1st December, 2021

Original Article

SPATIAL AND TEMPORAL VARIATIONS IN STEGOMYIA INDICES OF ARBOVIRAL VECTORS (*AEDES AEGYPTI* AND *AE. ALBOPICTUS*) IN AN URBAN AGGLOMERATION OF PORT BLAIR, ANDAMAN & NICOBAR ISLANDS, INDIA

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Date of submission : 11th Oct., 2021
Date of revision : 11th Nov., 2021
Date of acceptance : 18th Nov., 2021

ABSTRACT

Background: Dengue and chikungunya cases are prevalent throughout the year in Port Blair Municipality of

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Cite this article as:
Roy Avijit, Kaliyamoorthy M, De Amitabha, Sunish IP, Sahu VK, Takuya Tapash Kumar. Spatial and temporal variations in Stegomyia indices of arboviral vectors (*Aedes aegypti* and *Ae. albopictus*) in an urban agglomeration of Port Blair, Andaman & Nicobar Islands, India. J Med Arthropodol & Public Health. 2021; 1(2):9-27

Andaman & Nicobar Islands. To determine the status of vectors of these arboviruses in Port Blair, mosquito immature survey was carried out for two consecutive years during 2019 and 2020.

Methodology: Survey was conducted in nine localities of Port Blair municipality in the South Andaman district, Andaman & Nicobar archipelago. Door-to-door survey was carried out and all the containers in the houses were examined for the presence of mosquito immatures. A sample of immatures was brought to the laboratory for rearing and identification. A total of 263 dengue and 65 chikungunya cases were reported during the study period.

Results: A total of 41,277 containers in 10,538 houses were searched during the study period, and 14% of the houses and 6% of the containers were found positive for mosquito immatures. The House Index (HI) and Container Index (CI) during 2019 were 13.3 and 6.8, respectively, while HI value was comparatively higher (15.5) in 2020. Pre-monsoon months April-June was more productive for breeding of Aedes mosquitoes. The maximum Pupal Index/person was recorded at Phoenix Bay; 49.8 and 134.3 during 2019 and 2020, respectively. There was a strong correlation (r =0.9) between the case incidence (for both dengue and chikungunya) and *Stegomyia* indices (especially container and pupal indices), during the year 2020. In large capacity containers, cement tank was the most productive for pupae, which gives a proxy estimate of abundance of adult Aedes spp. Among the five species of mosquitoes identified, the dominant species were dengue and chikungunya vectors which included *Aedes aegypti* (58.1%) and *Ae. albopictus* (26.8 %). Other three mosquito species identified were *Culex sitiens, Cx. quinquefasciatus* and *Armigeres subalbatus*.

Conclusion: Our study showed that in Port Blair, both the container and pupal indices are ideal indicators of vector prevalence in an area. Even though most of the containers were positive for *Aedes* immatures, the most productive container, viz. the cement tank, should be targeted during community-based vector control programme. The assessment of pupal productivity index could be incorporated in dengue surveillance programme, allowing vector control managers to take appropriate actions for source reduction and to develop more effective mosquito control strategies.

Keywords: Junglighat, *Stegomyia* Indices, immature Survey, Port Blair, Dengue, Chikungunya.

INTRODUCTION

The risk of dengue virus transmission is increasing day-by-day, mainly due to lack of awareness in water storage practices. It is estimated that globally more than 3.9 billion people in 129 countries are at the risk of dengue infection, of which 96 million apparently manifest any level of disease severity.[1] More than one million people are affected by Zika virus and the associated microcephaly and other foetus malformations which have been reported widely in the Americas during 2016 and 2017.[2-5] Since 2014, major outbreaks of dengue, malaria, chikungunya, yellow fever and Zika had been badly affecting many communities, claiming precious lives and affecting health systems in many countries.[6]

Mosquito population dynamics are of particular interest because mosquito abundance shapes the entomological risk of vector-borne disease transmission[7]. Dissemination of pathogens is increased linearly with the abundance of the insect vector[8]. According to Dutta[9], outbreak of mosquito-borne diseases like malaria and dengue in India are regulated by climatic factors. Human behaviour is mainly responsible for vector proliferation by creating mosquitogenic environment.

Main vectors of chikungunya and dengue viruses are *Aedes aegypti* and *Aedes albopictus,* which are widely prevalent across India. During the past few years, these infections affected many urban areas, including Port Blair in the Andaman & Nicobar archipelago.[10,11] Dengue is an emerging disease in these Islands and mainly occur in epidemic and endemic forms.[12-14] Outbreak of dengue in the A & N archipelago was first reported in 2009[12], followed by infection in the security personnel housed in Haddo Wharf of South Andaman in 2013[14], and at Havelock Island during May-June 2014, where *Ae. albopictus* was found with dengue serotype-3.[15] Dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) were first observed in 2009 in A&N, during which vector prevalence was found very high.[10] Soon, the circulation of dengue serotypes 1,2 and 3 was established in the archipelago.[11,12] Currently, dengue is prevalent in several endemic areas, including tourist attractions. Travellers infected in these areas may carry the virus back to their home country or other regions.[16]

Chikungunya fever was first reported in these islands in 2006, in which the attack rate was more than 60 % in the population.[17] Subsequently, in 2009, an upsurge was observed in Bambooflat, which is in close proximity to Port Blair. In the year 2010, cases were also reported from Middle Andaman, and the aetiology was identified as chikungunya virus (CHIKV) .[18] In Asia and the Indian Ocean region, *Aedes aegypti* and *Aedes albopictus* are the main vectors of CHIKV.[19]

Aedes mosquitoes prefer to oviposit in different water holding containers, i.e., plastic, rubber, cement, glass, natural materials and others. Duration of larval development varied in different container materials.[20] Romero-Vivas et al[21] found that the number of *Aedes* immatures were not distributed consistently in each water container. This indicated that specific types of containers affected selection of oviposition by female mosquitoes. According to Vega-Rúa *et al.,*[22] the ability of *Ae. albopictus* population to disseminate or transmit different CHIKV genotypes is strongly associated with their degree of ancestry within a genetic lineage. Chompoosri *et al.*[23] suggested that arboviruses are maintained in nature by biological transmission, which depends on host and vector coexistence in time and space.

Immature survey of *Aedes* species is important in urban areas to determine the potential breeding sites of water holding containers, as these species prefer to breed near human habitations, especially in man-made water containers. *Aedes aegypti* and *Aedes albopictus* are the main vectors of chikungunya, dengue, Zika and yellow fever viruses. Preliminary survey of *Ae. aegypti* in Port Blair was carried out during the monsoon months of 1997.[24] In a cross sectional survey during 2012, preponderance of *Ae. albopictus* was observed in the localities along the Great Andaman Trunk Road (GATR).[25] Identification of vector breeding habitats in urban environment is a major challenge, which will enable to determine the habitats to be prioritized, in order to develop more effective vector control strategies.

MATERIAL AND METHODS

Study area

The study was conducted in nine localities of Port Blair Municipality (PBM) of South Andaman district, *viz*, Haddo, Delanipur, Junglighat, Dairy Farm, Shadipur, Dollygunj, Garacharma, Dignabad and Aberdeen Bazaar. The residents in these areas store water (used for domestic purpose) in drums and tanks, which create an ideal situation for the breeding of dengue vectors. The immature survey for *Aedes* mosquitoes, which are the potential vectors of dengue and chikungunya viruses, was carried out during the years 2019 and 2020.

In South Andaman, weekly application of temephos is being carried out in all the water containers/areas by the NVBDCP (National Vector Borne Diseases Control Programme) for the control of *Aedes* mosquitoes. In houses with dengue confirmed patients, pyrethrum space spray is used.

Prevalence of dengue and chikungunya

Both dengue and chikungunya are prevalent in the study area (Fig. 1). Number of cases of dengue was comparatively more than that of chikungunya throughout the study period. The peak number of dengue cases was observed during monsoon (July-September), while chikungunya cases peaked during summer.

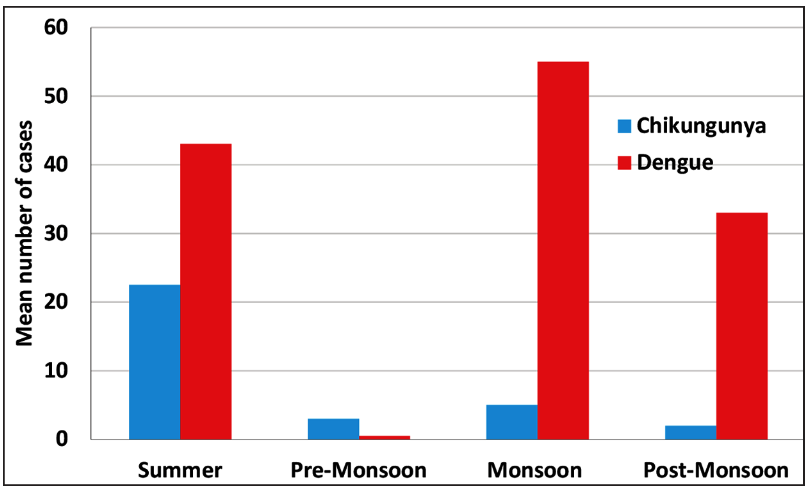


Fig 1. Dengue and Chikungunya cases in the study area (*Source:* IDSP, Port Blair)

Larval infestation survey

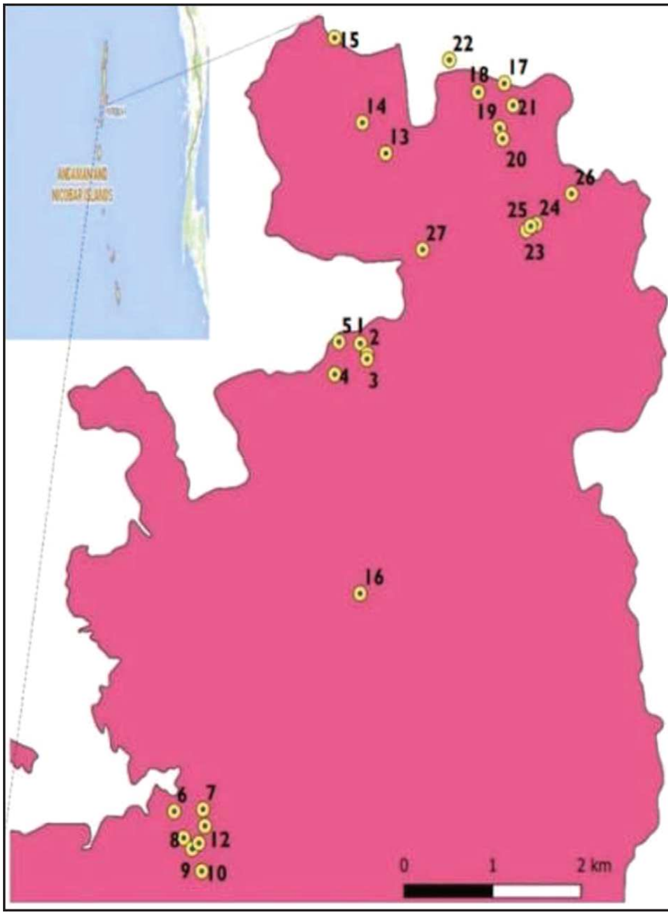
Door-to-door survey was made in households selected randomly, after obtaining prior permission from the residents. Less numbers of households were surveyed in the second year, due to Covid-19 pandemic restrictions, where many residents refused entry to their premises. The contents of the water-holding containers positive to mosquito breeding were strained through a sieve, and the contents were re-suspended in a small amount of clean water in a white enamel/plastic tray. Sweep nets (pore size - 0.2 mm) were used for large containers. Pupae retrieved from habitats were transferred to a labelled plastic container. These were brought to the IDSP Entomological Laboratory, Port Blair, and were raised to adults. The emerged adults were identified using standard taxonomic keys.[26] Rainfall data were collected from the weather report of "*Daily Telegram*" (local newspaper), Port Blair, Andaman and Nicobar Islands. CHIKV and DENV fever reports were collected from "*Integrated Disease Surveillance Programme*" Port Blair, and the data were grouped into four seasons for each year: summer (January-March), pre-monsoon (April – June), monsoon (July-September), and post-monsoon (October – December).

Data analysis

The collected data include number of houses visited, larvae positive houses, number of water containers examined with and without larvae, and number of pupae in each container. The study also determined species diversity and container preferences of mosquitoes. *Stegomyia* indices were estimated in each area, such as HI, CI and PI per person. Data recorded were analyzed for their significant differences using *chi square* and *student 't' test* using *stat plus* programme.

RESULTS

Twenty-seven places in nine areas/localities of Port Blair municipality were surveyed for *Aedes* infestation (Fig. 2). Human population in the surveyed area was 35,880. Total number of houses examined and those found positive in the surveyed area during the study period (2019-2020) were 10,538 and 1,486 (14.1%), respectively. Out of 41,277 containers examined, 2,426 (5.9%) were found positive.



Sl.No.	Surveyed area	Place
1	Dairy Farm	Milk Plant
2		Lalbijin
3		Lall Barrack
4		Ranji Basthi
5		Japan Road
6	Garacharma	GSS School
7		Netaji Nagar
8		Near BSNL
9		T.T. College
10		Shiv Mandir
11		Mt. Colony
12		Rajaji Nagar
13	Phoenix Bay	Sea Shore Road
14	Haddo	Anarkali Basthi
15		Sea Shore Road
16	Dollygunj	Telegu Basthi
17	R.P. Road	Near Fish Market
18	Bazar	Dignabad
19		Round Basthi
20		Supply line
21		Atlanta Point
22		Marine Hill
23	Sadhipur	Church
24		Near Temple
25		Temple
26		Machi line
27	Junglighat	Dean Street

Fig 2. Map showing the survey sites/ localities at Port Blair Municipality

The *Stegomyia* indices with respect to House (HI) during 2019 and 2020 were 13.3% and 15.5 %, while the container index (CI) were 6.8 and 4.9, respectively. The Pupal index/person in 2019 was 30.6 and in 2020 it was 79.5 (Fig. 3).

During 2019 and 2020, altogether 3293 and 2027 pupae were collected respectively. Five mosquito species were identified, viz, *Aedes aegypti, Ae. albopictus, Cx. sitiens, Cx. quinquefasciatus* and *Armigeres subalbatus* (Fig. 4). The species composition during the two year survey was similar, with *Ae. aegypti* constituting 54-67%, followed by *Ae. albopictus* which constituted 26-27%. The other three species were <10% during both the years.

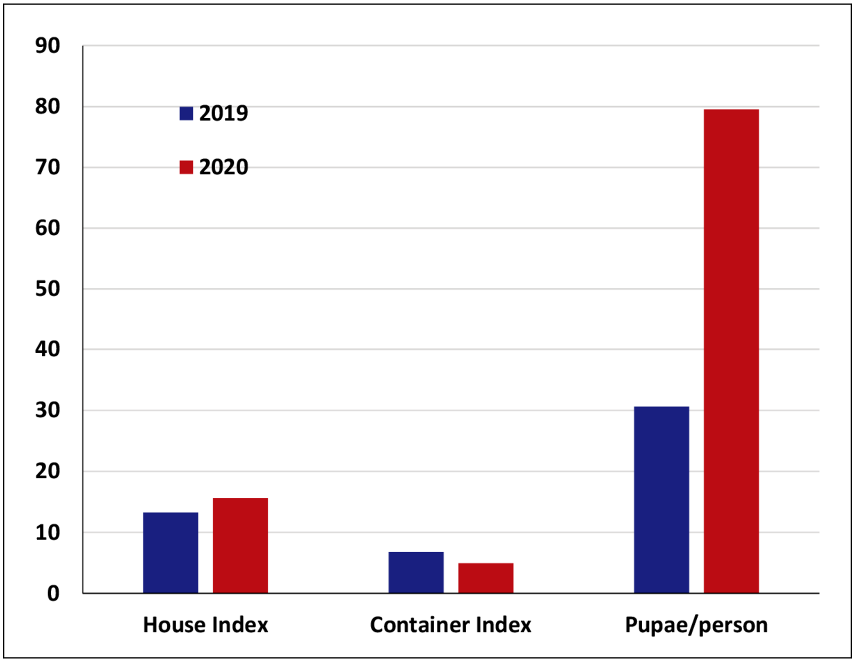
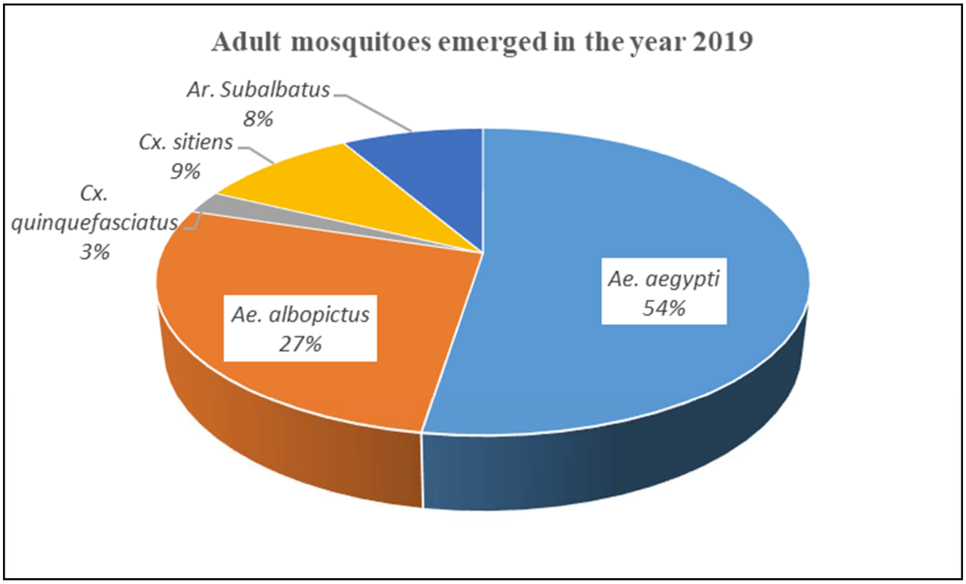


Fig 3. *Stegomyia* indices estimated during the two years surveyed



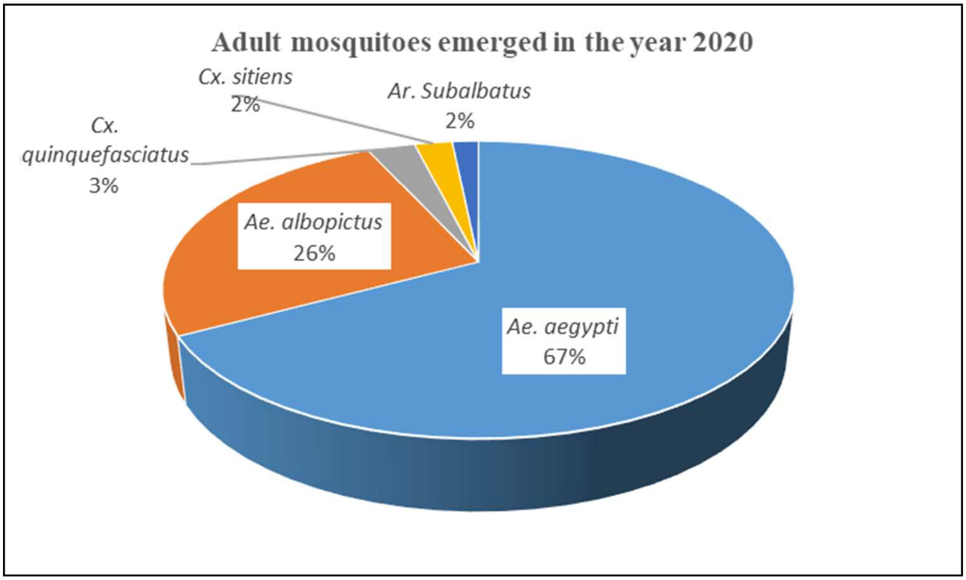


Fig 4. Species composition of mosquitoes in the study areas during 2019 and 2020

(i) *Stegomyia* indices in different seasons

A total of 6,851 and 3,687 houses were surveyed during 2019 and 2020, respectively. Total number of houses positive for mosquito immatures was 909 (13.3%) during 2019 and 577 (15.6%) during 2020. Maximum numbers of houses were examined in monsoon, during both the years. Between the two years surveyed, house positivity rate was highest in the second year (2020), except during pre-monsoon. During the year 2019, the percentage of houses positive was highest in the pre-monsoon (21.7%), while in 2020, it was during the post-monsoon (18.3%) (Table 1). During summer, no significant difference in house positivity rate was observed between the two years (X^2= 1.17; P>0.05). However, in the other seasons of the year, a significant difference was observed (P<0.05).

A total of 20,855 containers were examined in the year 2019, of which 1417 were positive, while in the subsequent year, among 20,422 examined, 1,009 were positive. In all the four seasons, container positivity was higher in the first year. A significant difference in CI was observed during pre-monsoon and monsoon seasons (P<0.05) (Table 1).

Table 1. Percentage positive houses and containers for the two years study duration

Season/Year	% of Houses +ve				% of containers +ve			
	2019	**2020**	**X^2**	***p*-value**	**2019**	**2020**	**X^2**	***p*-value**
Summer	12.3	14.5	1.17	0.279	8.1	7.6	0.2	0.653
Pre-Monsoon	21.7	14.3	5.61	0.018*	8.1	3.5	54.67	<0.001*
Monsoon	9.9	13.5	13.07	0.0003*	5.4	4.4	9.07	0.003*
Post-Monsoon	14.8	18.3	4.02	0.045*	6.8	5.9	2.12	0.146

*Significant at p<0.05

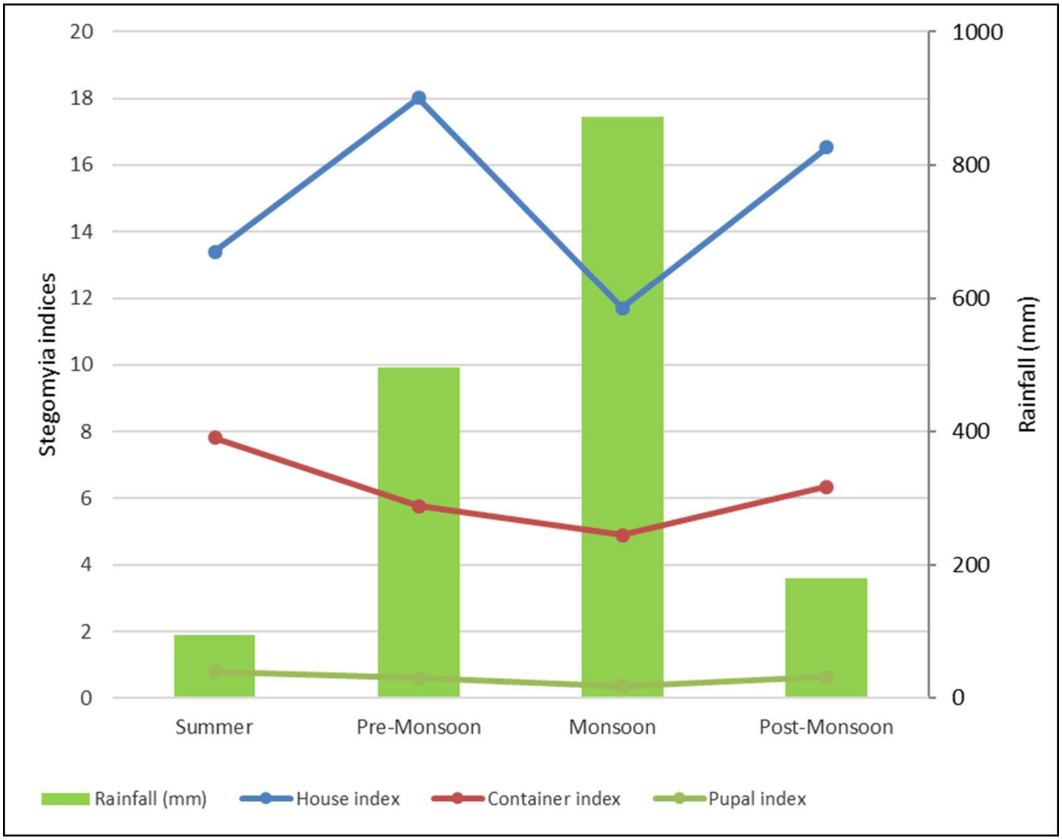


Fig. 5. Trends in *Stegomyia* indices and rainfall

Maximum HI value was recorded in pre-monsoon period (21.7%) followed by post-monsoon (14.8%) during 2019, while during 2020, it occurred in post-monsoon (18.3%) period. When the data for both the years were combined, the peak HI was in pre-monsoon which declined in the monsoon season, and later showed a rise (Fig. 5). Container index declined gradually from summer to pre-monsoon and was recorded lowest in monsoon. Pupal index did not seem to have any variation with rainfall.

(ii) Area wise abundance of mosquito immatures

Area-wise analysis showed that maximum houses were examined at Dairy Farm (1102), of which 188 houses were positive for mosquito immatures during

2019, and 114 out of 617 houses in 2020. During 2020, maximum houses were surveyed in Garacharma area, where 81 out of 619 houses were found positive.

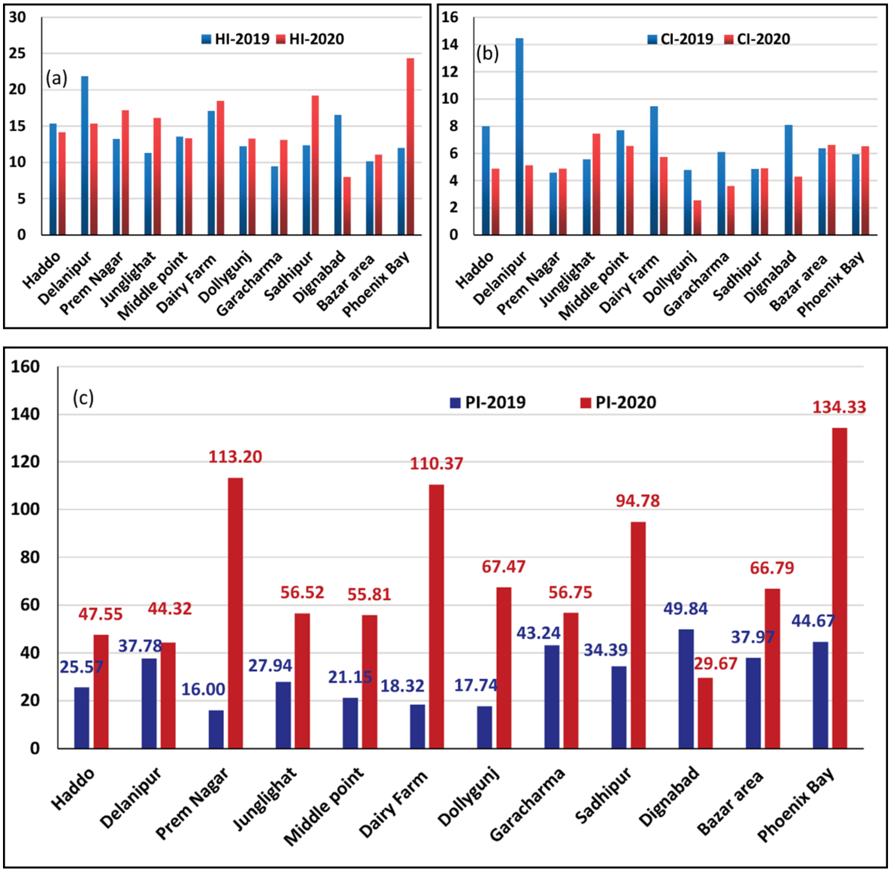


Fig. 6. Area-wise *Stegomyia* indices during the two years (a) House Index, (b) Container Index, and (c) Pupal index/person

During the study, HI and CI were found comparatively higher (in more than half the localities) during the first year (2019), but PI was found higher during the second year. Maximum and minimum HI values were recorded at Delanipur (21.9) and Garacharma (9.4) areas during 2019 and the same for 2020 were at Phoenix Bay (24.3) and Dignabad (8.0) respectively (Fig. 6a). For containers, the peak CI was recorded from Delanipur (14.5) during 2019 (Fig. 6b). PI was much higher in the year 2020 in 11 of the 12 localities surveyed (Fig. 6c).

The *Stegomyia* indices were anlayzed for their significant differences between the two years surveyed using “student *t* test”. The overall HI increased marginally during 2020, which was not significantly different (t =2.20; P>0.05), while a significant decline (P=0.049) was observed for CI in 2020, as compared to 2019.

(iii) Container wise analysis

Various types of water holding containers were observed in the house hold premises of Port Blair. During 2019 and 2020, almost 20,855 and 20,422 containers were examined, respectively.

Table 2. Details of containers examined and positive for mosquito immatures

Containers surveyed	Number Examined		Number Positive		% positive	
	2019	2020	2019	2020	2019	2020
Plastic container (<10 L)	3953	2930	344	87	8.70	2.97
Metal containers (<10 L)	3314	625	232	17	7.00	2.72
Refrigerator	824	475	21	4	2.55	0.84
Washing Machine lid	274	nil	2	nil	0.73	NA
Grinding stone	259	83	33	10	12.74	12.05
Plant pot	1609	2316	33	24	2.05	1.04
Earthen Pot	60	26	2	6	3.33	23.08
Tyre (discarded)	173	108	31	14	17.92	12.96
Thermocol box	71	nil	5	nil	7.04	NA
Fibre items	81	nil	7	nil	8.64	NA
Others	1949	936	67	22	3.44	2.35
Plastic container (10-200 L)	3162	6596	254	453	8.03	6.87
Metal container (10-200 L)	1417	562	68	58	4.80	10.32
Cement tank (10-200 L)	2098	2401	179	145	8.53	6.04
Plastic drum (>200 L)	1110	3019	120	141	10.81	4.67
Cement tank (>200 L)	501	309	19	28	3.79	9.06
Ring Well	nil	36	nil	0	NA	0.00

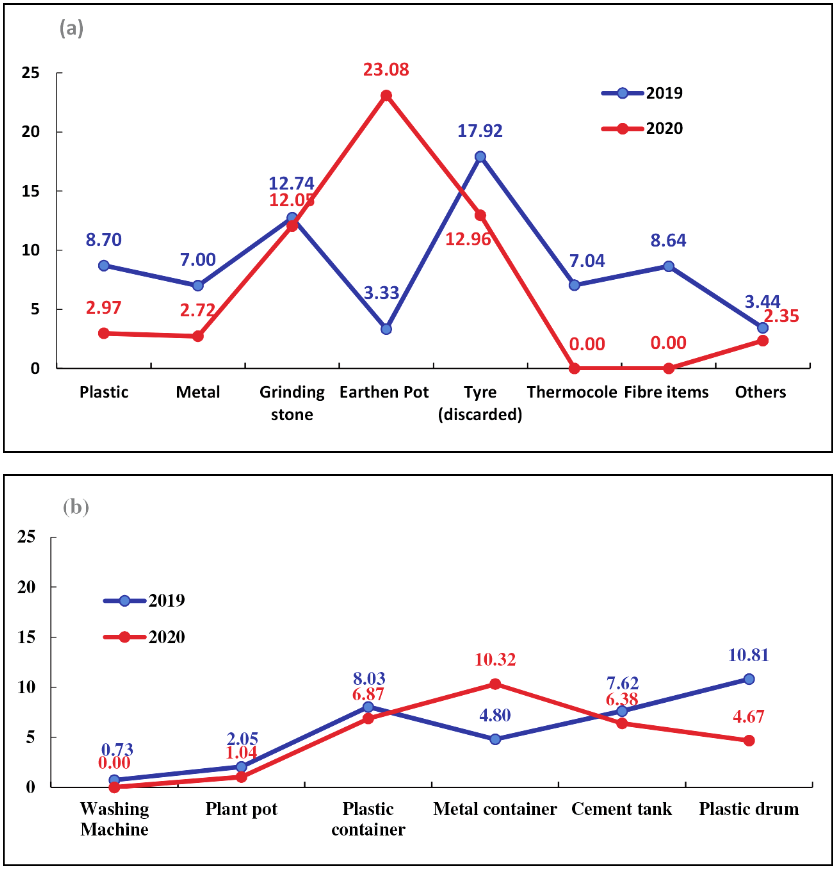


Fig. 7. *Stegomyia* index in the (a) rain dependent and (b) rain independent containers

Among all the containers examined, percentage positive containers were higher in 2019 than in 2020 (except in earthen pot, metal container of 10-200L and cement tank->200L) (Table 2). These containers were grouped into two categories, viz. rain-dependent and rain-independent. In the rain-dependent category, 9860 and 4708 containers were examined, of which 721 (CI=7.3%) and 156 (CI=3.3%) were found positive in 2019 and 2020, respectively (Fig. 7a). Among these containers; tyre (17.9%) and earthen pot (23.1%) were found with highest CI during 2019 and 2020 respectively (Fig 7a). The grinding stone was found with 12% positivity in both the years. In the second category (rain-independent), among 10,171 examined, 675 (6.6%) were positive in 2019, while the CI value was 5.6% in 2020. The CI was highest recorded in plastic drum (10.8%) in 2019, while metal container (10.3%) had highest positivity in the year 2020 (Fig. 7b). Overall, rain-dependent containers were found with higher CI than rain-independent category in the year 2019, but the reverse was true in the subsequent year.

DISCUSSION

Dengue and chikungunya are emerging vector borne diseases in the Port Blair municipality of South Andaman. In view of the absence of any specific treatment and vaccine, prevention and early control of mosquito vectors remain the most efficient way of managing vector bone diseases. *Stegomyia* indices can be considered as quantitative indicators for the risk of dengue outbreaks. In the present study, year round survey was carried out to identify the potential source of vector breeding in the house hold premises of an urban area at Port Blair, the capital city of Andaman & Nicobar Islands. Though controlling vector mosquito species in urban surrounding is a major challenge, identifying the ideal breeding habitats is essential for controlling *Ae. aegypti* populations in order to develop more effective mosquito control strategies.[27] Globally, dengue control is based on attempting to reduce the vector population density by eliminating or altering container habitats that work as mosquito breeding sites.

Discarded tyres, fibre and metal containers in vehicle workshops and repairing centres at Port Blair Municipal area are the principal source of mosquito breeding. Sensitization has to be provided among the people residing in these areas. Prolific breeding of mosquitoes in outdoor conditions signals the danger associated with indiscriminate disposal of unwanted containers, the act that is common in many areas of the town.[28] This needs immediate attention of health authorities and sensitization of people, especially in an active tourist hub like the Andamans.

In the present study, *Aedes* immatures were found throughout the year in the urban agglomeration of Port Blair. Rainfall in Andaman & Nicobar Islands occurs for at least six months*, i.e.,* June - November (3100 mm/ year), and water stagnation in the uncovered and discarded containers, which are thrown carelessly by the residents or tourists, creates mosquitogenic conditions. During the remaining months, due to water shortage and less rainfall, people residing in urban areas have to store water in containers. If these containers are not properly covered, they can serve as ideal breeding sites for *Ae. aegypti and Ae. albopictus*. The rainfall in the study area was high (1734.5mm) during July-September 2019, due to which dengue cases also were recorded high (110). This phenomenon was also reported by Benedum *et al.*[29] However, no correlation was observed between rainfall and incidence of dengue or chikungunya during the study period. The correlation with the case incidence was high (r >0.9), for container and pupal indices.

Container type and their availability are probably the most important factor determining breeding of *Aedes* spp., as artificial containers are the major larval habitats in and around human habitations. In Port Blair, almost 6% (2,426/41,277) of the containers examined were positive for mosquito immatures. Urbanization has created suitable breeding habitats for vector mosquitoes, with reduced predators, on one hand, and increased availability of human hosts, on the other.[30] Residents of urban area use plastic containers, *viz*; syntax overhead water storing urn, drum, bucket, mug etc., for meeting out their daily chores. In 20,770 plastic containers examined, 6.7% were found positive for mosquito immatures. The usage of metal drum for storing water was less. Potted plants (Plastic/Metal/Cemented) for decoration (n=1609) was observed in the porch of most of the houses which facilitated profuse emergence of adult mosquitoes providing ideal breeding and hiding / resting places. Container index in plastic drum and metal containers were recorded highest and contributed to the breeding of Aedes mosquitoes. This is in agreement with earlier studies by Kisan and Lakshmikant[31], where they showed plastic containers (tanks of capacity >10 L) with high number of larvae amongst different containers examined. Cement tanks with >200 liters capacity showed high positive rate for pupae. This could be due to operational failure, or the containers are filled up after the application of larvicide. Hence, these containers need to be targeted during the control operation.

As high correlation was observed between case incidence and the *Stegomyia* indices during the year 2020, these indices especially container and pupal indices can be considered as an ideal indicator for early warning of outbreaks.[32] Proper storage of water inside the house and weekly draining of these containers may help to reduce breeding[33] and prevent outbreaks. There is an urgent need to assess the environmental and entomological risk in order to stratify these areas, towards preparedness to prevent epidemics due to dengue and chikungunya in these islands.

CONCLUSION

An integrated approach is the most effective strategy to overcome the constant threat of dengue in Andaman & Nicobar Islands, in which the existence of main vectors and viral circulation are an undesirable reality. As cement tanks were observed to be a potential threat to high pupal productivity in the study area, these should be monitored frequently and targeted for control. Students in schools and colleges can be involved in eliminating the breeding source of *Aedes* mosquitoes, as well as create awareness among the people to prevent future arboviral outbreaks.

ACKNOWLEDGEMENTS

The authors sincerely thank the Integrated Disease Surveillance Programme (IDSP), Port Blair for financial support. The field staff of NVBDCP and staff of entomology section of ICMR-RMRC, Port Blair are also profusely acknowledged for their technical support.

Authors contribution: AR and AD – Overall supervision, work plan and design; MK – Work execution and field work; IPS- Manuscript revision, data analysis; VKS and TKT – Review and editing.

Conflict of interest: The authors declare that they have no conflict of interest.

REFERENCES

1. Samir Bhatt, Gething Peter W , Brady Oliver J , *et al*. The global distribution and burden of dengue. Nature. 2013; 496(7446):504-7.
2. Pan American Health Organization (PAHO), World Health Organization (WHO). Zika Cases and Congenital Syndrome Associated with Zika Virus, Reported by Countries and Territories in the Americas 2015-2017, Cumulative Cases. Washington, D.C., United States of America: PAHO. 2017.
3. Faria NR, Quick J, Claro IM, *et al*. Establishment and cryptic transmission of Zika virus in Brazil and the Americas. Nature. 2017; 546: 406–10.
4. Augustina Delaney, Mai Cara, Smoots Ashley, *et al*. Population-based surveillance of birth defects potentially related to Zika Virus Infection—15 States and U.S. Territories, 2016. MMWR. Morb. Mortal. Wkly. Rep. 2018; 67: 91–6.

5. Carrie K Shapiro-Mendoza, Rice Marion E, Galang Romeo R , *et al*. Pregnancy outcomes after maternal Zika virus infection during pregnancy, U.S. Territories, January 1, 2016 - April 25, 2017. MMWR. Morb. Mortal. Wkly. Rep. 2017; 66: 615–21.
6. WHO fact Sheet. Vector Borne Diseases. 2020; https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases
7. Dye C. Epidemiological significance of vector- parasite interactions Parasitol. 1990; 3:409 –15.
8. Garrett–Jones C. Prognosis for interruption of malaria transmission through assessment of mmosquitoes vectorial capacity. Nature 1964; 204: 1173.
9. Dutta P, Mahanta J. Potential vectors of dengue and the profile of dengue in the North-Eastern region of India: An epidemiological perspective. Dengue Bulletin. 2006; 30: 234-42.
10. Arun Sivan, Shriram AN, Sunish IP, Vidhya PT. Host-feeding pattern of *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae) in heterogeneous landscapes of South Andaman, Andaman and Nicobar Islands, India. Parasitol Res. 2015; 114:3539–46.
11. Sunish IP, Shriram AN, Arun Sivan, Vijayachari P. Spatio-temporal distribution of *Aedes* mosquitoes in Car Nicobar Island: Implication in the transmission of arboviruses. J Asia Pac Entomol. 2014;17: 761–6.
12. Vijayachari P, Singh SS, Sugunan AP, *et al*. Emergence of dengue in Andaman and Nicobar archipelago: eco-epidemiological perspective. Indian J Med Res. 2011; 134:235–7.
13. Chaaithanya IK, Bhattacharya D, Muruganandam N. *et al*. Dengue: a newly emerging viral infection in Andaman and Nicobar Islands, India. Epidemiol Infect. 2012; 140:1920–4.
14. Muruganandam N, Chaaithanya IK, Mullaikodi S, *et al*. Dengue virus serotype-3(subtype-III) in Port Blair, India. J Vector Borne Dis. 2014; 51:58–61.
15. Arun Sivan, Shriram AN, Sugunan AP, *et al*. Natural transmission of dengue virus serotype 3 by *Aedes albopictus* (Skuse) during an outbreak in Havelock Island: Entomological characteristics. Acta Trop. 2016;156: 122-9.
16. Wilder Smith A, Gubler DJ. Geographic expansion of dengue: the impact of international travel. Med Clin North Am. 2008; 92(6): 1377-90.
17. Manimunda SP, Singh SS, Sugunan AP, *et al*. Chikungunya fever, Andaman and Nicobar Islands, India. Emerg Infect Dis. 2007; 13:1259–60.
18. Muruganandam N, Chaaithanya IK, Senthil GS, *et al.* Isolation and molecular characterization of Chikungunya virus from the Andaman and Nicobar archipelago, India: evidence of an East, Central, and South African genotype. Can. J. Microbiol. 2011; 57: 1073–7.
19. Zeller H, Van Bortel W, Sudre B. Chikungunya: its History in Africa and Asia and its spread to new regions in 2013–2014. J Infect Dis. 2016; 214: S436–40.

20. Kumar G, Singh RK, Pande V, Dhiman RC. Impact of container material on the development of *Aedes aegypti* larvae at different temperatures. J Vector Borne Dis. 2016; 53(2): 144-8.
21. Romero Vivas CM, Arango Padilla P, Falconar AK. Pupal-productivity surveys to identify the key container habitats of *Aedes aegypti* (L.) in Barranquilla, the principal seaport of Colombia. Ann Trop Med Parasitol. 2006; 100(S1): S87-95.
22. Anubis Vega-Rúa, Marconcini Michele, Madec Yoann, *et al*. Vector competence of *Aedes albopictus* populations for chikungunya virus is shaped by their demographic history. Commun Biol. 2020; 3:326.
23. Jakkrawarn Chompoosri, Thavara Usavadee , Tawatsin Apiwat, *et al.* Vertical transmission of Indian Ocean Lineage of chikungunya virus in *Aedes aegypti* and *Aedes albopictus* mosquitoes. Parasites Vectors. 2016; 9:227.
24. Shriram AN, Sehgal SC. *Aedes aegypti* (L) in Port Blair, Andaman and Nicobar Islands - Distribution and larval ecology. J Comm Dis. 1999; 31(3):185-92
25. Shriram AN, Sivan A, Sugunan AP. Spatial distribution of *Aedes aegypti* and *Aedes albopictus* in relation to geo-ecological features in South Andaman, Andaman and Nicobar Islands, India. Bull Entomol Res. 2018; 108(2):166-74.
26. Barraud PJ. The Fauna of British India Including Burma and Ceylon. Diptera: Culicidae, Tribes Megarhinini and Culicini, Vol. v. Taylor and Francis, London, 1934.pp. 1–452.
27. André BB Wilke, Vasquez Chalmers, Carvaja Augusto l, *et al*. Proliferation of *Aedes aegypti* in urban environments mediated by the availability of key aquatic habitats. 2020; 10:12925.
28. Adeleke MA, Mafiana CF, Idowu AB, Adekunle MF, Sam-Wobo SO. Mosquito larval habitats and public health implication in Abeokuta, Ogun State, Nigeria. Tanzania J Health Res 2008; 10(2): 103-7.
29. Benedum CM, Seidahmed OME, Eltahir EAB, Markuzon N. Statistical modeling of the effect of rainfall flushing on dengue transmission in Singapore. PLoS Negl Trop Dis 2018;12(12): e0006935. https://doi.org/10.1371/journal.pntd.0006935.
30. Wilke ABB, Chase C, Vasquez C, et al. Urbanization creates diverse aquatic habitats for immature mosquitoes in urban areas. Sci Rep. 2019; 9:15335.
31. Thete Kisan D, Shinde Laxmikant V. Survey of Container Breeding Mosquito Larvae in Jalna City (M.S.) India. Biological Forum. 2013; 5(1): 124-8.
32. Garjito TA, Hidajat MC, Kinansi RR, *et al.* Stegomyia Indices and Risk of Dengue Transmission: A Lack of Correlation. Front Public Health. 2020; 8:328.
33. Kumari Roop, S Priya, P Sunita, Mujib M, Kanhekar LJ, Venkatesh S. Way Forward for Seasonal Planning of Vector Control of *Aedes aegypti* and *Aedes albopictus* in a Highly Dengue Endemic Area in India. Austin J Infect Dis. 2016; 3(1): 1022.

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