Indian J Med Res 120, September 2004, pp 173-182

A preliminary study of multilevel geographic distribution & prevalence of *Aedes aegypti* (Diptera: Culicidae) in the state of Goa, India

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Received September 1, 2003

***Background & objectives*: Dengue virus activity has never been reported in the state of Goa. The present study was carried out to document a multilevel geographic distribution, prevalence and preliminary analysis of risk factors for the invasions of *Aedes aegypti* in Goa.**

***Methods*: A geographic information system (GIS) based *Ae. aegypti* surveys were conducted in dry (April 2002) and wet (July 2002) seasons in the rural and urban settlements. The random walk method was used for household coverage. The non-residential area visits included ancillaries of roadways, railways, air-and seaports. Simultaneous adult mosquito collections and one-larva per container technique were adopted.**

***Results*: The *Ae. aegypti* larval and adult prevalence was noted in all the four urban areas in both dry (Density index (DI)= 3 to 6) and wet (DI= 5 to 7) seasons and only one out of 3 villages showed *Ae aegypti* presence in wet season (DI= 5 to 7). In the residential areas, hutments showed higher relative prevalence indices (Breteau index, BI=100; container index, CI=11.95; adult house index, AHI=13.33) followed by close set cement houses (BI=44.1; CI=12.0; AHI=11.24). *Ae aegypti* relative prevalence indices were also more for households with pets (BI=85.11; CI=12.5; AHI= 42.85); those with tap had higher risk (larval house index, LHI =32.03; relative risk, RR>2, n=256). Plastic drum was the most preferred breeding place (χ^2 = 19.81; *P*<0.01; RR=3.41) among domestic containers and rubber tyres (χ^2 = 11.86; *P*<0.01; RR=3.61)among sundry/rainfilled containers.**

***Interpretation & conclusion*: Established *Ae aegypti* prevalence in the urban settlements during dry and wet seasons and its scattered distribution in a rural settlement spell risk of dengue infection at macro-level. In the residential areas nature and types of the households, tap water supply and storage and communities' attitude and practices contribute to sustained meso-level risk of *Ae aegypti* prevalence dependant DEN. The non-residential areas offer transient meso-level risk as *Ae aegypti* prevalence was seasonally unstable and monsoon dependent. Risk at micro–level was due to the preferred larval habitats of *Ae aegypti* breeding *viz*., residential plastic-ware and tyres, and transport tyres in non-residential areas.**

Key words *Aedes aegypti* - dengue - geographic information system - prevalence indices

Among *Aedes aegypti* (Diptera: Culicidae) borne viral diseases in India, dengue (Flaviridae: Flavivirus) viruses (DEN) represent a case of continued re-emergence in the settlements across rural urban continuum; yellow fever (YF: Flavivirus) has a potential for emergence and the chikungunya (CHIK: Togaviridae: Alphavirus) has re-emerged about 18 yr after Barsi episode[1-3]. Risk factors for emergence of these diseases are continued urbanization, industrialization, and transport development, all of which contribute to the maintenance and spread of principal vector *Ae. aegypti* mosquito[4]. While the urban change and industrial development characterize the post independent India, rapid transport development that included road, rail, sea and airways changed ecology of the western coastal region considerably. DEN virus activity was reported in the West Coast at Kolencherry, Ernakulum district [National Institute of Virology (NIV), unpublished data 1983 & 1985], Thrissur (Trichur)[5] in Kerala; Mangalore in Karnataka, Gujarat state, and Mumbai in Maharashtra[6-8] but not yet in the state of Goa (NIV unpublished data and Govt. of Goa personal communication).

Until late 1960s the distribution of *Ae. aegypti* along the West Coast *i.e.*, south of Mumbai was scant[9]. In 1971-1973 survey, restricted focal distribution in tires was noted in 16 of the 22 coastal towns of Maharashtra along the National Highway (NH)17 indicating recent spread[10]. *Ae. aegypti* distribution was recorded at Mapusa, Goa State during the vector studies on Japanese encephalitis[11]. However, no comparable prevalence data are available to enable risk assessments of *Ae. aegypti* spread adequately. Essential data on the knowledge, attitude and practices of the community to facilitate community participation in vector control and prevention of dengue are also not available for the country[12].

The present study was undertaken to document the multilevel (*viz*., macro scale or settlement level, meso scale or ward premises level and micro scale or container habitat level) distribution and prevalence of *Ae. aegypti* in the state of Goa based on replicate surveys in dry and wet seasons. In addition, the role of people's perceptions, personal protection practices, housing types, house construction, water supply, differences of site and purpose of water storage on *Ae. aegypti* prevalence was also analyzed.

Material & Methods

Study area: Goa ($14^0$53'54"-$15^0$45'00" N; $73^0$40' 33"-$74^0$20'13" E) had 1,343,998 population in 2001 showing 14.89 per cent decennial growth since 1991 which is lower than the current 21.34 per cent national growth. Its 3,702 km^2 area is bounded by Maharashtra state in the north, Karnataka in the east and south and the Arabian sea in the west. Terrain is hilly and spurs of the Western Ghats reach up to the seaboard. This region is linked with the west by a major seaport at Marmugao. By 1971 the National Highway (NH) 17 connected Goa with Karnataka and Maharashtra states; and by mid 1990s the Konkan railway has provided connectivity to the entire West Coast [13,14].

Site selection: Surveys were conducted in residential wards, households of merchandise areas, slums *etc.*, representing the state's society and economy. The localities were selected so as to cover >1house type or construction. Among the non-residential areas, a major seaport, an airport, automobile workshops, private jettys, railway associated areas (waiting rooms, restaurants *etc.*) and an industrial area were visited.

Study design and collection methods: A modular geographic information system (GIS) chart was modified to cover settlement formations, demographic, residential (housing types, house construction *etc.*), non-residential and environmental components and adopted for this study[15-17]. In residential areas, households with single kitchen were considered as premises whereas in non-residential areas workshop, depot, industry, airport, railway station, seaport *etc.*, were considered as premises.

Mosquito surveys were conducted once in dry season (April-May 2002) and once during monsoon (July-August 2002) using aspirators for adults and one larva/pupa per container surveys simultaneously[10]. Households were selected by random walk method. Schedule-A (SA) was used to record the residential locality-wise data and Schedule-B (SB) for household data; and group data for the selected non-residential areas (SLS). Data recorded in SA included: (*i*) the housing types (*e.g.*, farmsteads, homesteads, cement houses or huts *etc.*); (*ii*) arrangement of the houses (row, close-set, spaced or scattered houses); (*iii*) peoples perceptions of the presence of mosquito activity (day and /or night biting); and (*iv*) personal protection practices (repellents/ insecticides/ bed-nets/ others). The SB was used to record (*i*) nature houses (residences/ shop houses/shops/mixed dwelling for men and live stock *etc.*); (*ii*) the source of water (tap/ bore well/well/river/others) and; (*iii*) types, purpose [potable-(p)=drinking and cooking nonpotable-(np)=washing and bathing / cooking / mixed purposes(mp)] and sites (indoor-ID/outdoor-OD) of water storage containers, which serve as larval habitats; adult *Ae. aegypti* positivity and the community efforts on vector control[7,12]. The collected specimens were identified following the key of Barruad[18].

Container type-wise classification of larval habitats was as follows: iron drums (Id), plastic drums (Pd), plastic containers (Pc), metal potable (Mp), metal-nonpotable (Mnp), earthen-ware potable (Ep), earthenware-nonpotable (Enp), earthenware-partly buried (EPb), cement tanks (CT), tyres (T), miscellaneous (Misc.); number of containers with water (N); and the houses (H)[7]. Containers with water positive for mosquitoes are given as N^+.

Statistical analyses: The relative prevalence indices of *Ae. aegypti* used were as follows (*i*) Breteau index (BI), denoted the number of containers with larvae per 100 houses visited; (*ii*) adult house index (AHI) and larval house index (LHI) denoted the per cent houses with the adults and larvae respectively; and (*iii*) the container index (CI) denoted the per cent containers with larvae. In addition, the concept of density index (DI) is used to facilitate mapping of *Ae. aegypti* prevalence[10,19]. Averages per household (⊗)or household-frequencies (F) were used to elucidate the variations in water storage practices at the settlement level.

2x2 χ^2 tests were performed to analyze differences in proportions, and assess the relative risk (RR) using STATCALC program of EPIINFO version (6.04)[20]. These tests compared the preferences of *Ae. aegypti* either for household attribute or a container characteristic as against the contrasting attributes/ characteristics following Southwood[21].

Results

Prevalence at settlement level: Present study covered four towns and two villages in dry and wet seasons with 123 N^+ for immature mosquitoes in 1803 N (CI=11.26%; n=447 residence visits). Four towns and one village were found positive for *Ae. aegypti*. In the dry season, larval prevalence was maximum in Marmugao and minimum in Panaji. The relative prevalence indices increased in the wet season with a maximum in Marmugao and a minimum in Madgao. Adult collections were maximal in Vasco and minimal in Madgao during dry season and in wet season it was maximal in Vasco and minimal in Marmugao (Table I).

Table I. Relative prevalence indices of *Aedes aegypti* by settlements

Town(U)/ Village(R)	H	Water containers Examined	+ve		BI	CI	AHI
Dry season:							
Vasco (U)	15	44	3	20	6.8	6.66	
Marmugao (U)	22	80	10	45.5	12.5	4.54	
Panaji (U)	63	428	9	14.28	2.10	1.58	
Madgao (U)	72	248	13	18.00	5.2	1.38	
Parvorim (R)	32	74	0	0	0	0	
Colva (R)	30	60	0	0	0	0	
Total	234	934	35				
Wet season:							
Vasco (U)	35	131	15	42.85	11.45	17.14	
Marmugao (U)	49	444	26	53.06	10.65	6.12	
Panaji (U)	51	252	26	50.9	10.31	11.76	
Madgao (U)	60	171	17	28.33	9.94	10.00	
Parvorim (R)	18	71	4	22.22	5.63	11.11	
Total	213	869	88				

BI, breteau index; CI, container index; AHI, adult house index; H, house

Table II. Summary of immature mosquito collections on the road, railway, air and sea transport and industrial areas (wet season)

Rural (R) / Urban (U)	Areas visited	Man.h	Premises	Total containers examined with					
				Water	Mos-quitoes	*Ae. aegypti*	*Ae. albopictus*	*Ae. vittatus*	Others*
Panaji city (U)	Boat jetties and a private work station	2	3	57	21	10	7	1	3Cq
Parvorim (R)	'Kadamba' divisional workshop	2	1	30	16	2	10	0	3Tx, 1Cx(L)
Marmugao (U)	Docks, Western India ship yard	8	3	43	16	2	5	0	4Ar, 5Cq
Madgao (U)	Madgao railway junction	2	1	13	8	0	6	1	1Cx(L)
Dabolim (U)	Airport canteen, air workshops	2.25	3	23	11	5	2	1	3 Cq
Verna (R)	Pharmaceutical industries	1.5	2	53	23	0	12	10	1Ar
	Industrial construction area	2.25	1	28	14	0	3	4	6Ar, 1Cx(L)
Total		20	14	247		19	45	17	28

*other spp. include: Ar, *Armigeres* sp., Cq, *Cx. quinquefasciatus*; *Cx* (L), *Cx (Lutzia)* sp.; Tx, *Toxorhynchites* sp.

Table III. Distribution of *Ae. aegypti* by residential/house attributes

Households		Water containers		BI	CI	AHI
Types	n- (%)	Examined	+ve			
R+ pets	7 (3.29)	48	6	85.11	12.5	42.85
R+ Shops	7 (3.29)	34	5	71.49	14.71	14.28
Shops	25 (11.74)	234	7	28.00	3.02	20.00
R	174 (81.69)	555	70	40.23	12.61	8.04
Total	213	871	88			

BI, breteau index; CI, container index; AHI, adult house index; R, residence

Table IV. Distribution of *Ae. aegypti* by house construction

Household construction	No. of households			No. of containers		BI	CI	AHI
	Total	+ve	LHI	Total	+ve			
Homestead	15	3	20.00	137	3	20.00	2.19	10.52
Flats	26	3	11.56	25	3	11.54	12.0	0.0
Huts	11	9	11.82	92	11	100.0	11.95	13.33
Cement houses	161	39	24.22	615	71	44.1	12.00	11.24

BI, breteau index; CI, container index; AHI, adult house index; LHI, larval house index

Table V. Presence/absence analysis of household *Ae. aegypti* prevalence in relation to the source of water

Town	Tap	Well & tap	Bore-well and tap	Well	Unrecorded
Panaji	21/85	0/1		0/1	0 /10
Madgao	20/50	0/3	1/7		
Vasco	13/33	0/2			
Marmugao	16/40	1/3		1/1	2/2
Parvorim	8 /18				
Total	78/226	1/9	1/7	1/ 2	2/12

Table VI. Analysis of water containers by availability, site and storage purpose in relation to *Ae. aegypti* breeding

Factors	Season	OD	ID	χ^2	*P*	OR
N	Wet	512	563	13.61	< 0.001	0.70
	Dry	419	322			
Season	Site	+ve	-ve			
Wet	OD	80	512	59.25	< 0.0001	11.00
	ID	8	563			
Dry	OD	9	419	11.63	< 0.001	0.27(1/ 3.703)
	ID	26	322			
Storage purpose						
Np	OD	0	0	-	-	-
	ID	0	304			
Nnp	OD	80	512	21.01	<0.00001	5.06
	ID	8	259			

N, available containers; p/np, potable/nonpotable; OD/ID, out -/indoors; OR, Odds ratio

Prevalence at household/premise level: 35 N^+ for *Ae. aegypti* in 934 N were present in 234 H (BI=14.95; CI= 3.74; AHI= 1.70) during the dry season and 88 N^+ out of 869 N in 213 H (BI=41.31; CI=10.13; AHI= 10.78) during wet season. Among the N^+, *Ae. aegypti* was predominant during the both surveys (dry-71.43%; wet-57.14%) and this was followed by *Ae. albopictus* (29.36%) during the wet season only. Other mosquito species encountered were *Culex quinquefasciatus* (dry-20.4%; wet-9.74%), *Cx. tritaeniorhynchus* (dry-4.1%; wet-1.3%) and *Anopheles spp* (dry-4.1%; wet-0.65%); whereas *Ae. vittatus* (0.65%), *Armigeres subalbatus* (1.95%), *Cx. (Lutzia)* spp. (2.6%) and *Toxorhynchites* spp. (1.9%) only during the wet season. Some adults emerging from field caught pupae included *Ar. aurolineatus* and *Cx.* (*Lutzia*) *fuscanus*.

Prevalence in non-residential areas: Exclusive non-residential premises chosen under this category included the areas of transport, its ancillaries, and some industrial areas. Smaller establishments which were inseparable physically (such as restaurants, shops, shop houses, *etc.*) were visited and analyzed along with the H. These areas contributed little to *Ae. aegypti* breeding during dry season. During wet season a total of 13 premises were visited and 13.75 man hours spent with 30.76 per cent CI (N=247;

Table VII. Analysis of water container habitats of *Ae. aegypti* breeding during the wet season

Container type	+ve 88	-ve 868	χ^2	*P*	RR	Cornfield limits	Frequency, n=213 +ve (%)	Frequency, n=213 -ve(%)
Mnp	5	158	7.99	<0.01	0.27	0.10-0.71	5 (2.35)	89(41.78)
Pd	21	73	19.81	<0.01	3.41	1.91-6.08	18 (8.45)	59(27.7)
Id	5	73	0.47	>0.05	0.66	0.23-1.75	5 (2.35)	49(23.0)
CT	1	13	0.07	>0.05	0.77	0.12-5.17	1 (0.47)	22(10.33)
Enp	2	20	0.13	>0.05	0.99	Invalid limits	2 (0.94)	30(14.08)
T	11	33	11.86	<0.01	3.61	1.65-7.79	11 (5.16)	23(10.8)
Pc	31	347	0.57	>0.05	0.82	0.50-1.32	29 (13.62)	170(79.81)
Misc	8	124	1.40	>0.01	0.60	0.26-1.32	7 (3.29)	42(19.72)
Natural containers	4	27	0.17	>0.01	1.48	0.43-4.60	3 (1.41)	14(6.57)

RR, relative risk; Mnp, metal non potable; Pd, plastic drums; Id, iron drums; CT, cement tank; Enp, earthenware nonpotable; T, tyres; Pc, plastic container; Misc, miscellaneous

BI=135.75;CI=7.69;AHI=28.54) (Table II).

Prevalence by housing types, house-construction, and by water supply: For majority of collections during dry season the SLS proforma was used. From grouped data thus gathered, scoring the H by the house type, by construction or household frequencies of water container types was difficult. During wet season data were scored using both the locality-wise (SA) and household schedules (SB). This facilitated summarizing data by settlements, localities and by household nature, household construction and with source of water.

Of 213 H surveyed exclusive residences were predominant (81.69%), followed by H with live pets (3.29%), shop houses (3.29%), and shops (11.74%) respectively. *Ae. aegypti* prevalence by housing types was not significantly different from those of exclusive human residences. However, *Ae. aegypti* prevalence indices were more for households with pets (BI=85.11; CI= 12.5; AHI= 42.85) (Table III).

The prevalence of *Ae. aegypti* in flats and homesteads was lower than huts and close set cement constructions. While the overall larval containers were not higher in the huts (χ^2 =0.01, P>0.05); $RR_{households}$ or RR of N examined did not differ from 1 when compared with the close set cement houses, which constituted maximum of households searched (Table IV).

Majority of H surveyed had tap water as exclusive source of water and LHI for *Ae. aegypti* breeding was 32.03 (82 / 256); nine had tap and well and seven had tap and bore-wells. No water supply was recorded in shops and in open areas where ownership of those premises could not be ascertained (Table V). The analysis showed higher RR of *Ae. aegypti* in the premises with tap as exclusive when compared with the houses with other sources (χ^2 (for difference) P> 0.05 and RR>2).

Peoples' perception and protection practices vis-a-vis Aedes spp. breeding: In a total of 81 (43.32%, n=187) households, people perceived day biting mosquitoes. This included exclusive perception of day biting mosquitoes in 2 households (1.07%), night + day biting in 79 (42.25%); among the rest 90 (48.13%) had exclusive night biting, 4 (2.14%) felt no problem of mosquito bites and 12 were shops where the response was either uncertain or indifferent.

The proportionate distribution of households with people's perception of day biting mosquitoes differed non significantly from those with actual presence of *Aedes (Stegomyia)* spp (42.25%) breeding (χ^2= 0.02;

P>0.05) but significantly from the households with *Ae. aegypti* (28.88%) breeding (χ^2= 8.45; *P*<0.05). The non-significant difference was also noted between the households with the combined presence of *Ae. aegypti* larval breeding and adults (44.91%, n= 187) vs the perception of day biting mosquitoes; (χ^2 = 0.1; *P*>0.5).

Among the personal protection practices the repellents (mats and coil) (75.93%) were used in maximum households followed by none of the methods (9.60%), fan (8.02%), insecticide (7.49%), smoke (5.53%) respectively.

Prevalence of Ae. aegypti at container habitats: In general available outdoors containers were more than those available indoors during the wet season. These containers included rain filled and sundry were contributed by 230 plastic (44.92 %), 111 other artificial containers (21.68%), and 31 natural containers such as plant leaf axils, tree holes *etc*. (6.05%); They contributed to a total of 29 (CI=12.61%), 8(CI=7.21%) and 7 (CI=22.5%) mosquito breeding places respectively; these in turn included 29(CI=12.61%), 7(CI=6.31%), and 4(CI=12.9%) *Ae.aegypti* breeding places. Outdoor containers positive for *Ae. aegypti* were more than indoors positive containers during the wet season and the opposite was true in the dry season. Since none of the containers with potable water contributed to *Ae.aegypti* breeding, further analyses included only the containers with nonpotable water (Table VI).

In all, nine types of containers contributed to *Ae. aegypti* breeding. The household frequency for earthenware, cement tanks and natural containers were <3. Excluding these the frequencies for type of containers were significantly different (χ^2 = 20.84, df=5, *P*<0.001).

Plastic drum ranked, as the most preferred breeding place among domestic containers and rubber tyres among sundry/rain filled container when compared with the other containers (Table VII). In the non residential premises three *Aedes* spp.were encountered in different containers. In these areas the outdoor breeding were significantly higher than the indoor breeding (χ^2 = 11.86; *P*<0.01; OR=3.61) but none of the containers showed more preference for breeding over the other containers though the rubber tires had the maximum breeding in these areas.

Discussion

This study records an increase in knowledge due to the presence of *Ae. aegypti* in six settlements, in addition to the sole earlier record at Mapuca[11]. From the present ecological data multilevel epidemiological risk is being assessed using tools for spatial analysis[22].

On the macro scale (*i.e.*, rural-urban continuum of settlements) the detection of *Ae. aegypti* indicates a risk at nominal level. Its establishment in the rural and urban areas showing DI >3 is suggestive of the risk at interval level for DEN and YF viruses. These DI were further raised during wet season consistently [19].

Tourism, transportation and trade links also augment the risk of dengue in the state. Panaji, the state's capital is linked by road with Mumbai (360 km), Pune (450 km) and Bangalore (450 km) all of which have known DEN virus activity[8]. Madgao, Vasco and Marmugao, the trade and commercial centers being the hubs of people's activity potentiate the formation of epicenters for DEN outbreaks. Invasion of *Ae. aegypti* is of significant nodal risk for dengue spread and rational risk is due to the inter-settlement linkages[23].

Ae. aegypti is absent at Verna, where industrial development is underway by peri-sylvan clearance. While *Ae. albopictus*, a potential mosquito vector could invade these areas during the monsoon, presence of *Ae. vittatus* here could pose a risk of DEN transmission albeit at a low level [24,25].

On the meso level both the residential and non-residential biotopes contribute to *Ae. aegypti* breeding thus help formation of disease nidi (=niche) at community level[23]. Saliently, *Ae. aegypti* prevalence depends on the water storage practices in the residential areas of Panaji, Madgao, Marmugao and Vasco da Gama. Tap water supply among drinking water sources is known to be a risk factor in India[26]. Presently in Goa too the households with tap water supply predominate with increased risk of *Ae. aegypti* breeding.

The household types and/or nature of construction among the visited localities are heterogeneous. So, no single factor could account for the risk of *Ae. aegypti* prevalence in these wards. Exclusive human dwellings and close-set households with cement constructions had prolific *Ae. aegypti* breeding. The residences with livestock or pets were too few to make a generalized comment. Potential places of community interaction such as exclusive shops and shop-houses had poor water storage; so they supported *Ae. aegypti* breeding poorly. The restaurants or the cold drink shops or the vulcanizers, which occasionally interspersed the residentia, also contributed to *Ae. aegypti* breeding in the community. These factors could impose variations in *Ae. aegypti* source reduction strategy.

The bungalows (homesteads) with scattered distribution in our collections offered poorly to water storage dependent *Ae. aegypti* breeding, but the premises condition with rain filled sundry supported the breeding of *Ae. albopictus, Armigeres* spp., *Culex quinquefasciatus etc.* In addition, the phytotelmates or the plant containers too contribute to the species like *Ae. albopictus* as was also noted in the recently introduced countries[23].

The households at Caranzale (Panaji) had close-set housing with linear formation, but have open yards or patios akin to bungalows. The junk water containers there in were usually tyres. Exposure of every house to open environment with green cover enhances risk of *Ae. albopictus* breeding. Tyres in shopping areas or the public transport systems with the varing tyre dump sizes (100s or 1000s) require added control inputs.

Ae. aegypti breeding was found poorly in the multi-storeyed flats/apartments, but predominantly in ID containers similar to that in Pune[27]. On the other hand, huts and cement/ brick constructions of middle or low economic areas contributed to copious *Ae. aegypti* breeding. Present assessments of risk based on water storage were similar to that in the Maharashtra and Gujarat coasts[7,10].

Linking the community awareness of the day-biting mosquito profile, personal protection practices and the distribution of *Ae. aegypti* in the residential biotopes is attempted. Such analyses were considered important to prioritize community needs and help community-based interventions. We attempted documentation of responses to routine questions while seeking house entry. Observed frequencies of people's perception were similar to *Ae. aegypti*'s relative prevalence. But the mosquito prevention practices help to reduce the nocturnal mosquito bites. These results are akin to the studies conducted in Trinidad and Tobago[12]. The residents in Goa used fans owing to warm humid climate, which was curiously felt to be preventive against day-biting mosquitoes as well. The potential use of such data in dengue prevention and/or disease surveillance was not documented hitherto. These clues could be utilized for optimal sampling for the vector populations or their susceptibility to the potential control agents.

At micro level 18 different potential habitat-sites and purpose were scored to assess their contribution to N^+ of *Aedes* spp. in the residential areas. These categories included confounding variables N (OD/ID), and Mp, Mnp, Ep & Enp. Such recording facilitated exclusion of Np in further analyses. As the study progressed, four additional categories accounted for the profuse use of plastic ware *viz.*, $Pd_{(OD\&ID)}$ and $Pc_{(OD\&ID)}$. Their inclusion improved the representation of the available habitats (N) in the coastal region significantly over the previous studies[7,10,26]. The characteristics of N^+ for *Ae. aegypti*, N-distributions, household frequencies and their ranks adopted in this study are consistent with current trends[12,28] and serve as precursors of the *Ae. aegypti* productivity studies and/or their contribution in the transovarial transmission of DEN viruses, an aspect gaining importance currently[29].

The Pd, Pc and T are important N^+ of the residential biotopes whereas only T at the nonresidential ones[10].

In the residential areas the RR≥3 in $N^{+}_{Pd/ Pc/ T}$. Earlier in the Maharashtra coast[10] $N_{(Pd \& Pc)}$ <5 per cent and $N^{+}_{(Pd \& Pc)}$ < 0.1 per cent. N_{Id} was predominant among N^{+}. In Gujarat $N_{p} \subset N^{+}$; N_{CT}^{+} was predominant[7]. In both these states N_{OD} & N^{+}_{OD} were high during the wet season. Certain residential localities in Goa contributed to N_{T}^{+} (RR > 1) in significant numbers during the wet season. This partly owed to the admixture of tyre shops and the neglected tyre in the ambit of homesteads. In addition to *Ae. aegypti, Ae. albopictus* breeding was common in the areas with vegetation cover. Otherwise *Ae. vittatus* colonized these habitats. This feature can be expected in the biogeographically similar areas.

The attempts to locate breeding of DEN vectors in the non-residential habitats during dry season were mostly futile except for N_{np} containers at tyre vulcanizers/restaurants. On the other hand in wet season N^{+} owed more to the rain-filled containers, more frequently infested by the competing *Aedes* (*Ae. albopictus, Ae. vittatus), Toxorhynchites* spp. *Armigeres* spp., *Culex (Lutzia)* spp., *etc*. The frequency of their habitats depends on species specific relative frequency in those areas[28]. The predacious larvae of *Toxorhynchites* spp., *Armigeres* spp., *Culex (Lutzia)* spp., known to regulate populations and thus seem to exert pressure on *Ae. aegypti* at the Kadamba tyre dumps.

At the air-and seaports the larval frequency of *Ae. aegypti* breeding was low. Opportunities for *Ae. albopictus* augmentation appear to be considerably high since areas were developed by the temporary vegetation clearance of the undulating laterite based landscape. This contrasted from that in the ports in Mumbai where N^{+} for *Ae. aegypti* was considerable during both the dry and wet seasons[10]. On the other hand at Shewa port (JNPT), Raigadh district, N^{+} was also found to be aggregated in the junk yard and stores (NIV unpublished data, 1995).

In all these non-residential and transport associated areas the rain filled containers showed limited focal build up of *Ae. aegypti*. Importance of tyres in the productivity of *Ae. aegypti* appears to be limited at the State Road Corporation (Kadamba) owing to its extra domestic locations and high frequency of the competing species present. Its prexence spells the risk of dengue as well as potential risk of vector spread. Hence, the transport areas demand massive control operations weather the diseases borne by *Ae. aegypti* are prevalent or not in that area.

In conclusion, the usage of a modular GIS format for the domiciliary vector distribution and prevalence studies has magnified the scope of collection, storage, retrival, analysis and interpretation of data on multiple scales. Databases generated by such structured sampling would hopefully be predictive in diverse geographic, demographic, and ecological settings for *Ae. aegypti* and diseases borne by it. In addition, increase in the tourism aided by international air travel could enhance vector spread[30]. Continued vigil on progressive environmental degradation[31] and the increasing risk of DEN viral influx in Goa would be necessary in the wake of raised density indices of *Ae. aegypti*.

Acknowledgment

We thank Drs J.R. Bhatt and Ashok Bhatia, Ministry of Environment and Forests, Government of India for financial assistance for the Coastal *Aedes* Project; Dr R. Tamba (Epidemiologist), Dr M.B. Kaliwal (Entomologist), Directorate of Health services, Government of Goa State, Panaji, for useful discussions and local facilities; Dr P.D. Ajgaonkar, Chief Medical Officer, Goa Port-Trust, Marmugao and the Airport authority, Dabolim for permission to visit the sea and air ports; field staff of the project and the Division of Medical Entomology of NIV for assistance.

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