Mosquito-borne diseases such as chikungunya, dengue, Zika, and malaria are important public health problems. Chikungunya virus (CHIKV) is primarily transmitted by *Aedes* mosquitoes (Chabra et al. 2008), and its first Asia outbreak occurred in Bangkok, Thailand, in 1958. In 2018, a subsequent outbreak in Kolkata, Southern India, between 1963 and 1964 (Chabra et al. 2008). Chikungunya virus reemerged in Thailand during August 2008 and 2009 in the rural areas of Narathiwat province in Southern Thailand (Chusri et al. 2014). Afterward, a chikungunya outbreak was reported in October 2018. According to the Thai Ministry of Public Health (MOPH), 2,143 cases of CHIKV were reported between January and February of 2019 (MOPH 2018). The virus is transmitted through the bite of *Aedes* mosquitoes, mostly *Ae. aegypti* (L.) and *Ae. albopictus* (Skuse) (Thavara et al. 2009).

Entomological surveillance is an important vector control method and can be used to determine changes in the abundance and distribution of vector-borne disease. In addition, container habitat monitoring is of particular concern in suburban and urban areas (Rozilawati et al. 2015). *Aedes* mosquitoes inhabit stagnant water-holding containers such as discarded tires, empty cans, abandoned car parts, plastic containers, brick holes, rock pools, dead leaf piles, and tree holes (Simard et al. 2005). However, *Ae. aegypti* mostly feeds and rests indoors, while *Ae. albopictus* is more active outdoors. Moreover, *Ae. albopictus* is a major concern to urban and suburban areas due to its ability to adapt to environmental changes. Thus, the objective of this study is to determine mosquito aquatic habitats and larval abundance, and to identify container habitats involved in the chikungunya outbreak within the urban area of Hat Yai district in Songkhla province. Identification of common container habitats is necessary for an efficient mosquito control program; hence this study will provide data of potential container habitats responsible for CHIKV outbreaks in urban areas. Results of this study can be used to execute community action plans to prevent future outbreaks. The ability of different types of containers to hold water was integrated into this study to understand the significance of entomological surveillance tools and vector control programs at preventing the spread of chikungunya in urban areas.

This study was focused on an area of southern Thailand that has experienced a high rate of chikungunya. A high morbidity rate was detected in urban areas due to its ability to adapt to environmental changes. Thus, the objective of this study is to determine mosquito aquatic habitats and larval abundance, and to identify container habitats involved in the chikungunya outbreak within the urban area of Hat Yai district in Songkhla province. Identification of common container habitats is necessary for an efficient mosquito control program; hence this study will provide data of potential container habitats responsible for CHIKV outbreaks in urban areas. Results of this study can be used to execute community action plans to prevent future outbreaks. The ability of different types of containers to hold water was integrated into this study to understand the significance of entomological surveillance tools and vector control programs at preventing the spread of chikungunya in urban areas.

The potential container habitats of chikungunya vector in outbreak area of southern Thailand

**Key Words** Chikungunya, container habitats, mosquito, outbreak, Thailand

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Adult mosquitoes were identified under the stereomicroscope, using the identification keys by Rattanarithikul et al. (2010). The occurrence of immature mosquitoes in positive houses and containers was used to calculate and analyze the larval stage: HI, BI, PI, and CI. The SCI is the percentage of specific type of container with mosquito larvae. The calculation of larval indices was based on the following mathematical formulae.

\[
HI = \left( \frac{\text{Number of houses infested}}{\text{total number of houses inspected}} \right) \times 100
\]

\[
BI = \left( \frac{\text{Number of containers infested}}{\text{total number of houses inspected}} \right) \times 100
\]

\[
PI = \left( \frac{\text{Number of pupae infested}}{\text{total number of houses inspected}} \right) \times 100
\]

\[
SCI = \left( \frac{\text{Number of positive containers infested}}{\text{total number of containers inspected}} \right) \times 100
\]

In total, 75 houses were surveyed within the 4 villages. Cases were found in 32 houses, whereas no cases were found in 43 houses (Table 1). Among the 75 houses surveyed, 34 were positive for mosquito container habitats, and 78 out of 438 containers were positive for mosquitoes. The HI values were higher for houses with cases compared to houses without cases, while the value of BI, PI, and CI in noncase houses were higher than values for houses with cases (Table 1). The result showed larval indices and distribution of mosquito container habitats in noncase houses. Furthermore, the SCI (the percentage of container type with immature mosquitoes) was considered. Similar types of containers were found in both noncase and case houses; however, discarded containers showed the highest specific container index, followed by plant pots, anti ant bowls, plant saucers, tires, and plastic buckets, respectively. These containers served as habitats for mosquitoes and constituted high risk of adult emergence of mosquitoes within the houses surveyed.

Rearing of immatures stages to adults showed 3 species of mosquitoes: *Ae. aegypti*, *Ae. albopictus*, and *Culex quinquefasciatus* (Say). The major breeding indoor habitats in noncase houses were plastic buckets, anti ant bowls, and refrigerator water trays. *Aedes aegypti* were found in outdoor containers, with a majority found in waste containers, plastic buckets, plastic bottles, tires, fountain basins, and plant saucers. *Aedes albopictus* were found in plastic buckets, fountain basins, waste containers, and empty cans. *Culex quinquefasciatus* were found in plastic buckets, fountain basins, waste containers, and empty cans. *Culex quinquefasciatus* were found in waste containers and plastic bottles (Table 2). *Aedes aegypti* indoors container habitats included anti ant bowls, plastic buckets, and plastic water bucket lids, whereas outdoor container habitats were plastic buckets, plant pots, plastic bottles, tires, water cups, and plant saucers (Table 2). Based on immature collections, the most abundant species was *Ae. aegypti* at 2,309 (94%), followed by at *Ae. albopictus* 118 (5%), and *Cx. quinquefasciatus* at 30 (1%) in that order. Female adult mosquitoes outnumbered male mosquitoes.

Entomological investigation, mosquito distribution, and container habitat are important study parameters in the control of mosquito-borne diseases. The results of HI, BI, PI, and CI varied from 0.00 to 71.43, 0.00 to 142.86, 0.00 to 783.33, and 0.00 to 31.48, respectively (Table 1), which were higher than the HI >5%, and BI > 20 World Health Organization (WHO) standards for urban areas with high risk for dengue transmission (WHO 2003). Thus, the results suggested a high

| Location and house | Total houses | Positive houses | Total containers | Positive containers | P | HI | BI | PI | CI |
|--------------------|--------------|-----------------|-----------------|--------------------|---|----|----|----|----|
| Khoh Hong          |              |                 |                 |                    |   |     |     |    |    |
| Noncase            | 7            | 4               | 29              | 8                  | 1 | 57.14 | 114.29 | 14.29 | 27.59 |
| Case               | 3            | 0               | 8               | 0                  | 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| Khlong Toei        |              |                 |                 |                    |   |     |     |    |    |
| Noncase            | 15           | 6               | 114             | 19                 | 76 | 40.00 | 126.67 | 506.07 | 16.67 |
| Case               | 7            | 5               | 74              | 10                 | 30 | 71.43 | 142.86 | 428.57 | 13.51 |
| Chlong Wa          |              |                 |                 |                    |   |     |     |    |    |
| Noncase            | 12           | 6               | 54              | 17                 | 94 | 50.00 | 141.67 | 783.33 | 31.48 |
| Case               | 10           | 5               | 45              | 10                 | 12 | 50.00 | 100.00 | 120.00 | 22.22 |
| Chlong Hae         |              |                 |                 |                    |   |     |     |    |    |
| Noncase            | 9            | 3               | 40              | 4                  | 8 | 33.33 | 44.44 | 88.89 | 10.00 |
| Case               | 12           | 5               | 74              | 10                 | 45 | 41.67 | 83.33 | 375.00 | 13.15 |
| Total              | 43           | 19              | 237             | 48                 | 179 | 44.19 | 111.63 | 416.28 | 20.25 |
| Noncase            | 32           | 15              | 201             | 30                 | 87 | 46.87 | 93.75 | 271.88 | 14.92 |

1 P = Pupae; HI = House Index; BI = Breteau Index; PI = Pupal Index; and CI = Container Index.

Table 1. Larval indices of mosquito in Hat Yai district, Songkhla province.
potential risk of CHIKV transmission. Table 1 showed that the surveyed villages had high risk of CHIKV transmission judging from the number of *Aedes* larvae found in the epidemic area. The HI, BI, and CI during dry seasons in Thailand varies from 52.00 to 96.00, 99.00 to 190.00, and 22.00 to 78.00, respectively (Chareonviriyaphap et al. 2003). Larval indices in Tamil Nadu, India, indicated that HI, CI, BI, and PI varied from 2.50 to 18.26, 0.83 to 9.03, and 0.00 to 46.15, respectively (Bhat and Krishnamoorthy 2014), whereas Nofita et al. (2017) reported HI = 9.00–49.00, BI = 9.00–102.00, and CI = 1.20–26.10 in Padang, West Sumatra, Indonesia. The average HI for case houses (46.87) exceeded that of noncase houses (44.19). In addition, positive houses were found to contain container habitats, which might play vital role in the distribution of mosquitoes. Statistical analysis showed a correlation between HI and the spread of chikungunya as well as the number of patients in houses. However, the BI and CI were lower in the case houses (Table 1) due to the destruction of water-holding containers, which led to a decrease in container habitats and mosquito larval population. Moreover, the results indicated that positive testing outdoor containers in both noncase and case houses included discarded items such as waste containers, empty cans, plastic bottles, and buckets, as well as in-use containers such as plant pots, tires, basins, and animal feed containers. Hence, emphasis should be placed on the destruction of discarded containers to decrease the development of

| Area and container type | *Ae. aegypti* | *Ae. albopictus* | *Cx. quinquefasciatus* |
|-------------------------|---------------|-----------------|----------------------|
|                         | F  | M  | F  | M  | F  | M  |
| Noncase houses          |    |    |    |    |    |    |
| Indoor                  |    |    |    |    |    |    |
| Plastic bucket          | 257| 189| 2  | 1  | 0  | 0  |
| Flower vase             | 4  | 2  | 6  | 3  | 0  | 0  |
| Anti ant bowl           | 16 | 18 | 0  | 0  | 0  | 0  |
| Refrigerator water tray | 15 | 7  | 0  | 0  | 0  | 0  |
| Total                   | 292| 216| 8  | 4  | 0  | 0  |
| Plastic bucket          | 141| 81 | 16 | 8  | 0  | 0  |
| Cement tank             | 10 | 7  | 0  | 0  | 0  | 0  |
| Jar                     | 12 | 7  | 0  | 0  | 0  | 0  |
| Plant saucer            | 31 | 17 | 0  | 0  | 0  | 0  |
| Lotus basin             | 5  | 3  | 0  | 0  | 0  | 0  |
| Outdoor                 |    |    |    |    |    |    |
| Fountain basin          | 36 | 12 | 8  | 0  | 0  | 0  |
| Plant bucket            | 11 | 3  | 0  | 0  | 0  | 0  |
| Tire                    | 39 | 28 | 0  | 0  | 0  | 0  |
| Waste container         | 139| 133| 43 | 13 | 9  | 7  |
| Plastic bottle          | 69 | 56 | 0  | 0  | 9  | 5  |
| Used can                | 6  | 2  | 2  | 3  | 0  | 0  |
| Total                   | 499| 349| 69 | 24 | 18 | 12 |
| Case houses             |    |    |    |    |    |    |
| Indoor                  |    |    |    |    |    |    |
| Plastic bucket          | 34 | 23 | 0  | 0  | 0  | 0  |
| Anti ant bowl           | 48 | 46 | 0  | 0  | 0  | 0  |
| Bucket lid              | 2  | 0  | 0  | 0  | 0  | 0  |
| Total                   | 84 | 69 | 0  | 0  | 0  | 0  |
| Plastic bucket          | 147| 95 | 0  | 0  | 0  | 0  |
| Plastic basin           | 5  | 3  | 0  | 0  | 0  | 0  |
| Flower pot              | 12 | 6  | 0  | 0  | 0  | 0  |
| Plastic basin           | 3  | 2  | 0  | 0  | 0  | 0  |
| Outdoor                 |    |    |    |    |    |    |
| Plant saucer            | 15 | 15 | 0  | 0  | 0  | 0  |
| Water cup               | 20 | 11 | 0  | 0  | 0  | 0  |
| Watering pot            | 8  | 7  | 0  | 0  | 0  | 0  |
| Plant pot               | 114| 92 | 0  | 0  | 0  | 0  |
| Whetstone bucket        | 12 | 8  | 0  | 0  | 0  | 0  |
| Tire                    | 24 | 16 | 0  | 0  | 0  | 0  |
| Waste container         | 15 | 6  | 0  | 0  | 0  | 0  |
| Plastic bottles         | 78 | 54 | 2  | 5  | 0  | 0  |
| Used can                | 11 | 10 | 0  | 0  | 0  | 0  |
| Disposable glass        | 4  | 7  | 0  | 0  | 0  | 0  |
| Total                   | 468| 332| 5  | 8  | 0  | 0  |

1 F = Female; M = Male.
pupae into adult mosquitoes. Container habitat around the homes can be a potential place for *Aedes* breeding (Prasetyowati et al. 2018), thus highlighting the need to destroy container habitats of *Aedes* mosquitoes in both noncase and case houses in endemic areas and risk areas. These indices are necessary as surveillance tools for strategic control of *Aedes* mosquitoes, vectors of both chikungunya and dengue viruses. Furthermore, container habitat surveillance for immature mosquitoes in endemic areas indicated that the specific container index was similar for both noncase and case houses. The present results also support a previous study, which showed that the SCI are tires, discarded containers, plant saucers, water storage containers, flower vases, and anti ant bowls (Thammapalo et al. 2005). A majority of water storage containers included buckets, concrete tanks for bathrooms (Prasetyowati et al. 2018), and cookware found in urban and rural area (Prasetyowati et al. 2018). Based on immature collections in our study, mosquito species abundance was * Ae. aegypti* (94%), *Ae. albopictus* (5%), and *Cx. quinquefasciatus* (1%). The results were consistent with the findings in the districts of Tamil Nada (Bhat and Krishnamoorthy 2014). The study showed that *Ae. aegypti* was the most predominant species in all the villages studied. This suggests that *Ae. aegypti* might be the major vector of the CHIKV transmission in the urban areas. This is consistent with reports in Northeast Brazil that *Ae. aegypti* was the transmitter of CHIKV in urban areas (Aragão et al. 2018). Knowledge of *Aedes* mosquitoes is important to determine the origins of emerging diseases caused by arboviruses, particularly CHIKV endemics in urban areas. Our results further suggest that container habitats of *Aedes* mosquitoes in urban areas were related to the work habits and routines and lifestyles of inhabitants. The predominance of *Ae. aegypti* in all villages studied suggests that it could be the main vector of the CHIKV in the endemic areas. Although more studies are needed, the results of this preliminary study may help in better understanding the development and spread of chikungunya in endemic urban areas of Hat Yai district, Songkhla province. In addition, it may also guide policy makers in environmental decision making.

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REFERENCES CITED

Aragão CF, Cruz ACR, Neto JPN, Oliveira MHA, Da Silva EVP, Da Silva SP, Pinheiro VCS. 2018. Circulation of Chikungunya virus in *Aedes aegypti* in Maranhão, Northeast Brazil. *Acta Trop* 186:1–4.

Bhat MA, Krishnamoorthy K. 2014. Entomological investigation and distribution of *Aedes* mosquitoes in Tirunelveli, Tamil Nadu, India. *J. Curr Microbiol Appl Sci* 3:253–260.

Chabera S, Mittal V, Bhattacharya D, Rana UVS, Lal S. 2008. Chikungunya fever: a re-emerging viral infection. *Indian J Med Microbiol* 26:1–5.

Chareonviriyaphap T, Akratanapuk P, Nettanomsak S, Huntamai S. 2003. Larval habitats and distribution patterns of *Aedes aegypti* (Linnaeus) and *Aedes albopictus* (Skuse), in Thailand. *Southeast Asian J Trop Med Public Health* 34:529–533.

Chusri S, Siripaitoon P, Silpapojakul K, Hortiwakul T, Charermmak B, Chinnawiropisarn P, Jarman RG. 2014. Kinetics of chikungunya infections during an outbreak in Southern Thailand, 2008–2009. *Am J Trop Med* 90:410–417.

MOPH [Ministry of Public Health]. 2018. *Chikungunya: National disease surveillance* (Report 506, 4861) [Internet]. Bangkok, Thailand: Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health [accessed May 7, 2019]. Available from: http://www.boe.moph.go.th/boedb/surdata/506wk/y61/en/d84_4861_en.pdf.

Nofita E, Hasmiwati RS, Irwati N, 2017. Analysis of indicators entomology *Aedes aegypti* in endemic areas of dengue fever in Padang, West Sumatra, Indonesia. *Int J Mosq Res* 4:57–59.

Prasetyowati H, Ipa M, Widawati M. 2018. Pre-adult survey to identify the key container habitat of *Aedes aegypti* in Dengue endemic areas of Banten Province, Indonesia. *Southeast Asian J Trop Med Public Health* 49:23–31.

Rattanarithikul R, Harbach RE, Harrison BA, Panthusiri P, Coleman RE, Richardson JH. 2006. Illustrated keys to the mosquitoes of Thailand VI. Tribe Aedini. *Southeast Asian J Trop Med Public Health* 41:1–225.

Rozilawati H, Tanasevi K, Nazni WA, Mohd MS, Zairi J, Adanan CR, Lee HL, 2015. Surveillance of *Aedes albopictus* Skuse breeding preference in selected dengue outbreak localities, peninsular Malaysia. *Trop Biomed* 32:49–64.

Simard F, Nchoutpouen E, Toto JC, Fontenille D. 2005. Geographic distribution and breeding site preference of *Aedes albopictus* and *Aedes aegypti* (Diptera: Culicidae). *Southeast Asian J Trop Med Public Health* 36:426–433.

Thammapalo S, Chongsuwiwatwong V, Geater A, Lim A, Chareonviriyaphap T, Akratanakul P, Nettanomsak S, Chabra M, Mittal V, Bhattacharya D, Rana UVS, Lal S. 2018. *Circulation of Chikungunya: National disease surveillance (Report 506, 4861)* [Internet]. Bangkok, Thailand: Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health [accessed May 7, 2019]. Available from: http://www.boe.moph.go.th/boedb/surdata/506wk/y61/en/d84_4861_en.pdf.

World Health Organization. 2003. *Guidelines for dengue surveil- lance and mosquito control* [Internet]. Manila, Philippines: WHO Regional Office for the Western Pacific [accessed May 7, 2019]. Available from: https://apps.who.int/iris/handle/10665/206987.