DETERMINANTS OF TRANSMISSION RISK AND THE ROLE OF VECTOR PUPAL PRESENCE IN THE DEVELOPMENT OF INTEGRATED APPROACHES TO DENGUE CONTROL IN MUNTINLUPA CITY, THE PHILIPPINES

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Abstract. A study was conducted in Muntinlupa City, a fast expanding city in southern Metro Manila to understand the implications of different ecological, biological, and social determinants affecting vector pupal indices and dengue transmission risk in the area. Selected barangays (administrative 'villages') were categorized as either high or low dengue incidence areas based on the reported dengue incidence of the area at the time of study. These communities were further classified into either high or low human population density areas (HPD and LPD clusters) to determine the influence of socio-economic factors on vector density and disease risk. Study findings found HPD and LPD clusters with low dengue incidence were generally more knowledgeable about dengue and have more access to sources of information about the disease and prevention. However, communities' knowledge on dengue does not necessarily translate to reduction of vector density in their areas as indicated by statistical test performed in the study. Statistical analyses also revealed that some of government interventions and community/household-based prevention practices were shown effective for dengue control to reduce infection risk, but require more frequent monitoring to maintain sustainable control of the vector population. Moreover, the percentage of green areas in the surveyed clusters has an effect on the vector density of the study. An overall analysis using chi-square showed that there is a correlation between pupal density and human population density and number of dengue cases.

Keywords: dengue control, transmission risk, vector pupal indices, HPD cluster, LPD cluster, integrated approach

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INTRODUCTION

The public health impact of dengue infection in the Philippines has been significant since its first recorded outbreak in 1926. The exceptionally high numbers of reported cases in a span of six years, in 2010 (173,033 and 1,057 deaths), in 2011 (125,975,000 cases and 654 deaths), in 2012 (187,031 cases and 654 deaths), in 2013 (204,906 cases and 660 deaths) in 2014 (121,580 cases and 465 deaths), and in 2015 (200,415 cases and 598 deaths) attest to its importance as a leading cause of preventable morbidity and death in the country (Philippine Integrated Disease Surveillance and Response, 2016).

Aedes aegypti, the primary vector of dengue viruses, is highly anthropophagic (predilection to bite humans over other animals) and behaviorally both endophagic (greater tendency to bite indoors) and endophilic (preference to rest indoors) (Gubler and Trent, 1993; Harrington *et al*, 2001). Together with a strong association with domestic and peri-domestic environments, this species shows a remarkably strong vectorial capacity to transmit viruses to humans (to include yellow fever, chikungunya, and Zika viruses).

Ideal conditions for *Aedes* mosquitoes exist in many urban areas of the Philippines, particularly where basic services for water provision and waste disposal are very poor or inadequate. Once fairly confined to urban and semi-urban areas, dengue infections have also spread into the rural areas of Mindanao Island and in the mountainous regions of northern Luzon (Espino *et al*, 2012).

The aim of the Philippine government's National Dengue Control and Prevention Program of the Department of Health (NDCP-DOH) is to reduce or eliminate natural and artificial vector breeding sites through community mobilization and participation and dengue awareness campaigns, thereby providing a sustainable approach for reducing transmission and disease. The program utilized traditional indices for measuring immature *Aedes* infestations and identification of the key containers responsible for the majority of vector production. The program recommends routine surveys of containers, with prevention campaigns directed at eliminating or limiting water-holding containers as much as possible. The Philippine Local Government Code mandates Local Government Units (LGUs) to implement these measures at provincial, city, and smaller municipal levels down to the barangay ('village' unit). The national-level DoH further contributes to dengue prevention and control of outbreaks by implementing administrative orders and agreements with relevant national agencies.

After decades of multi-media campaigns, the general public awareness on dengue is regarded as high. Despite these proactive initiatives and regulations, most LGUs only implement mosquito larval reduction measures in response to dengue cases and deaths reported from local hospitals or by the media.

The objective of this study was to identify factors (determinants) that influence dengue mosquito vector presence in Muntinlupa City, a city in southern Metropolitan Manila. These determinants fall under any of these categories: ecological factors, social factors, and biological factors. The ecological/demographical factors that may influence dengue risk include the human population density, availability of 'green'localities in residental areas, basic infrastructure, and general condition of households, the adjacent community clusters, and recent vector control activities in the respective areas. The biological factors include surveyed water receptacles in private and public spaces and the estimation of vector mosqutio densities. Qualitative and quantitative research methodologies were used to determine the associations between human socio-behavioral factors and varying levels of vector density and dengue transmission risk.

MATERIALS AND METHODS

This study employed a stratified cluster systematic sampling design. A total of 1,231 households were randomly selected for entomological surveys (immature stages) in private and public spaces and for conducting a Knowledge, Attitude, and Practice (KAP) survey. The households were numbered according to the cluster for random selection. At least 100 randomly nominated households per cluster were chosen for the KAP and entomological surveys during the rainy and dry seasons.

A background investigation was performed for each study cluster. Each cluster (including its public spaces such as ground depressions, vegetative land cover, and businesses) was inspected for the presence of large and small water containing vessels. The general housing conditions of the communities (*eg*, type and house structure materials, integrity), mean distance between houses, presence of gardens, green commons areas, vegetation type, vicinity of garbage dump areas from cluster, and permanent pools of water were recorded.

Focus group discussions (FGD) among randomly selected respondents as well as key informant interviews (KII) with barangay and city health workers and other government officials were conducted to provide additional information and verify the data collected using the various survey methodologies.

Study site

Muntinlupa City is located in the southern part of Metropolitan Manila along the western side of Laguna Lake. In 2007, the average ambient 24 hour diel temperature ranged from 26 to 33°C with an average relative humidity of 73.3% and total rainfall of 1,965 mm. Muntinlupa City has active health referral and surveillance systems for dengue infection among its passive primary, secondary, and tertiary health care facilities. Occurrence of dengue cases has been reported annually in the city for more than 20 years. The dengue incidence in the city in 2007 was 184.6 per 100,000 population.

In a stepwise process, one high dengue incidence barangay (Putatan) and one area with low dengue incidence (Buli-Cupang) were selected for this study (Fig 1). The barangay was defined as either 'high' or 'low' incidence for dengue if the mean dengue incidence was either above or below (≥2±SD) the mean dengue incidence of the city as a whole (70/100,000 population) over a 3-year reporting period (2003-2005).

In classifying clusters as either high population density (HPD) or low population density (LPD) areas, a map was prepared based on a technique by Chang *et al* (2009). They were selected according to the density of houses of the cluster from the aerial view of the prepared map.

The polygon shape file of the selected barangays were exported from ArcGIS 9.1 (ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute) to Google Earth using free access software (KML Home Companion 3.1 [https://developers.google.com/kml/documentation/kmlreference] superimposed on Google Earth 4.0.2327(Google,

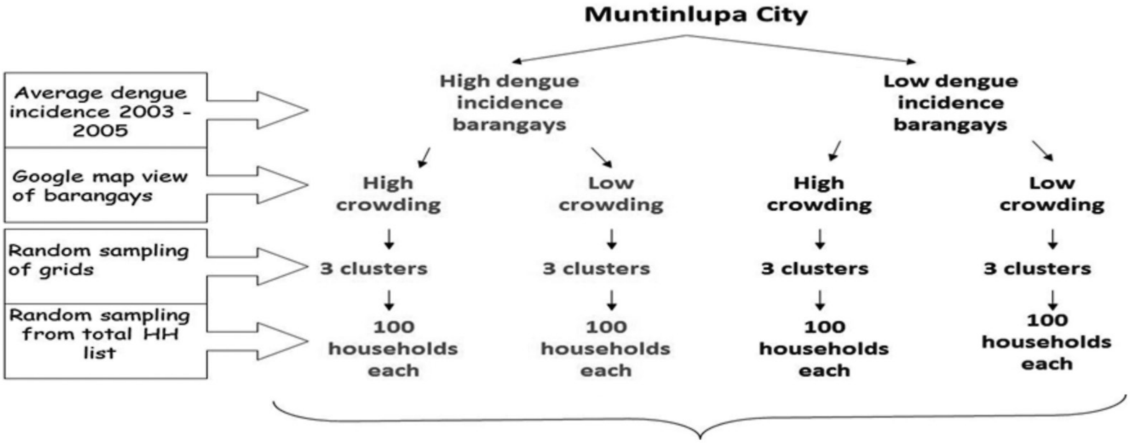


Fig 1 Stepwise process for cluster selection in Muntinlupa City.

Mountain View, CA). Multiple screenshots of the study sites from the eastern to western boundaries were taken from an altitude of approximately 700 m elevation. The reconstructed image was then geo-referenced using ArcGIS 9.1. A 1 ha (100 x 100m) grid was drawn using the North American Datum of 1927 (US Coast and Geodetic Survey, 1921) as reference and coordinate system. The ArcGIS maps were printed and merged to form two large maps of barangay Buli/Cupang and Putatan (152.4 x 106.7 cm and 132 x 96.5 cm), respectively. These printed maps were used for cluster identification and classification purposes.

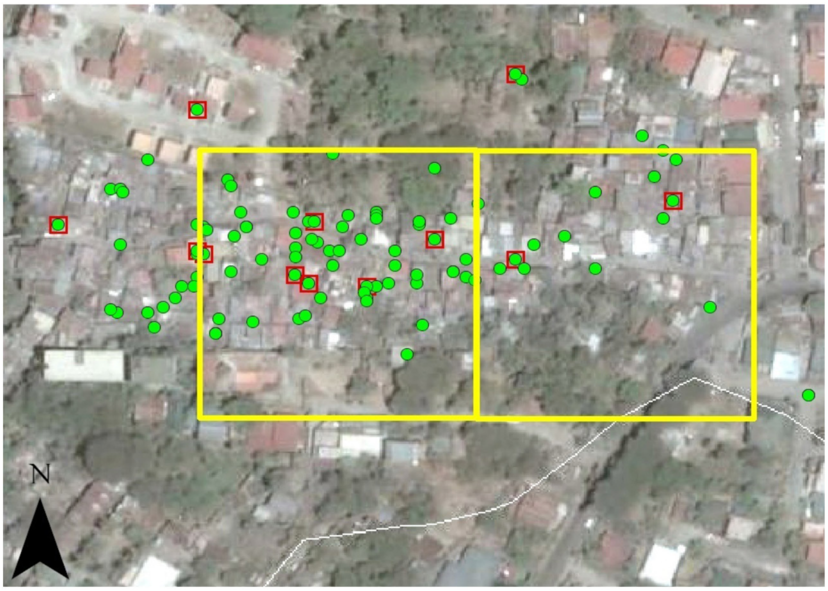
Those classified as high population density (HPD) clusters in Brgy. Buli/Cupang were Purok 6, Purok 4 and Purok 1; while Intercity Homes Subdivision, San Jose Village, and Rizal Mintcor Townhomes were classified as low population density (LPD) clusters. For Brgy. Putatan, selected HPD clusters were Pasong Makipot, Bagong Sibol, and Manggahan; while Lakeview Homes, Agro Homes, and Mutual Homes fell under LPD classification. Further ground inspection during cluster background survey confirmed the classifications of HPD and LPD clusters (Fig 2A-D).

All the households for the clusters that had less than 100 houses were included in the survey. To meet the minimum 100 households, adjacent grids starting above the cluster (as shown in the prepared map) were added in a clockwise direction until reaching the desired number.

Characterization of the ecological parameters in the selected clusters include the population density and availability of 'green'(number and size) areas, presence of basic infrastructure and public spaces, recent vector control activities provided by the local government and other relevant community-based dengue control activities. Public areas immediately adjacent to the study clusters were also noted.

Analysis

Entomological parameters were expressed using traditional *Stegomyia* indices and the pupa/e per person index (PPI, number of pupae collected per person that slept in the household the night before the survey x 100) for each of the clusters. Key

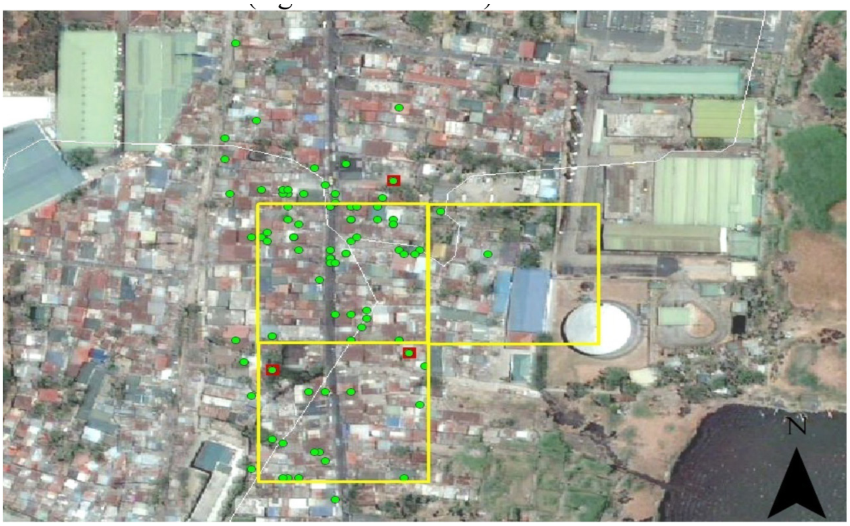


A. HDI +HPD cluster (Pasong Makipot).

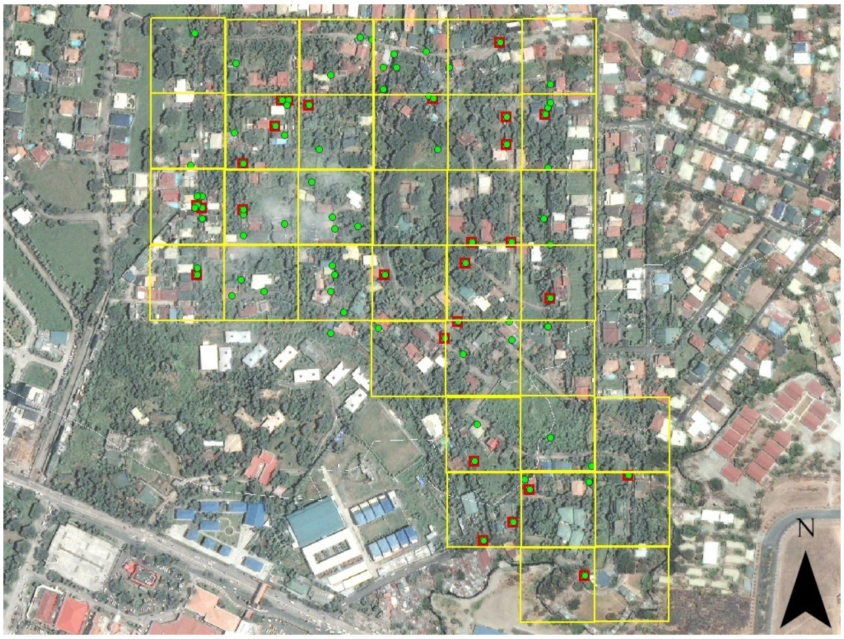
B. HDI +LPD cluster (Agro Homes/ Bliss).

by house and container. The Pupal House Index (PHI) represents the percentage of houses or premises positive for *Aedes* pupae. The Pupal Container Index (PCI) is the percentage of water-holding containers with *Aedes* pupae, and the Pupal Breteau Index (PBI) is the number of positive containers per 100 households in a specific location (WHO, 2003). Statistical tests were conducted to understand the implications of different ecological and social factors affecting vector density in the sentinel site. Pearson product-moment correlation coefficient (*r*) were performed between the pupal count and the condition of houses in each cluster which are classified as either good (wood or concrete, in good condition), satisfactory (recycled materials, in good condition), or poor (recycled

containers were also determined for all the representative clusters. Dengue vector densities were measured using five indices to determine the number of mosquito pupae (combined or separated by species *Ae. aegypti,* and *Ae. albopictus)* in each area



C. LDI +HPD cluster (Purok-6).



D. LDI +LPD cluster (San Jose).

Fig 2 (A-D)–Representative examples of households surveyed by cluster and those found positive (green points) for *Aedes* pupae.

materials, poor condition); and between the pupal count and the type of establishment per cluster which are classified as 'purely residential' or 'both residential and commercial'. The same analysis was conducted between the percentage of green areas and pupal count in each cluster. Pearson's *r* test was also performed between pupal counts and socio-economic classifications identified in the sentinel sites (upper middle status, lower middle status, and lowest status) to determine if correlations exist. Similar statistical test was conducted between the pupal counts and interventions conducted by the residents/government in order to measure their effectiveness as well as the pupal counts and the sentinel site's knowledge on dengue. To determine whether there is significant association between the pupal counts in low/high human population density areas and low/high dengue incidence areas, a chi-square test was conducted.

RESULTS

Ecological determinants

Socio-economic characteristics of population and green areas

The households in HPD clusters were in the lower middle and lowest economic strata. Informal settlers represent most of HPD clusters, except Purok 4 and Manggahan. Twenty to forty percent of houses in these clusters were in poor condition made of disposable materials; the rest were deemed satisfactory (made of more permanent material as wood and concrete). The mean distance between the houses ranges from less than one meter to one to three meters (greater distance between rows of houses or when streets separate the houses). Green areas were limited in number and size and were mostly less than 10% of the total land area inside the study cluster.

The households in the LPD clusters mostly belong to the upper middle strata. Their housing conditions are mostly good (made of cement, metal, good wood and galvanized iron). Twenty percent of the households in Lakeview Homes are informal settlers whose housing conditions are either satisfactory or poor. The distance between houses is at least 3 m except for Rizal-Mintcor due to the presence of townhouses. The distance of the townhouses, because of the nature of their structure, are from one to two meters apart. Vacant residential lots are common in four clusters particularly in San Jose Subdivision. Except for Agro Homes/ Bliss, more than 50 percent of homes in these clusters have gardens.

The households in each cluster classified by density are similar with regard to residential function and types. Except for Pasong Makipot, Bagong Sibol and Manggahan, all had defined public spaces for leisure activities. The most common ones are basketball courts and multi-purpose halls. High tides and severe storms periodically flood the clusters along the lake shore (Purok 1, 4 and 6), especially during the rainy season. Portions of the San Jose Village were also flooded during wet months of the year.

Basic infrastructure

Electricity is available in almost all of the households; however, the connections are mostly illegal in four of the high-density clusters, as reported. Most roads are paved; solid waste collection is done every week; and a tire-capping facility was found in Rizal/Mintcor Townhouses and Purok 1.

Inadequacy of water supply is common to both HPD and LPD clusters. Numerous homes in the HPD clusters do not have access to a piped water supply. Most homes in Purok 1 and Purok 6 have piped water supply but the water supply is not adequate. Households purchase water from a distributor in a water truck supplied either privately or by the city government. A public faucet is available in Purok 6. Although most of the homes in the low density cluster have piped water supply, the supply is not adequate; most homes have deep wells that supplied water through a motorized pump (See Table 1 and Table 2 for more details).

Key containers

The key containers found in the private spaces are drums (62%), tires (7%), and those falling under others category (14%). Containers falling under the others category include discarded items (jar, pot, pot cover, plastic plate, plate trays, drum cover, dipper, flower pot, and Styrofoam ice box) and trash (plastic mineral water containers, basketball ring stand, rolled canvass). It also included dish racks found in kitchens and one fountain in a garden. When examined by population density and reported dengue case incidence, drums are still the key pupa containers. Seventy-three drums were observed to contain pupa; 92% (*n*=72) of the drums were used for household purposes.

Household container collections yielded a total of 1,864 *Aedes* pupae. Based on adult emergence, only two *Aedes* species were collected (*n*=493)—*Ae. aegypti* (97%) or *Ae. albopictus* (3%). In areas with higher dengue incidence, the total pupal count in high human population density areas was 764 compared to 285 in low population density areas. Conversely, in locations with low dengue incidence, total pupal counts in high population areas were 104 compared to 711 pupae in low population areas.

Adjacent areas

The immediate areas of the clusters are other residences, vacant lots with greens, highways and factories. Within 500 m are the lakeshore for Purok 6, Purok 4 and Purok 1 (all HPD, low incidence clusters); garbage dump in Pasong Makipot, Manggahan, Lakeview Homes and San Jose Village; tire-capping facility in Purok 1 and Rizal/Mintcor Townhomes. All clusters except for Purok 1 have vegetative land cover and more shaded areas.

Biological determinants

Pupal/Larval productivity data in private spaces (households) and public spaces

The summary of the pupal survey results in private and public spaces of selected clusters of Muntinlupa City, Philippines from September to October 2007 is shown in Table 1 and 2, respectively. Two-hundred thirty nine (7%) of the more than 2,000 containers in the households were found to have pupa.

Although a much smaller number of water holding containers was observed in the public spaces of the clusters, the proportion of the containers with pupa was higher (36 of 130 or 28%). Surveys from public spaces revealed tires (41%) to be the overall key container, with those under others (15%) category (consisting of old cup and discarded toilet water tank top cover) and coconut shells (12%). At the individual cluster level, flower vases in Rizal-Mintcor, buckets in Mutual Homes, coconut shells in Agrohomes-Bliss clusters, bowls in Pasong Makipot and containers under other category (consisting of cracks from concrete cement and discarded hat) in Purok-6 were found to be key containers.

The mean *Stegomyia* indices (%) for households surveyed in different clusters are the following:

For High Dengue Incidence; High Population Density (HDI-HPD) Clusters [Pasong Makipot (Fig 2A), Bagong Sibol, Manggahan], the mean Pupal Container Index (PCI) is 1.61; the mean Pupal House Index (PHI) is 10.08; the mean Pupal Breteau Index (PBI) is 4.37 while the mean Pupa per Person Index (PPI) is 51.50.

For High Dengue Incidence; Low Population Density (HDI-LPD) Clusters [Lakeview Homes, Mutual Homes, Agro-Homes/Bliss, (Fig 2B)], the mean PCI is 5.00; the mean PHI is 7.88; the mean PBI is 6.12 while the mean PPI is 16.67.

For Low Dengue Incidence; High Population Density (LDI-HPD) Clusters [Purok-1, Purok-4, Purok-6) (Fig 2C), the mean PCI is 2.35, the mean PHI is 3.59, the mean PBI is 3.22 while the mean PPI is 6.68].

Finally, for Low Dengue Incidence; Low Population Density (LDI-LPD) Clusters [San Jose Subdivision (Fig 2D), Rizal-Mintcor Homes, Intercity Homes), the mean PCI is 11.65, the mean PHI is 19.32, the mean PBI is 13.98 while the mean PPI is 40.78.

Generally, a HI greater than 5% and or a BI greater than 20 or PPI > 1% for any locality is an indication that the locality is dengue receptive for active transmission. The BI and HI are commonly used for determination of risk priority areas for control measures. For epidemiological purposes, the HI is commonly used to estimate relative risk and potential spread of virus through an area once an infected (viremic) person enters an area to potentially infect vector mosquitoes.

Aedes aegypti is the dominant vector for all clusters with mean pupae/positive container of 11.1. *Aedes albopictus* was observed from pupa reared from clusters identified to have low reported dengue incidence and low density such as San Jose Village, Rizal-Mintcor and Intercity Homes. This species was observed in only one cluster with reported high dengue incidence, Mutual Homes. Although a much smaller number of water holding containers was observed in the public spaces of the clusters, the proportion of the containers with pupa is higher (37%, *n*=134).

Social determinants

Local government programs

All City Health Officials interviewed concurred that there was no functional dengue vector control program in Muntinlupa City. What was being implemented was the 4S strategy ('Search and destroy, Say no to indiscriminate fogging, Seek early treatment, and Self-protection) mandated by the central DoH when the Local Government Code assigned the Local Health Offices to LGUs, they were originally under the suppervision of the Central Government through the Department of Health. All dengue-related activities became integrated within larger programs controlled by the Sanitary Inspectors due, in part, to the lack of an allocated dengue control budget and dedicated personnel. Furthermore, because of the heavy workload of the BHWs, some activities such as the Barangay and School Dengue Brigade, were not sustainable and discontinued. Lectures were instead done in different health centers regarding various diseases with dengue as only a sub-topic and generally only emphasized during the rainy season. Some activities such as the clean-up drives and dengue information dissemination campaigns were conducted on a case-to-case basis. Fogging was also conducted during outbreaks, although the periodic preventive fogging that has been promoted by the City Health Office has been overshadowed by the 'political fogging' campaigns by different barangay officials, usually around each election cycle. This was one reason why the majority of residents in FGD findings have had misconceptions about fogging and its usefulness. Another important development that occurred in 2007 was the change in the city administration. The reshuffling of personnel to different positions in the City Health Office was cited by many health officials for the perceived non-continuity of dengue initiatives.

Knowledge, Attitude, and Practice (KAP) about dengue

High dengue incidence barangay (Putatan)

More than half (58 %) of respondents in all clusters have knowledge of dengue. A total of 543 respondents in this barangays were also included for the Knowledge, Attitude, and Practice (KAP) Survey. Almost all of the KAP respondents

Table 1
Vector population measures at private households in different clusters surveyed in Muntinlupa City, 2007.

Cluster	Households (HH)			Containers (*N**)				Total collected	HH with pupa (%)	PCI (%)	PHI (%)	PBI (%)	PPI (%)	Adults emerged
	Total	No. surveyed (%)	Human pop of surveyed HH	Number with water	With larva or pupa or both	With larva	With pupa							
High Dengue Incidence; High Population Density (HDI-HPD)														
Pasong Makipot	132	99 (75)	497	286	9	9	5	219	12	1.75	12.12	5.05	44.06	5
Bagong Sibol	158	100 (63)	462	278	6	6	3	76	7	1.08	7	3	16.45	21
Manggahan	133	99 (74)	499	249	9	9	5	469	11	2.01	11.11	5.05	93.99	90
High Dengue Incidence; Low Population Density (HDI-LPD)														
Lakeview Homes	142	92 (65)	478	160	8	8	4	59	5	2.5	5.43	4.35	12.34	13
Mutual Homes	156	120 (77)	619	156	23	22	14	205	14	8.97	14.17	11.67	33.12	75
AgroHomes/BLISS	171	99 (58)	463	113	7	6	4	21	4	3.54	4.04	2.34	4.53	0
Low Dengue Incidence; High Population Density (LDI-HPD)														
Purok-1	175	107 (61)	542	130	6	6	6	59	5	4.66	4.67	5.61	10.89	30
Purok-4	143	96 (67)	519	155	3	3	2	16	3	1.29	3.13	2.08	3.08	4
Purok-6	148	101 (68)	477	180	2	2	2	29	3	1.11	2.97	1.98	6.08	32
Low Dengue Incidence; Low Population Density (LDI-LPD)														
San Jose Subdivision	182	100 (55)	593	236	36	34	19	387	31	8.05	31	19	65.26	117
Rizal-Mintcor Homes	102	100 (98)	516	69	28	26	17	143	10	24.64	10	17	27.71	43
Intercity Homes	120	118 (98)	616	308	18	17	7	181	17	2.27	16.95	5.93	29.38	73

*N**- total number1. PCI, Pupal Container Index; PHI, Pupal House Index; PBI, Pupal Breteaux Index; PPI, Pupale per Person Index.

Table 2
Vector population measures in public spaces in different clusters surveyed in Muntinlupa City, 2007.

Cluster	Number holding water	Containers			Pupal counts	Pupa/e per container	Adult females			
		With larva or pupa or both (%)	With larva (%)	With pupa, CI (%)			*Ae. aegypti*		*Ae. albopictus*	
							Positive containers (*N*)	No. emerged	Positive containers (*N*)	No. emerged
High Dengue Incidence; High Population Density										
Pasong Makipot	3	2 (67)	2 (67)	2 (67)	30	15	2	99	0	9
Bagong Sibol	0	0 (0)	0 (0)	0 (0)	0	0	0	0	0	0
Manggahan	0	0 (0)	0 (0)	0 (0)	0	0	0	0	0	0
High Dengue Incidence; Low Population Density										
Lakeview Homes	24	5 (21)	5 (21)	1 (4)	2	2	0	0	0	0
Mutual Homes	4	4 (100)	2 (50)	1 (25)	1	1	1	1	0	0
AgroHomes/BLISS	8	8 (100)	8 (100)	5 (63)	57	11	1	0	1	3
Low Dengue Incidence; High Population Density										
Purok-1	0	0 (0)	0 (0)	0 (0)	0	0	0	0	0	0
Purok-4	1	0 (0)	0 (0)	0 (0)	0	0	0	0	0	0
Purok-6	40	5 (13)	3 (8)	4 (10)	62	16	1	0	0	0
Low Dengue Incidence; Low Population Density										
San Jose Subdivision	30	24 (80)	24 (80)	18 (60)	98	5	5	7	3	46
Rizal-Mintcor Homes	12	3 (25)	3 (25)	1 (8)	12	12	0	0	0	0
Intercity Homes	8	8 (100)	8 (100)	4 (50)	150	38	0	0	0	0

Table 3
Frequencies of response to KAP interview, Muntinlupa City, September - November 2007.

	Brgy. Putatan (high incidence barangays)						Brgys. Buli-Cupang (low incidence barangays)					
	HPD Clusters			LPD Clusters			HPD Clusters			LPD Clusters		
	Pasong Makipot 101	Bagong Sibol 100	Manggahan 100	Lakeview Homes 94	Mutual Homes 92	Agro homes 56	Purok 1 98	Purok 4 98	Purok 6 95	San Jose 80	Mintcor Rizal 76	Makipot 88
Knowledge on dengue (K)												
Have knowledge on dengue, *n* (%)	61 (60.4)	57 (57)	53 (53)	52 (55.3)	59 (64.1)	35 (62.5)	73 (74.5)	66 (65.3)	65 (68.4)	60 (74.1)	54 (100)	66 (75)
Sources of information, *n* (%)												
TV	51 (83.6)	45 (78.9)	43 (81.1)	41 (78.8)	54 (91.5)	31 (88.6)	63 (86.3)	63 (95.5)	61 (93.8)	52 (86.7)	46 (85.2)	62 (93.9)
Radio	12 (19.7)	8 (14)	17 (32.1)	9 (17.3)	8 (13.6)	5 (14.3)	5 (6.8)	18 (27.3)	12 (18.5)	11 (18.3)	16 (29.6)	12 (18.2)
Newspaper	12 (19.7)	9 (15.8)	15 (28.3)	17 (32.7)	36 (61)	15 (42.9)	24 (32.9)	27 (40.9)	14 (21.5)	24 (40)	14 (25.9)	30 (45.5)
Health worker	30 (49.2)	15 (26.3)	32 (60.4)	4 (7.7)	1 (1.7)	1 (2.9)	9 (12.3)	13 (19.7)	33 (50.8)	0	4 (7.4)	4 (6.1)
Friends	9 (14.8)	11 (19.3)	2 (3.8)	8 (15.4)	3 (5.1)	1 (2.9)	8 (11)	9 (13.6)	3 (4.6)	6 (10)	1 (1.9)	2 (3)
Community/ neighbor	35 (57.4)	26 (45.6)	14 (26.4)	12 (23.1)	2 (3.4)	1 (2.9)	32 (43.8)	18 (27.3)	13 (20)	8 (13.3)	8 (14.8)	12 (18.2)
Poster	3 (4.9)	4 (7)	0	0	1 (1.7)	1 (2.9)	1 (1.4)	3 (4.5)	1 (1.5)	1 (1.7)	0	0
Hospital	10 (16.4)	10 (17.5)	6 (11.3)	9 (17.3)	12 (20.3)	6 (17.1)	11 (15.1)	8 (12.1)	14 (21.5)	15 (25)	15 (27.8)	14 (21.2)
Others	3 (4.9)	4 (7)	1 (1.9)	5 (9.6)	3 (5.1)	6 (17.1)	1 (1.4)	1 (1.5)	3 (4.6)	4 (6.7)	0	3 (4.5)
Attitude towards dengue prevention (A)												
Participated in training for dengue control, *n* (%)	27 (44.3)	28 (49.1)	28 (52.8)	9 (17.3)	15 (25.4)	8 (22.9)	19 (26)	27 (40.9)	20 (30.8)	17 (28.3)	15 (27.8)	22 (33.3)
Vector-related practices (P)												
Household practices, *n* (%)												
Indoor spraying	62 (61.4)	49 (49)	52 (52)	63 (67)	58 (63)	44 (78.6)	64 (65.3)	67 (66.3)	71 (74.7)	65 (80.2)	60 (78.9)	72 (81.8)
Cleaning garbage	98 (97)	99 (99)	99 (99)	94 (100)	92 (100)	56 (100)	97 (99)	95 (94.1)	93 (97.9)	81 (100)	75 (98.7)	88 (100)
Covering water containers	89 (88.1)	90 (90)	92 (92)	83 (88.3)	89 (96.7)	46 (82.1)	64 (65.3)	65 (64.4)	66 (69.5)	68 (84)	38 (50)	80 (90.9)
Putting medicine in water	19 (18.8)	3 (3)	10 (10)	7 (7.4)	1 (1.1)	1 (1.8)	6 (6.1)	10 (9.9)	9 (9.5)	10 (12.3)	2 (2.6)	8 (9.1)
Putting larvae-eating fish in water	0	0	1 (1)	6 (6.4)	6 (6.5)	3 (5.4)	3 (3.1)	3 (3)	0	6 (7.4)	1 (1.3)	5 (5.7)
Killing with chemicals	56 (55.4)	46 (46)	38 (38)	62 (66)	75 (81.5)	37 (66.1)	65 (66.3)	57 (56.4)	46 (48.4)	64 (79)	52 (68.4)	69 (78.4)
Use of insect repellants	35 (34.7)	40 (40)	44 (44)	44 (46.8)	51 (55.4)	29 (51.8)	59 (60.2)	57 (56.4)	57 (60)	55 (67.9)	52 (68.4)	55 (62.5)
Storing of water	90 (89.1)	90 (90)	91 (91)	64 (68.1)	74 (80.4)	24 (42.9)	46 (46.9)	43 (42.6)	43 (45.3)	58 (71.6)	26 (34.2)	78 (88.6)
Nothing	1 (1)	1 (1)	3 (3)	0	1 (1.1)	0	11 (11.2)	10 (9.9)	0	0	0	0

who said that they have knowledge about dengue acknowledged that disease can be prevented (305/317; 96%). The respondents' knowledge regarding the vector and the disease were obtained mostly from media sources (particularly television and radio) as well as from the City Health Office (CHO) through the brochures and lectures given by the sanitary inspectors and those in the health center. This is also evident in the answers given by the KAP respondents where television ranked highest among the choices with 84% (in both high density and low density clusters), followed by newspapers with 47% (for those in the low density areas) and health workers with 45% (for those in the high density areas).

Residents from the high density clusters reported that 49% of their population were able to learn and participated in any local government training for dengue control. In comparison, only 22% of the respondents from low density areas said that they have learned about or participated in any local government training for dengue control. This low percentage may have been due to the varying attitudes of the members of the community towards government health workers who facilitated these trainings. The BHWs related that they were not received well by the families that were assigned to them, notably by those belonging from the low density clusters, as mentioned in the FGDs. On the other hand, BHWs who were assigned in high density clusters reported that there were residents who had received them positively, especially when they provided free medicine or free checking of blood pressure. However, it was noted that participants usually lacked the initiative and often opted to engage themselves in unrelated social undertakings rather than to participate in the health activities.

In both high density and low density clusters, almost all respondents (99%, *n=543*) have identified that cleaning the garbage is an important intervention to reduce the number of mosquitoes while 90% mentioned covering of water containers as another important intervention among the choices given. More than half (54%, *n*=543) of the respondents participated in the community program to clean the environment, with majority of these claimed that they had eliminated possible breeding places in their respective areas.

The garbage of 396 (69%) cluster respondents from this barangay is collected by the garbage collectors/trucks. However, the manner and frequency of collection varies according to the cluster density wherein 92% of garbage in LPD communities is collected directly from individual households. In HPD communities, only 42% has this mode of garbage disposal and the rest place their wastes in specific dumpsites where it will be collected by a garbage truck.

Fifty-one percent (*n*=543) of respondents from a high dengue incidence barangay obtain water from the deep wells while only 32% have piped water supply.

Unused tires are the identified key containers in public spaces in this study and it was observed to be present in both areas. A fewer number of households (12%,) from the high dengue incidence areas were also observed to practice keeping unused household and garden utensils (*eg*, pails/buckets, basins, etc) indoors and/or turning these containers upside down when not in use, as compared to the low dengue incidence clusters.

Accumulation of rainwater in roof gutters also serve as a potential breeding site of mosquitoes. Majority of households surveyed in the high density areas of this barangay do not have roof gutters due to the nature of house construction. In the low density area, not all roof gutters were inspected due to inaccessibility and non-permission of the household owners. Despite the limited number, most of the roof gutters in this area were in good condition.

Low dengue incidence barangays (Buli/Cupang)

In low dengue incidence barangays, a higher number (72%, *n*=535) of respondents were knowledgeable about dengue. The responses from the FGDs as to the features of the vector from this barangay were similar to the responses from the previously mentioned barangay. Nearly all of the KAP respondents who claimed that they have knowledge about dengue agreed that the disease can be prevented (370/384; 96%). In this area, the media (*eg*, television) as well as supporting materials (leaflets/flyers) and the sanitary inspectors played an important role in providing the knowledge they acquired. Television (90%) is the top knowledge provider identified by the KAP respondents.

Dirty water as a site in which the dengue vector frequently breeds remained the most common misconception, as seen in both the KAP and FGD results in both high dengue incidence and low dengue incidence barangays. All data regarding the knowledge base of the surveyed clusters were shown in Table 3.

During the FGDs conducted with the BHWs from the low dengue incidence barangays, their most common complaint was the difficulty experienced in motivating and obtaining the cooperation of mothers in the community.

Another common problem cited by the BHWs was the communities' inability to sustain their interest over the government programs to control dengue. The BHWs observed that during the start of new programs or activities, the community members displayed interest and would actively participate in the said activities. This enthusiasm however was not endured and the participation of the community slowly dissipated. Hence, in most instances, health programs or activities introduced in the community were not sustained. These responses coincided with the results of the KAP survey, which indicated that only 26% of the surveyed respondents from the low density areas and 33% from the high density areas reported that they had learned or participated in training for dengue control.

Majority of the respondents (78%, *n*=535) cited fogging as the most evident government action/intervention aimed at reducing the number of dengue mosquitoes in their respective communities, which is similar to the high dengue incidence clusters. Checking of water containers by BHW's (42%) was also mentioned by residents. Other government actions that were mentioned during the FGDs in these two barangays included the treatment of canals with larvicides, conduct of information drives, and larvae trapping. Almost all respondents (99%) indicated that health education was the most useful intervention the local government can implement in order to improve dengue control in the city despite their competent knowledge as shown in the survey.

More than half (57%, *n*=535) of the residents in these two adjacent barangays obtained water from the deep well while 20% have piped water supply. Deep wells provide water supply to most households in the low density communities. Community deep wells and water pumps were placed in strategic areas in HPD communities for public water supply.

More than half (55%, n=535) of the residents in these two barangays store water. However, there were more households from the LPD clusters (66%, n=244) that store water compared to the households from HPD clusters (45%, n=291). It was noted that most of the respondents reported replacing stored water almost every day regardless of the size of containers. Except for water used for cooking, failure to cover some of these containers was also observed.

The respondents from this area also perceived proper garbage disposal (99%) and indoor spraying (75%) as the top two interventions that should be done to reduce the number of dengue mosquitoes. A higher number of respondents (72%, n=535) participated in the community program to clean the environment; the same number of respondents claimed that they have eliminated possible mosquito breeding sites.

As to the community efforts observed in the barangay, respondents from FGDs mentioned that backyard burning in the clusters near the Laguna de Bay are conducted while another respondent in the LPD clusters cited that the residents clean their surroundings individually. This reveals that no community effort is being done in this cluster. It was further mentioned that homeowners who did not comply with the said activity were reported to the homeowners' association officers.

Majority (91%, n=535) of the waste materials in these barangays are collected by garbage collector trucks. Garbage was collected from individual households by schedule in LPD areas. In high density areas, residents bring their garbage in a designated site wherein it is picked up by the collectors every morning or evening since streets in the household areas are relatively narrow for larger vehicles.

Several waste materials were also scattered in the communities that can potentially function as mosquito breeding sites once water is collected in these receptacles. These items are consistent with those found in the high dengue incidence clusters. Tires were also noted in the high density areas but are properly stored and kept under shelter. No tires were found in households surveyed in the low density areas. Moreover, more households (27%) in the low dengue incidence areas practice draining garden utensils (27%) than those in the high dengue incidence barangay.

Correlation of housing conditions/green areas and pupal count

Results showed that there is no significant relationship between the housing conditions and the pupal count between the study sites. There is negligible correlation between the percentage of houses with good condition and pupal count (r = 0.08, 95% CI: -0.521-0.622); percentage of houses with satisfactory condition and pupal count (r = -0.15; 95% CI: -0.668-0.462), and percentage of houses with poor condition and pupal count (r = -0.08, 95% CI: -0.628-0.515). Pupal count per cluster is also not affected as the number of houses with only one floor or houses with more than one floor increase in the sentinel site (r = 0.04, 95% CI: -0.550-0.597; r = 0.04, 95% CI: -0.597-0.550, respectively). However it appears that there is weak positive relationship between pupal count and percentage of establishments with purely residential purpose (r = 0.27, 95% CI: -0.363 – 0.729); and a weak negative relationship between pupal count and percentage of establishments with both residential and commercial purposes (r = -0.27, 95% CI: -0.729 – 0.363).

It is also noticeable that a strong positive relationship exists between the percentage of green areas and pupal count at all clusters (*r* = 0.55, 95% CI: -0.034 – 0.855). This may imply that the presence of green areas greatly contributes to the prevalence of dengue vectors in the sentinel site.

Correlation of socio-economic classifications and pupal counts

Results of the Pearson's *r* test revealed no significant relationship between pupal counts and socio-economic classifications in all clusters. There is negligible correlation between the percentage of residents who belong to upper middle economic status and pupal count (*r* = 0.08, 95% CI: -0.521-0.622); percentage of residents who belong to lower middle economic status and pupal count (*r* = -0.05, 95% CI: -0.603-0.543); and percentage of residents who belong to lowest economic status and pupal count (*r* = -0.06, 95% CI: -0.613-0.532). There is also negligible relationship between the percentage of residents who have knowledge on dengue and pupal count (*r* =- 0.16, 95% CI: -0.670-0.459).

Correlation of pupal counts and government programs against dengue

Of interventions conducted by community healthcare workers of government to prevent dengue, five practices yielded a negative correlation which may indicate that they are effective measures to decrease the pupal counts in the area, and thus reduce dengue transmission risk include: At least one healthcare worker visit to the communities a month before the study (*r* = -0.248, 95% CI: -0.720-0.380), Government inspection of water containers (*r* = -0.262, 95% CI: -0.726-0.367), outdoor spraying (fogging) of insecticides in and around households (*r* = -0.323, 95% CI: -0.757-0.308), health education (seminars) regarding dengue prevention (*r* = -0.268, 95% CI: -0.729-0.362), and distribution of lid covers for water containers (*r* = -0.284, 95% CI: -0.737-0.347).

Respondents who indicated they were visited by at least one healthcare worker two to six months before the study yielded a strong positive relationship with a higher pupal count (*r* = 0.29, 95% CI: -0.340-0.741) in contrast with the visit of healthcare worker a month before the study, which yielded negative correlation (*r* = -0.264, 95% CI: -0.728-0.365). This indicates respondents' households (or the community as a whole) would benefit more from more frequent visits from the healthcare worker, probably on a monthly basis at the minimum. Meanwhile, the following government interventions appear to have had no significant effect in reducing vector densities in the study sites: Distribution of support materials to prevent dengue (*r* = 0.11, 95% CI: -0.494-0.644), implementation of fogging in the area (*r* = -0.11, 95% CI: -0.645-0.493), and initiatives to reduce/remove excess vegetation in the area (*r* = -0.10, 95% CI: -0.637-0.503).

Correlation of vector density with ecological and social determinants

An overall analysis using chi-square showed that there is a correlation between pupal density and human population density and number of dengue cases (X^2 0.05 (1) = 3.84) as the pupal counts in areas with low or high human population densities was associated with pupal count in areas with high or low dengue incidence (*p*<0.001; 95% CI: 70.06-75.44).

DISCUSSION

A range of ecological, biological, and social factors can influence dengue transmission and the impact of control and prevention activities (Spiegel *et al*, 2005). Dengue control requires strategies outside the typical disease triangle of vector, host and infectious agent. Guha-Sapir and Schimmer (2005) reviewed recent literature that raised issues on the changing epidemiology of dengue and argued for population-based studies which included human behavioral risk factors and targeted, operational research. In this study, many of these factors were explored to explain how these might affect dengue prevalence at the community level. A significant number of respondents claimed that they are knowledgeable on dengue transmission and disease (65.5%). Various forms of media (particularly television) potentially plays a significant role in relaying knowledge on dengue to the population (with 72% having access to media outlets in high dengue incidence clusters and over 90% in low dengue incidence clusters). However, some studies have concluded that having a good knowledge base on dengue did not translate into better protective practices in the community (Jennings *et al* 1995; Nalongsack *et al*, 2009; Abedi *et al*, 2011) or influence more effective dengue control (Hairi *et al*, 2003). This was also observed in the communities surveyed in this study as Pearson's *r* test indicated that there is a negligible correlation between the knowledge on dengue of the communities surveyed and pupal counts in different clusters (r=-0.156, 95% CI: -0.670-0.459).

This finding is further supported by the presence of used containers or discarded waste materials that can potentially collect water, especially during the rainy season. Moreover, the importance of the BHW role in the community has been downplayed, misunderstood and generally dismissed as not productive. Many respondents believe the prevention of dengue as the government's sole responsibility and not a community enterprise nor a private one. Thus, this indicates that stronger, more persuasive health messaging may be needed, especially with regard to the importance of good physical hygiene practices for dengue prevention and dispelling misconceptions about the disease and its control.

Larval source reduction of aquatic habitats advocated by organized control programs is one key strategy that needs to be re-structured and new competencies developed at the community level for the methodology to significantly contribute to dengue prevention (Focks, 2003; Parks *et al*, 2004). In this study, the presence of key vector production containers was recorded in all clusters, both private and public spaces; however the variation of types were different according to cluster population and past dengue incidence. Stored water was the major source of *Aedes* production and most households surveyed reported storing water due to inadequate supply or intermittent access. Notably, significantly more residents (78%, p< 0.0001) from high dengue incidence areas stored water compared to those in the low dengue incidence clusters (55%), which may have contributed to higher PPI (0.34>0.23, respectively). The common presence of uncovered containers was observed in all clusters.

It is also interesting to note that the Low Dengue Incidence, Low Population Density clusters (LDI-LPD Clusters) have the highest *Stegomyia* indices, even higher than the clusters with High Dengue Incidence and High Population Density (HDI-HPD Clusters), when it should be the LDI-LPD Clusters which are supposed to have the lowest *Stegomyia* indices. This indicates that a potentially useful index of pupal surveillance has yet to be confirmed. As Focks and Chadee (1997) pointed out, results from field studies indicate that there is an inconsistent relationship between indices and virus transmission rates. Moreover, Focks and Chadee's study showed that the traditional *Stegomyia* indices used to document the density of *Ae. aegypti* and predict the threat of dengue transmission (the House, Container, and Breteau indices), were seen to have virtually no correspondence with the actual number of pupae per hectare or per person.

Despite having sufficient awareness on dengue, differences in attitude can also affect the execution of community-based control measures. In Laos PDR, Mayxay *et al* (2013) found that despite adequate knowledge about dengue, the inadequate response in communities increased dengue transmission risk, particularly the negative attitudes and perceptions and general poor acceptance of government barangay public health workers as primary facilitators for dengue control and other health-related efforts . Community acceptance of BHWs conducting health activities varied across all clusters. In low density areas, there was less acceptance and the credibility of BHWs was questioned with regard to providing health information to the community. Conversely, residents of high density areas were found generally more welcoming to their message. Regardless of cluster density, BHWs reported that most participants were unable to sustain their attention on health-related efforts of the government if it would consume their time. Similar behavior was also observed in a study conducted in a different city in the Metro Manila area (Espino *et al*, 2012). It can be inferred from interviews that most respondents in both clusters relied on outdoor space spraying by the local government to control dengue vectors, stating that this was the most visible effort in their respective communities and they did not recognize other activities (*eg*, larval monitoring and control) as important or useful.

At the community level, it is insufficient to draw conclusions without further understanding of the other factors that may affect the general perspective and perceptions of the community in relation to dengue control. One key informant (DoH Program Manager for Dengue and Emerging Diseases) in this study pointed out the DoH National Dengue Prevention and Control Program was responsible for providing the national guidelines, policies and recommendations on dengue control. However, in the decentralized structure, it is the duty of the local governments to implement the control programs and was entirely dependent on the priority and discretion of the local chief executive. It was further explained that in different regions, where there is no specific dengue control program, it was only categorized under the Infectious Diseases control cluster. In each cluster, there was a designated person in charge of programs for certain diseases. Because the situation varies by region, the funds actually allocated for dengue programs may be used for other serious issues and diseases.

Practices related to routine or organized campaigns for cleanliness remains an unfulfilled priority in the barangays. Adequate and safe water supply also remains a chronic problem that necessitates the common practice of storing water for household use. Some localities in Muntinlupa City, particularly those in HPD areas occupy unfavorable environmental conditions that favor vector production. One important aspect which should be given greater attention is the routine inspection and cleaning of all water storage containers as well as the proper disposal of unused or refuse containers which could unintentionally store water and serve as larval habitats for mosquitoes.

Preventing dengue transmission is a multi-faceted endeavor that does not cease on only identifying potential vector habitats and controlling adult vectors. As with other studies having examined the ecological, biological and social factors of dengue control in communities, accurate baseline information should be collected for strategy planning before implementing community-based vector control. Without baseline information, measurement of program performance and progress is difficult and imprecise. However, measuring the more common factors may not be sufficient to assess and understand the impact of dengue control in certain communities as there may be other poorly defined factors that may profoundly influence the effectiveness and sustainability of programs. In Muntinlupa City, the collective effort of the local officials and community members is required to apply an effective focused strategy, such as reducing unwanted containers and thus vector productivity. The inability to mobilize and coordinate local community and public sector resources, and to sustain preventive practices and behavior, serve as serious impediments for imrpoving health in the community. Nevertheless, working together the local government and the community can make use of interventions and practices which are viewed as most effective in reducing dengue vectors in the city. Examples include healthcare worker visits to the communities, the monitoring of water containers, spraying of insecticides in and surrounding households when appropriate, health education regarding dengue, and the distribution of lid covers for water storage containers to protect against mosquitoes. On a broader level, awaiting the application and enforcement of clear legislative orders while addressing the social and community determinants and transmission-enabling practices is a task the National Dengue Control and Prevention Program will continue to grapple with and struggle to overcome.

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