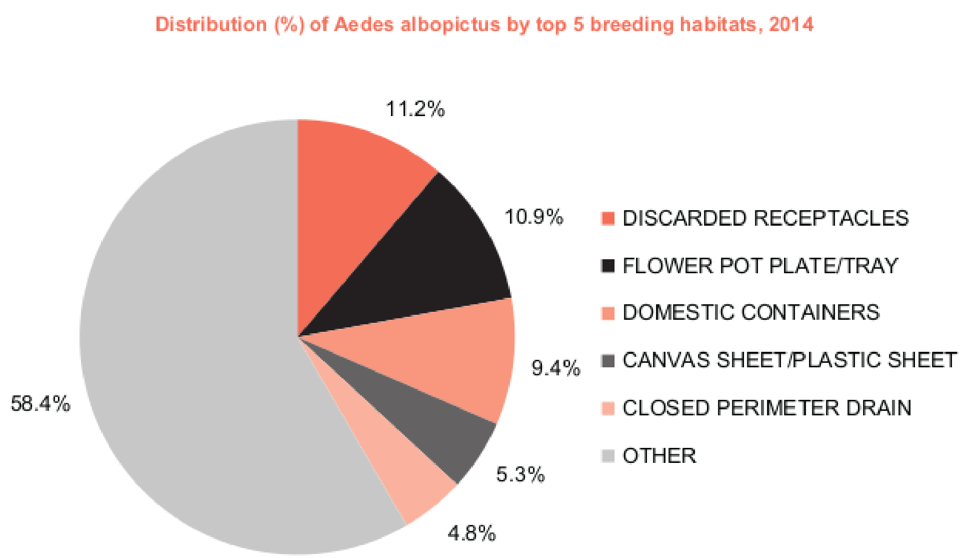


Figure 71: Breeding habitats of Aedes Albopictus in 2014[30].

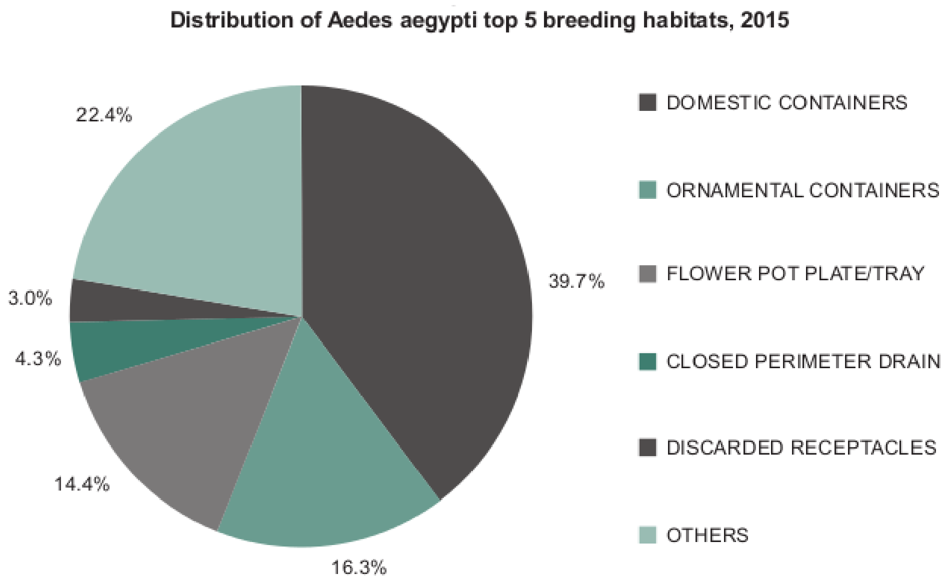


Figure 72: Breeding habitats of Aedes Aegypti in 2015[29].

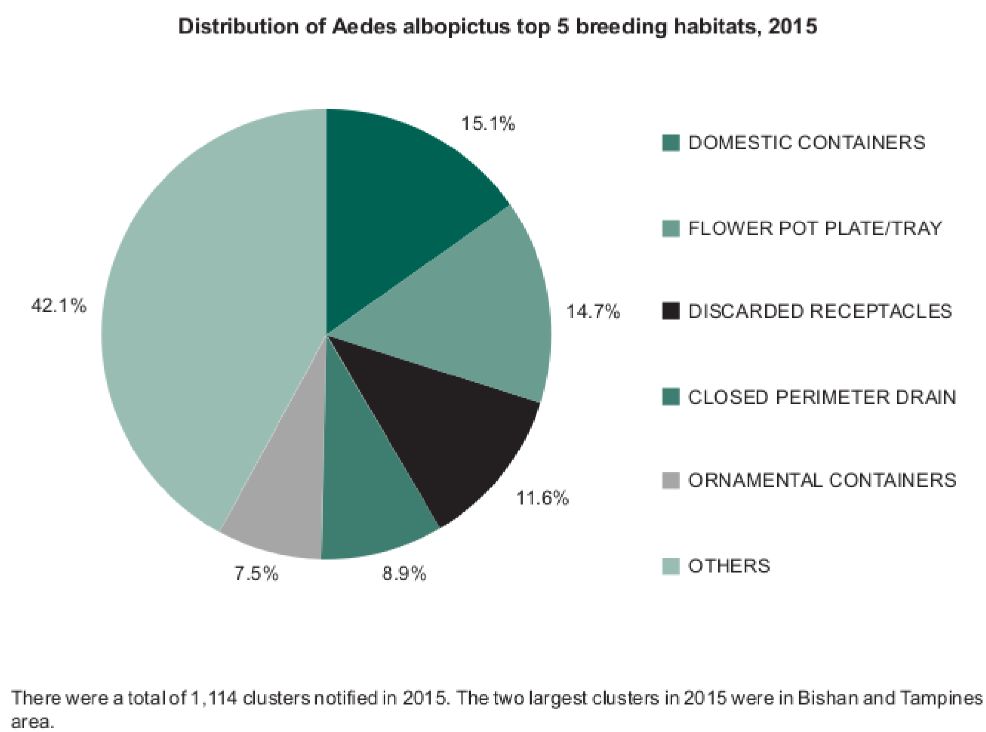


Figure 73: Breeding habitats of Aedes Albopictus in 2015[29].

7. **Imported Dengue Cases.**

Imported DF/DHF cases, 1996-2000					
	Year				
	1996	1997	1998	1999	2000
Southeast Asia					
Indonesia	113	103	51	116	171
Malaysia	99	107	66	65	64
Thailand	8	20	18	9	5
Philippines	4	4	1	1	3
Vietnam	1	2	1	2	0
Cambodia	0	5	3	2	2
Brunei	1	0	3	0	5
Myanmar	0	4	1	3	0
Laos	1	1	6	0	0
Indian subcontinent					
India	14	8	2	7	6
Bangladesh	2	0	0	4	9
Sri Lanka	4	0	0	6	3
Pakistan	1	0	0	0	0
Others					
China	2	0	0	0	0
Maldive Islands	0	0	0	1	1
Nigeria	0	0	0	0	1
Libya	0	0	1	1	1
Unknown	1	7	0	0	0
Total	251	261	153	217	271

Figure 74: Imported DF/DHF cases 1996 to 2000[44].

Imported DF/DHF cases, 2001 – 2005

	Year				
	2001	2002	2003	2004	2005
Southeast Asia					
Brunei	2	0	0	0	0
Cambodia	8	4	8	4	0
East Timor	1	0	0	0	0
Indonesia	142	155	93	17	11
Malaysia	77	139	100	22	2
Myanmar	8	2	1	1	0
Philippines	5	6	2	1	0
Thailand	32	43	18	3	1
Viet Nam	0	0	2	0	0
South Asia					
Bangladesh	8	3	1	1	0
India	19	14	14	7	0
Nepal	0	0	1	0	0
Pakistan	1	1	1	0	0
Sri Lanka	3	9	3	2	0
Other Regions	2	9	2	3	0
Total	308	385	246	61	14

Figure 75: Imported DF/DHF cases 2001 to 2005[39].

Imported DF/DHF cases, 2006 – 2010

	Year				
	2006	2007	2008	2009	2010
Southeast Asia					
Brunei	0	1	0	1	0
Cambodia	4	4	4	3	0
East Timor	0	1	1	1	1
Indonesia	34	34	40	19	42
Laos	1	0	0	1	0
Malaysia	25	31	42	32	34
Myanmar	0	4	1	1	0
Philippines	5	6	4	3	9
Thailand	8	14	15	2	11
Viet Nam	2	8	8	4	6
South Asia					
Bangladesh	5	2	2	0	0
India	12	20	13	9	26
Maldives	2	0	1	0	0
Nepal	0	0	0	1	0
Pakistan	0	0	0	0	0
Sri Lanka	1	2	1	0	1
Other Regions	4	12	11	6	6
Total	103	139	143	83	136

Figure 76: Imported DF/DHF cases 2006 to 2010[34].

Imported DF/DHF cases, 2011 – 2015

	Year				
	2011	2012	2013	2014	2015
Southeast Asia					
Brunei	1	0	1	1	0
Cambodia	8	11	2	1	1
East Timor	2	4	1	5	0
Indonesia	110	111	116	143	116
Laos	0	0	0	1	0
Malaysia	21	39	90	214	191
Myanmar	3	1	9	8	9
Philippines	12	13	10	17	26
Thailand	15	22	21	27	21
Vietnam	9	4	6	8	7
South Asia					
Bangladesh	13	5	4	6	6
China	1	3	12	9	2
India	16	32	17	39	35
Maldives	1	2	1	6	3
Nepal	0	0	0	1	0
Pakistan	2	0	1	0	1
Sri Lanka	5	4	1	6	2
Other Regions	12	12	15	22	18
Total	**231**	**263**	**307**	**514**	**438**

Figure 77: Imported DF/DHF cases 2011 to 2015[29].

Possible reasons behind the 2005 and the 2013 dengue outbreaks.

1. Wikipedia article on '2003 dengue outbreak in Singapore' has mentioned that,
   - 'The National Environment Agency said that the dengue fever problem may be worsening because of higher temperatures and changes in viral strains. The mean temperature rose to 28.2 °C (82.8 °F) from 27.8 °C in 2003.
   - Health Minister Khaw Boon Wan said that one of the concerns is that more Singaporeans are infected with Dengue Type 3, which is a new strain of the dengue virus.
   - Dr Paul Reiter, Professor of Entomology at the Pasteur Institute in France, suggested that Singapore's success in suppressing the dengue has partly contributed to this year sudden increase in dengue cases. The population born over the last two decades has a low herd immunity and therefore more susceptible to the virus[47].'
2. A review report on 'Globalization and infectious diseases: A review of the linkages' has mentioned following points regarding outbreak of vector borne diseases,
   - In the South pacific region, outbreaks of dengue in areas on the fringe of the endemic zone in 1990 to 1995 correlated reasonably well with the El Nino events[49].'
   - **Due to refugee camps:** Conditions also favour the outbreak of vector-borne diseases, since refugees often travel from their home in non-endemic regions and may not be immune to local pathogens.
3. **El Nino effect:**
   - 'El Nino is a climate cycle in the Pacific Ocean with a global impact on weather patterns. The cycle begins when warm water in the western tropical Pacific Ocean shifts eastward along the equator toward the coast of South America. Normally, this warm water pools near Indonesia and the Philippines. During an El Niño, the Pacific's warmest surface waters sit offshore of northwestern South America[52].'

   - 'El Nino is the warm phase of the El Niño Southern Oscillation (Commonly called ENSO) associated with a band of warm ocean water that develops in the central and east-central equatorial Pacific (between approximately the International Date Line and 120°W), including off the Pacific coast of South America.
     El Niño Southern Oscillation refers to the cycle of warm and cold temperatures, as measured by sea surface temperature, SST, of the tropical central and eastern Pacific Ocean. El Niño is accompanied by high air pressure in the western Pacific and low air pressure in the eastern Pacific. The cool phase of ENSO is called "La Niña" with SST in the eastern Pacific below average and air pressures high in the eastern and low in western Pacific. The ENSO cycle, both El Niño and La Niña, causes global changes of both temperatures and rainfall.

   - Extreme weather conditions related to the El Niño cycle correlate with changes in the incidence of epidemic diseases. For example, the El Niño cycle is associated with increased risks of some of the diseases transmitted by mosquitoes, such as malaria, dengue, and Rift Valley fever[50].'

   - A paper titled '2013 Dengue Outbreaks in Singapore and Malaysia Caused by Different Viral Strains' published in the 'American journal of tropical medicine and hygiene' mentions that characterization of 14,079 circulating dengue viruses in a cross-border surveillance program, UNITEDengue, revealed that the 2013 outbreaks in

Singapore and Malaysia were associated with replacement of predominant serotype. While the predominant virus in Singapore switched from DENV2 to DENV1, DENV2 became predominant in neighboring Malaysia. Dominance of DENV2 was most evident on the southern states where higher fatality rates were observed[51].

DailyDengueClusters.py :Python code for Web scraping dengue cluster data and Geocoding of dengue clusters.

```
import urllib.request
from urllib.request import Request, urlopen
from bs4 import BeautifulSoup
import pandas as pd
import datetime

# Request a link.
wiki = Request("http://www.dengue.gov.sg/subject.asp?id=74",
headers = {"User-Agent": "Chrome/53.0.2785.116"})
page = urlopen(wiki).read()               # Read a link webpage.

# Extract webpage info using lxml parser.
soup = BeautifulSoup(page, 'lxml')
soup.prettify()                           # Neatly arrange the file content.

#Find all the table tags in html file.
all_tables=soup.findAll('table')
right_table=soup.find('table', class_='MsoNormalTable') # Find the table to
parse by specifying class.

data = {
        'Location' : [],
        'cases' : []
       }

# Find table tags in right_table.
rows = right_table.findAll("table")

#Find the rows of table:
for row in rows:
    cells = row.findAll('tr')[1:]         # Omit the 1st row of each table.
    for i in cells:
        cols = i.findAll('td')            # Find the table data cell.
        data['Location'].append( cols[0].get_text().strip() )  # append cell
                                        content to the corresponding va
        data['cases'].append( cols[1].get_text().strip() )
        data['Location'] = [item.replace("\r\n", "") for item in data['Location'

DengueData = pd.DataFrame( data )
DengueData.loc[:,'Date'] = [datetime.date.today()] * len(DengueData)
DengueData.to_csv("DC20170413.csv", index=False)


f = open('DengueClusters.csv', 'a')
```

```
DengueData.to_csv(f, header=False, index=False)
```

DengueClustersGeocodes.py :Python code to record the latitude and longitude coordinates of dengue clusters.

```
import googlemaps
from datetime import datetime
import pandas as pd

gmaps = googlemaps.Client(key='AIzaSyAKjQWIoXq2q0lhHvNIoOWUDszRU8N0sgA')
# Enter the key received while setting up the project.
colname = ['Location', 'Cases', 'Date']
data = pd.read_csv('DengueClusters.csv', names=colname)

Locations = data.Location.tolist()
Locations2 = Locations[1:]
Dates = data.Date.tolist()
Dates2 = Dates[1:]
LatLong = []
LatLong2 = []
Latitude = []
Longitude = []

# Geocoding an address
for i in Locations2:
    geocode_result = gmaps.geocode(i + ',Singapore')
    for j in geocode_result:
        LatLong.append(j['geometry'])
for k in LatLong:
    LatLong2.append(k['location'])
for elem in LatLong2:
    Latitude.append(elem['lat'])
    Longitude.append(elem['lng'])

Table = pd.DataFrame({'Locations' : Locations2,
                      'Latitude' : Latitude,
                      'Longitude': Longitude,
                      'Date': Dates2})
Table.to_csv('GeocodeswithDate.csv', index=False)
```

How do these python codes given above work?

1. DailyDengueClusters.py

- Before running this code update the name of the csv file as per the date.
- Depending on which browser user is using to access the NEA's website, the 'headers' value will differ for variable 'wiki'. User should check for his/her browser's 'User-Agent' id and update it in the code accordingly.

2. DengueClustersGeocodes.py

Before running this code do the following necessary steps:

- Login to 'Google Maps APIs' with your gmail and password.
- Create a new project for this code. Follow the instructions given here https://developers.google.com/maps/documentation/geocoding/start
- Enable the API.
- Get an API key.
- Add this API key into 'gmaps' variable.
- Update the name of the csv file as per the date. Geocodes of the updated dengue clusters will be appended to the 'GeocodeswithDate.csv' file.
  Note: Google maps geocoding API is limited to 2500 free requests per day. If your input file 'DengueData.csv' has more than 2500 entries then you will get an error upon running this code. Hence, I recommend that fetch a single dengue cluster file generated on a particular day (by running 'DailyDengueClusters.py' code) and update the file name for 'data' variable with the newly generated csv file.

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