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Aedine Diversity, Composition, and Abundance in An Island Ecosystem Impacted by Tsunami, 2004

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Abstract

Environment plays an important role in the distribution of Vector Borne Diseases, which influences vector-pathogen transmission cycle, encompassing the vector distribution, abundance and diversity. Arbo-viral pathogens respond to changes in environment at different transmission levels and upsurges when environment is altered. Mosquito biodiversity and relative abundance of vectors in altered scenario is scanty. *Aedes* spp abundance was investigated, across three ecological settings in Teressa Island of Nicobar district. Each village was grouped into three ecotomes/settings, viz, domestic, peri-domestic and sylvatic. In Teressa island, all the households are clustered at one place, due to developmental activities during post-tsunami. All the available water holding containers and Aedine breeding sites were surveyed. There were ten species of *Aedes* in this island. The abundance of arboviral vector species such as; *Aedes aegypti* and *Aedes albopictus* showed decreasing trend from Domestic to sylvatic settings, while the diurnally subperiodic filariasis vector; *Aedes niveus* (now renamed as *Downsomyia nivea*) showed a reverse trend. Since three species among the 10 identified are known vectors of pathogens, the habitats of these three species need to be monitored frequently and appropriate control strategies to be devised to reduce the disease burden. The results are an important first step for understanding the dynamics of *Aedes* spp distribution under the changing ecology across the remotely located Teressa Island, inhabited by the native Nicobarese.

Keywords
Aedes spp, *Downsomyia nivea*, ecosystem, tree holes, Andaman and Nicobar Islands.

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INTRODUCTION

The transmission of vector borne disease pathogens viz. *Plasmodium falciparum*, *P. vivax* (malarial parasites-protozoan), *Wuchereria bancrofti* (filarial parasite-nematode), Dengue virus (flavivirus), chikungunya virus (Alphavirus), Zika virus are mediated by mosquitoes [2, 14]. *Aedes* mosquito species viz. *Ae. aegypti* and *Ae. albopictus* colonize an array of man-made, artificial and natural breeding receptacles in domestic and peri-domestic settings [32]. The quantum of breeding of these two mosquito species is expected to increase due to burgeoning urbanization, changes in climate, and availability of water holding containers [10]. *Aedes* mosquitoes transmit several viral pathogens which include chikungunya [33], dengue [6] and zika [14].

Information on the larval and adult abundance paves way towards understanding the occurrence, distribution and mosquito species composition of an ecotope. Besides, information on these lines aid in envisaging site and species specific vector control options [5]. In the contemporary, significant events in the domain of public health have occurred by the worldwide spread of *Ae. albopictus*, an invasive mosquito [4]. The distribution and abundance of this vector mosquito is associated with vegetation, abundant water-filled receptacles and stagnant artificial containers [7]. Erstwhile, *Ae. niveus* referred to as *Downsiomyia nivea* [20] in the present day, has been implicated in the transmission of diurnally subperiodic form of *Wuchereria bancrofti* (DspWB), endemic to Nancowry islands, Nicobar district [24, 25, 30]. This species has been reported to breed exclusively in cryptic breeding sites i.e. the tree holes [30].

The tsunami 2004, inflicted extensive damage to property and loss of human lives [18]. This catastrophe dislocated the residence of native Nicobarese from their traditional homestead, the Nicobarese hut (huts raised on wooden stilts), located on the coast and in the dense jungles interspersed with coconut and areca nut plantations. Rehabilitation and reconstruction of the Nicobar group of islands was undertaken by the Andaman and Nicobar administration. Permanent shelters were constructed to rehabilitate the Nicobarese. The other rehabilitation measures included provision of safe water, sanitation, electricity and restoration of approach roads. Elsewhere, it has been observed that eco-topographical changes have an impact on the bio-ecology of mosquito species, for instance breeding habitats, capability to adapt and transmit pathogens [17,16]. Larval breeding sites could range from manmade artificial containers to natural receptacles, which supports breeding of *Aedes* spp. Besides, these mosquito species have the ability to successfully breed and colonize permanent water and semi-permanent water receptacles [19]

Studies undertaken prior to tsunami focused on the medical importance of predominant mosquito species/vectors, epidemiological, transmission and population dynamics with respect to the DspWB form of filariasis [23,24,25,26]. Alterations in the habitats of native Nicobarese could play an important role in altering the ecological balance within which mosquitoes breed, develop and transmit diseases. Land use changes include water control systems (water management), and urbanisation, which can affect mosquito abundance, biodiversity, human biting behaviour, and vector competence. Such a scenario warranted identifying mosquito species in the primary forests *per se* and also in the domestic and peri-domiciliary locations. Therefore, it is important to study mosquito species succession for comprehending any shift from a forest dwelling habitat towards an urban like setting. Such a phenomenon could increase the risk of exposure to infective bites of vector mosquito. Information generated on these lines is discussed, which would pave way to develop appropriate strategy for the reduction of vector mosquitoes.

MATERIALS & METHODS

Study Area:

The remotely located Nancowry group of islands (8.16° N and 93.36° E) comprises of 5 islands viz., Chowra, Kamorta, Katchal, Nancowry and Teressa of Nicobar district, Andaman & Nicobar Islands. The total population inhabiting these islands is 10,634, constituted predominantly by the Nicobarese tribe. The total number of households in these islands is 2790, and the total surface area is 638.7 Km^2. The present study was undertaken in Teressa Island, which spans an area of 101.26 Km^2. (source:https://www.wikiwand.com/Teressa_island) Nicobarese population of 1,934 (2011 census) reside in eight villages viz. Aloorang, Bengali, Kalasi, Kanamhinot, Enam, Minyuk, Luxi and Chukmachi.

Mean minimum temperature on this island ranges between 22.97°C (January) and 25.44°C (March) and mean maximum temperature between 28.31°C (January) and32.36°C (March). Relative humidity is high and range between 72.9 per cent (January) and 87.0 percent (November). Rainfall is heavy from May to November, and is influenced by both the southwest and northeast monsoon. In the other months, rainfall is generally low, with February being the driest month. The rainfall ranges between 32.7

mm (March) and 351.1 mm (May), (source:http://andssw1.and.nic.in/ecostat/stationwiserain.php). The soil is porous coral sand, quickly absorbing the rainwater and leaving hardly any water to stagnate.

The existing permanent shelters in which the native Nicobarese tribe reside are clustered around a single place, or in other words they are not dispersed. This implies that human inhabited settlements are clearly demarcated. Therefore, in the present study, in each of the eight villages the ecotope was classified as; domestic, peri-domicilliary and forested/sylvatic areas. Domestic setting included the space within the human dwelling and the immediate surroundings. Peri-domicilliary setting included an area under 10 meters radius from the backyard of the human dwelling. While, the forested area encompassed an area under 20-25 meters radius from where peri-domicilliary setting ends. GPS co-ordinates were used to demarcate these three zones. Thus, three concentric circles emerge, depicting the three ecological zones.

Entomologic survey

In order to assess the abundance, diversity and ecology of mosquito population, intensive entomological collections were undertaken in the areas under the three zones, as described elsewhere during 2017-18, covering monsoon and post-monsoon seasons of the year. Immature survey was carried out in all the eight villages. All the water holding receptacles from in and around the accessible households were inspected for larvae and pupae, followed by peri-domestic and sylvatic zones. Ladles, dippers, droppers, plastic suction pumps and pipettes were used for collecting the mosquito immature samples. The collected larvae and pupae were brought to the field laboratory and were allowed to emerge into adults. A unique code was assigned for each breeding habitat in all the three settings. The adults were identified morphologically by using standard taxonomic keys [1, 21 ,28]

Data analysis:

The mosquito abundance data was transformed into log values for normalization and unequal variances in the raw data. This log-transformed data was used to produce matrix plots for each setting. Principal Component Analysis (PCA) was performed using the transformed data. PAleontological STatistics (PAST) version 3.21 [9] was used to plot heat maps and PCA plot. Relative abundance data was used to plot a setting based comparative graph.

RESULTS AND DISCUSSION

A total of 4527 mosquitoes belonging to Aedes spp. were identified from the immature samples collected during the period of observation. The most abundant species, in descending order, were Ae. albopictus (31.79%), followed by Ae. aegypti (28.92%) and Do. nivea (25.12%), Ae. malayensis (6.21%), Ae. edwardsi (3.62%), Ae. scutellaris (2.69%), Ae. andamanensis (0.75%), Ae. greeni (0.62%), Ae. simplex (0.27%), Ae. cancricomes (0.02%). All these mosquito species were included in the estimation of mosquito diversity setting wise and richness.

In all, 35, 32 and 13 water holding receptacles were detected with *Aedes* breeding in domestic, peri-domicilliary and forested/sylvatic settings respectively. The former two settings supported six and eight, while the latter setting supported ten *Aedes* spp. Six *Aedes* spp were observed to breed in domestic setting, and these were also found in the peri-domicilliary and forested/sylvatic settings. While, *Ae*. *andamanensis* and *Ae*. *cancricomes* were found to breed exclusively in the forested/sylvatic setting. Tree holes were found to support maximum number of *Aedes* spp (n=10). Among the 10 Aedine species identified, *Ae*. *aegypti* and *Ae*. *albopictus* are the established vectors of dengue, chikungunya and ZIKA viruses, while *Do*. *nivea* (earlier known as *Ae*. *niveus*) has been implicated in the transmission of DspWB. *Ae*. *aegypti* was observed to breed in 29, 25 and 10 water holding receptacles, while *Ae*. *albopictus* was detected in 22, 17 and 6 receptacles, observed in domestic, peri-domicilliary and forested/sylvatic settings respectively. *Do*. *nivea*, was found to breed predominantly in tree holes and few were collected from tar drum.

The species diversity of *Aedes* spp. was maximal in forested/sylvatic settings. However, the number of habitats found to support *Aedes* spp breeding was less than half that was observed in domestic and peri-domicilliary settings.

Clustering analysis (PCA Bi-plot, Fig 1) of the log transformed data revealed that *Ae. aegypti* and *Ae. albopictus* predominantly prefer to breed in receptacles like coconut shells, plastic buckets, plastic drums, syntex tanks, metal drums and plastic gallons. Further, the bi-plot showed that *Do. nivea* preferred to breed in tree holes across all the three ecological settings.

Heat maps depicting abundance of each mosquito species with respect to habitat in each setting are shown in (Figure 2). The heat maps reveal that the tree holes from all the three ecological settings support the breeding of most of the *Aedes* species, including *Do. nivea*. Although tree holes were observed to be the exclusive breeding sites for *Do. nivea*, few were also observed in tar drums in peri-domestic setting. Additionally, plastic drums, syntex tanks, coconut shells and tyres in domestic and peri-domestic settings supported the breeding of *Ae. aegypti* and *Ae. albopictus*. All the water holding receptacles inspected for the presence of *Aedes* larvae were plotted and the emerged species were also plotted as per their log values, with respect to domestic setting. *Aedes spp*. were observed to breeding in an array of water holding receptacles. Maximum breeding of *Aedes albopictus* was observed in plastic drums. Besides, plastic drum supports breeding of three species, *Aedes aegypti*, *Aedes albopictus* and *Aedes malayensis* respectively. The other breeding sites for this vector species are syntex, plastic bucket, coconut shells, metal drums, aluminium vessel, tree holes etc. *Aedes malayensis* was breeding only in plastic drum, plastic bucket, plastic tray and tree holes. *Aedes edwardsi* was observed to breed in tree holes, coconut shells and coconut husks, *Aedes scutellaris* was found in the coconut husks, coconut shells, zarda bottles and tree holes, while *Do. nivea* was found to breed exclusively in tree holes.

In the peri-domestic setting, all the water holding receptacles inspected for the presence of Aedes larvae were plotted and species emerging were also plotted as per their log values. Mainly breeding of vector species *Do.nivea* was observed in tree holes, besides, it supported all other Aedes species breeding in this setting. The other arboviral vectors *Aedes aegypti* showed multiple breeding habitats but was pre-dominant in tyre, coconut shells and plastic buckets, *Aedes albopictus* was observed to breed pre-dominantly in syntex tank, tree hole and metal drum, *Aedes malayensis* mainly preferred coconut shells and coconut husks along with tree holes, *Aedes greeni* and *Aedes simplex* found to breed only in Tree holes. *Aedes edwardsi* was found to breed in tree holes along with coconut shells, bamboo stumps and only species observed in coral rocks. In this setting only *Aedes malayensis* and *Aedes edwardsi* were found to breed in Bamboo stumps. *Aedes scutellaris* was found to breed in coconut husks along with tree holes, tar drum and coconut shells. *Do.nivea* exclusively breeds in tree-holes in all settings was also found to a less number in tar drums.

The breeding of DspWB vector *Do.nivea* was observed in tree holes in this sylvatic setting and this habitats supported the breeding of other observed *Aedes* species breeding in it. Arboviral vectors; *Aedes aegypti* and *Aedes albopictus* was observed more in coconut shells and tree holes respectively. *Aedes malayensis* was observed to breed more in coconut shells. *Aedes cancricomes* and *Aedes greeni* were observed to breed only in tree holes. *Aedes simplex* and *Aedes edwardsi* were found only in tree holes and coconut shells in this setting, *Aedes scutellaris* was observed to breed only in tree holes and Coconut husks. *Aedes andamanensis* and *Aedes malayensis* are the only *Aedes* species observed in stream. All the species available in domestic and peri-domestic were also available in sylvatic setting.

Furthermore, a decreasing trend in the relative abundance of *Ae. aegypti* and *Ae. albopictus* was observed from domestic (36%, 48%) to Peri-domestic (30%, 22%) and sylvatic (12%, 8%) settings. However, a reverse trend was observed in the abundance of *Do. nivea* (Fig 3). Also, the diversity of species showed an increasing trend from domestic, peri-domestic to sylvan settings. The prevalence of *Aedes scutellaris, Aedes edwardsi, Aedes greeni* were < 10% in all the three settings.

In the contemporary, as a consequence of expansion of human and vector population world over, new and emerging infectious diseases are on the ascent, most often resulting in upsurges, and have been associated with changes in the biodiversity of affected communities [3]. Biodiversity could facilitate plasticity in the resident communities to change [8]. One of the attributes of troubled ecosystem include the emergence of infectious diseases, which often correlates with the biodiversity loss [3, 11]. The Asian tsunami 2004, caused extensive damage in the Nicobar district, resulting in dislocation of the native Nicobarese tribe, from their traditional Nicobarese hut, located alongside the coast and in the dense jungles interspersed with coconut and arecanut plantations towards the interior parts of the islands, rehabilitated in permanent shelters. The rehabilitation package included provision of potable water, sanitation, electricity, restoration of approach roads etc. Such changes in lifestyle would alter the mosquito ecology *vis a vis* mosquito biodiversity. In this study we examined the association between Aedine diversity in the backdrop of habitat changes of the native Nicobarese tribe, across a range of sites, from domestic setting to peri-domicilliary to a forested sylvatic setting, in Teressa Island. The mosquito population sampled encompassed important vectors of dengue, chikungunya, zika viruses and filariasis. We observed that the diversity of *Aedines* and relative abundance of disease vectors varied by habitats, with lowest diversity of mosquito in domestic settings, leading to maximal diversity in forested/sylvatic setting. In all the villages, vectors of disease were least in forested/sylvatic setting, excepting the vector of diurnally sub-periodic form of filariasis.

The field survey was integrated with an analytical approach, to explore the association between ecological changes and *Aedine* diversity. All the 96 sites that were representative of three settings were characterized, which varied from least to most: forested/sylvatic setting, peri-domicilliary and domestic setting. We combined clustering analysis (PCA Bi-plot) of the log transformed data and heat maps to understand species and habitat diversity in these three settings.

This is the first organized effort to assess the Aedes mosquito diversity in Teressa island, keeping in perspective the post tsunami developmental measures and rehabilitation of the native Nicobarese. Transmission sequence of viral pathogens differs with respect to different ecological settings, which could be associated with Aedine fauna [30], implying that the present field survey focused on the diversity of Aedine fauna. Over the three ecological settings surveyed in Teressa island, 2461 of the total 4527 mosquitoes identified were Aedes species comprising of 10 species. Aedes mosquito diversity varied in each ecological setting. As per PCA Bi plot and heat map analysis, the diversity of Aedine species was more in forested/sylvatic setting followed by peri-domicilliary and domestic setting. The estimates of diversity in forested/sylvatic are probably conservative and underestimate the diversity in comparison to the other two settings. This could be due to lesser number of Aedes breeding habitats. This probably suggests that tree holes are harder and difficult to survey and perhaps there could be alternate micro niches that supports Aedes breeding. The underlying mechanisms for such differences in diversity in different ecological settings have not been understood. However, some studies indicate that the habitat diversity correlates positively with species diversity [22, 15]. The domestic settings had water holding receptacles, that favored human adapted mosquitoes such as *Ae.aegypti* and *Ae. albopictus*. Elsewhere, it has been reported that environmental changes alter the ecology of *Aedes* spp. [13]. In the study on the spatial distribution of *Aedes aegypti* and *Aedes albopictus* in relation to geo-ecological features in south Andaman revealed that *Aedes aegypti* showed more abundance in the densely populated settings and domestic areas, where as *Ae. albopictus* showed more abundance in forested areas. *Ae. aegypti* was absent in little Andaman [27]. Spatio-temporal distribution of Aedes mosquitoes in carnicobar island was studied in which *Aedes albopictus* was breeding more in Domestic and peri-domestic settings and *Aedes aegypti* was breeding less in the yearlong study, the pre-dominant *Aedes* species breeding habitat in Car nicobar was large plastic tanks with maximum species diversity in metal Drum [29]. The present study was carried out in an isolated remote Teressa island scenario, which was far from other Andaman Islands.

The distribution of medically important Aedine species differed across the three settings, which is interconnected with the changes in the ecosystem, and could have significant implications for transmission of arbo-viral pathogens in Teressa Island. Our results indicate that *Ae. aegypti* and *Ae. albopictus* was most abundant in the domestic setting, while these two species along with *Do. nivea* were prevalent in the transition zone (peri-domicilliary setting). These two mosquito species are vectors of dengue, chikungunya [12] and recently been implicated in the transmission of zika virus [14]. These vectors were observed less in the forested/sylvan setting. *Do. nivea* exclusively belonged to forested/sylvatic setting. A noteworthy observation in the present study is the detection of *Do. nivea* to breed in the tar drums in peri-domestic setting. Whether this behaviour is an adaptation towards the man-made habitats or not needs to be studied longitudinally.

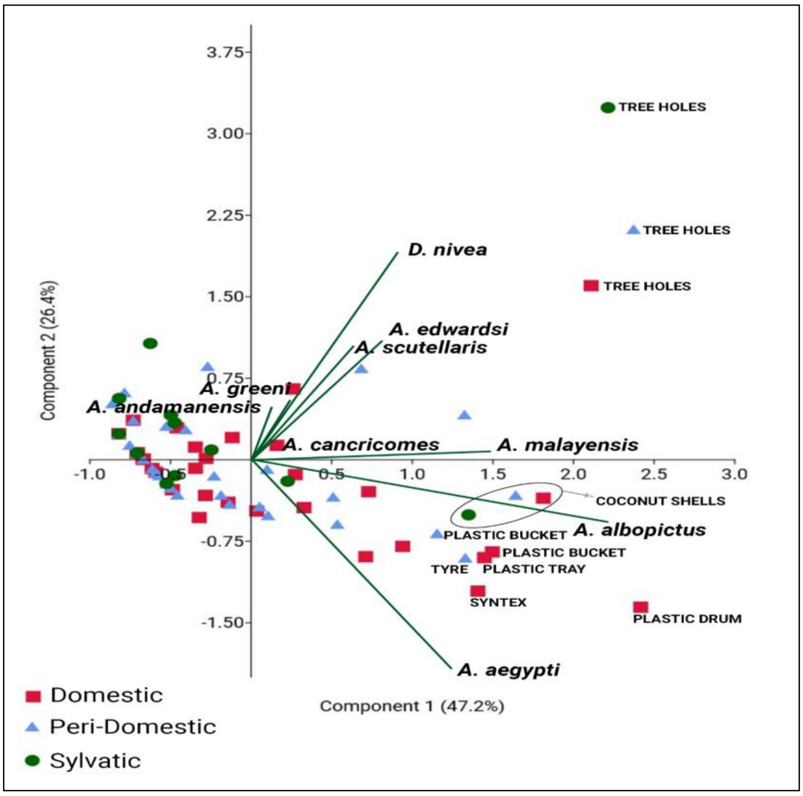
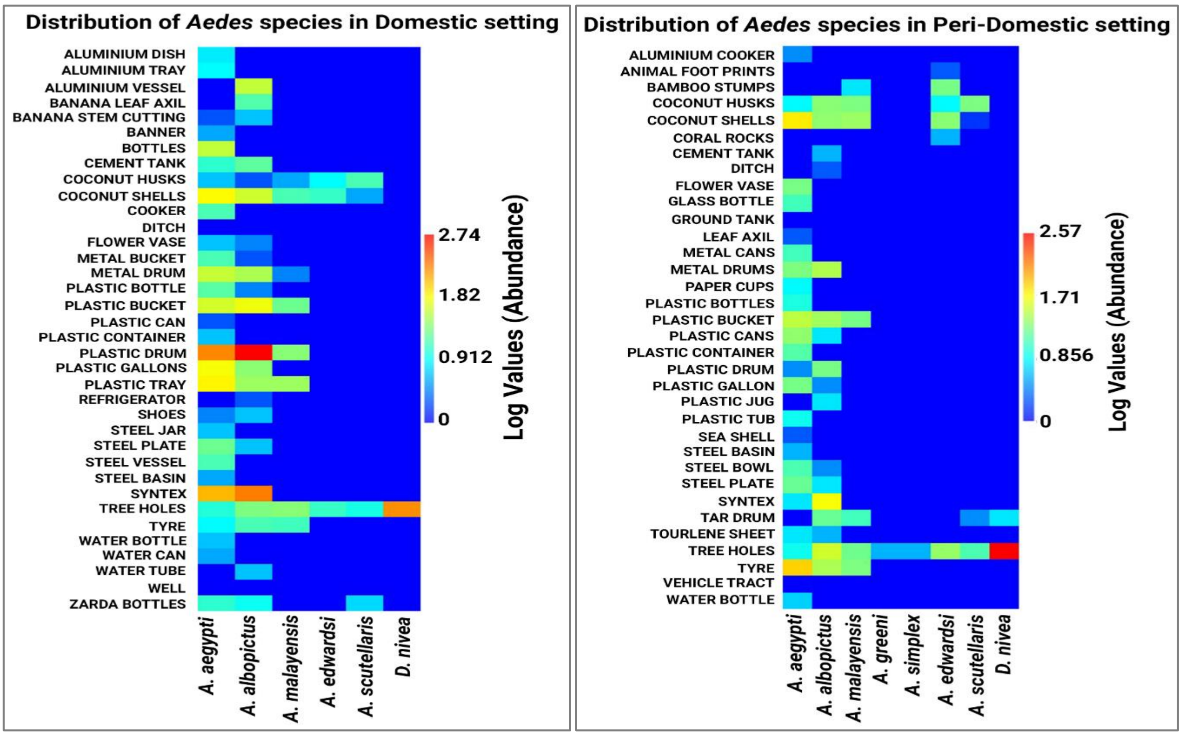


Fig 1: PCA Bi-plot showing the distribution of various breeding habitats from all the three settings along with the extent of variations exhibited by the mosquito species. *A. aegypti* and *A. albopictus* are the top breeding mosquitoes, which occur prominently in domestic and peri-domestic settings. *D. nivea* is the third highest breeding mosquito exclusive to tree hole breeding in all the settings.



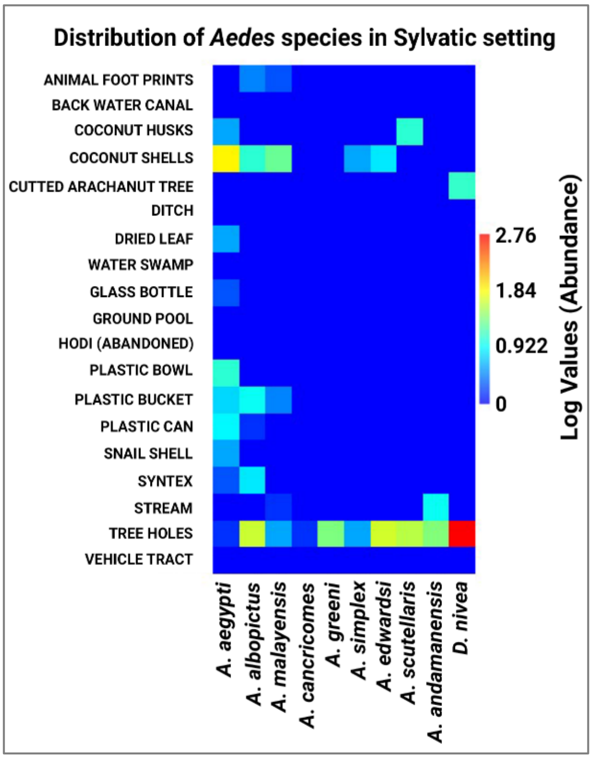


Fig 2: Habitat wise distribution of mosquito species in a) Domestic, b) Peri-domestic, and c) Sylvatic settings

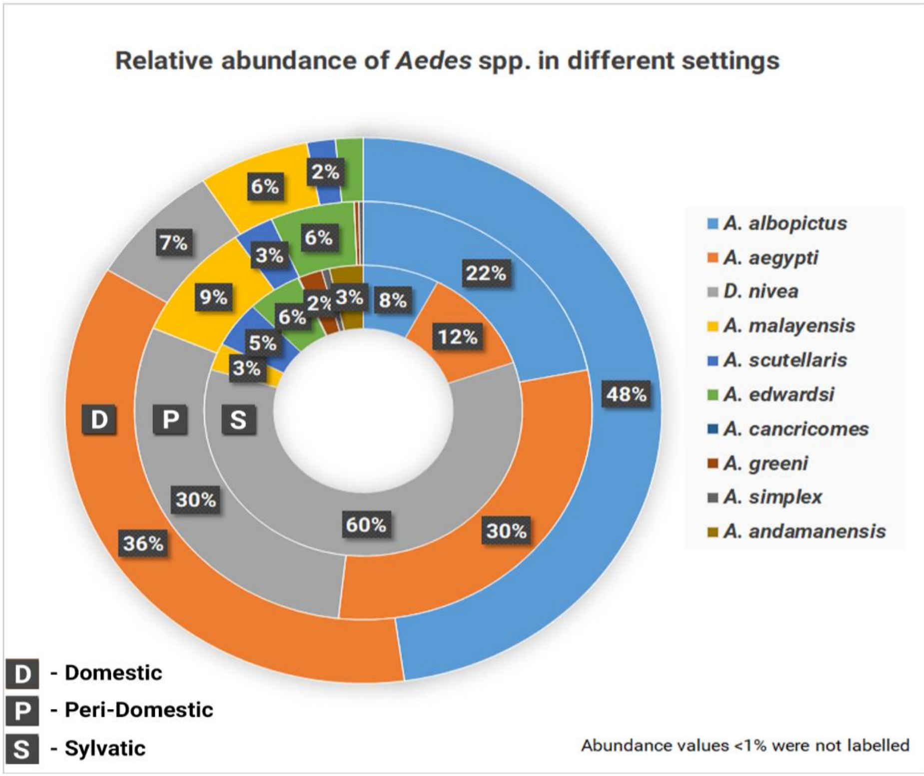


Fig 3: *A. albopictus* and *A. aegypti* showing a decrease in the abundance from domestic to peri-domestic and sylvatic settings. Whereas, *D. nivea* is showing an increasing trend in abundance

Table: Number of mosquitoes collected in the three ecological settings from different villages.

Village	Domestic	Peri-domestic	Sylvatic	Total
Aloorang	231	58	35	324
Minyuk	474	117	338	929
Bengali	452	339	89	880
Kalasi	141	40	117	298
Enam	263	64	113	440
Kanamhinot	525	225	10	760
Luxi	63	146	127	336
Chukmachi	123	273	164	560
	2272	1262	993	4527

CONCLUSION

In this study we assessed the diversity of Aedes spp. across three ecological settings as a consequence of developmental activities leading to a modified life style of the native Nicobarese, as the first step towards identifying risk of Aedes transmitted arbo-viral pathogens. Our study documents the biodiversity changes in an island, hitherto a forested/sylvatic tract. Teressa island is receptive to dengue, chikungunya and zika viruses rendering the population at risk to these pathogens. Competitive predispositions between the two invasive vector species viz. *Ae*. *aegypti* and *Ae*. *albopictus* and the presence of *Do*. *nivea* in peri-domestic locations, provides us an opportunity to comprehensively understand the bionomics of these three vector species in totality.

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