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ORIGINAL RESEARCH

Exploring the relationships between dengue fever knowledge and *Aedes aegypti* breeding in St Catherine Parish, Jamaica: a pilot of enhanced low-cost surveillance

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Purpose: Dengue fever has re-emerged as an increasingly significant global health threat amid diminishing resources pledged for its control in developing nations. Efforts to limit breeding of the dengue vector *Aedes aegypti* are often hampered by lack of community awareness of the disease.

Methods: Sixty-eight households in St Catherine Parish, Jamaica completed a pilot knowledge, attitude, and practice questionnaire as part of a routine container survey for presence of *A. aegypti* larvae.

Results: Infestation levels were high according to traditional *Stegomyia* indices (Breteau index = 325); however, general knowledge of dengue symptoms, *A. aegypti* breeding sites, and preventive practices was low. After examining the links between demographic characteristics, dengue knowledge, and the number of breeding sites per house, higher educational achievement was associated with higher dengue knowledge, but also with more unprotected containers. Overall dengue knowledge was not associated with household container counts. Spatial statistics identified weak clustering of larvae-positive containers, and larvae were concentrated in three key container types.

Conclusion: Residents may only understand the role of certain container types, and significant gaps in general knowledge of the disease may inhibit vector control. This pilot demonstrates the feasibility of conducting inexpensive, rapid assessment of community knowledge and breeding levels for local governments lacking the resources for a more methodologically robust vector assessment strategy.

Keywords: GIS, community knowledge, KAP survey

Introduction

Dengue fever has been recognized in the Americas for over 200 years and has established itself globally as the most important mosquito-borne viral disease. Each of the four dengue serotypes arrived in Jamaica between 1963 and 1981 in separate outbreaks,[1,2] and continues to circulate on the island and throughout the Caribbean.[3] Jamaica's recent outbreak over the winter of 2007–2008 approached case levels of previous major Caribbean outbreaks in 1995 and 1998. In 2007, the Jamaica Ministry of Health (MOH) reported 882 confirmed cases and 4260 suspected cases after only reporting 44 and 71 confirmed cases in 2005 and 2006 respectively. Jamaica remains an epicenter of high transmission risk.

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There are currently no effective vaccines or clinical cures for dengue fever. Vector control remains a key strategy for prevention, and can be accomplished through removal of water-holding containers that serve as *A. aegypti* breeding sites, use of insecticide sprays to kill adult mosquitoes, or via reducing human contact with mosquitoes via use of screens and bed nets or other modifications to daily activity spaces. The Jamaica MOH emphasizes source control in the absence of resources for screening, nets, and insecticides. Eliminating breeding sites is dependent on human knowledge and action, and can be promoted at low cost in resource-constrained communities.

Knowledge, attitude, and practice (KAP) surveys, traditionally used to evaluate the utility of health interventions, have been used in the context of dengue fever vulnerability analysis in Jamaica,[4,5] as well as in Trinidad and Tobago,[6] Vietnam,[7] and Thailand[8] to assess relationships between dengue knowledge and prevention practices. Larvae-focused container surveys are being replaced internationally by more robust pupal-demographic survey tools,[9] but are easy to implement and often yield comparable measures of *Aedes* infestation.[10–12]

This study was designed as a pilot for a broader rapid assessment of dengue knowledge and breeding levels in Jamaica. The goal of the pilot was to evaluate how an inexpensive methodology can support MOH efforts to provide community dengue education and mosquito control in a resource-limited setting, ideally as part of a broader socioecological control program.[13] In the process, three research questions were explored: 1) Do demographic characteristics help explain dengue fever knowledge? 2) Is dengue fever knowledge associated with the number of water-holding containers in a household's yard? and 3) Is there spatial clustering of residents by dengue fever knowledge or number of water-holding containers? Container and KAP survey data are presented from the small community of Tryall Heights in St Catherine Parish and were gathered in August 2007, just days before the arrival of Hurricane Dean, a category 4 storm that caused substantial agricultural damage and ultimately fueled the 2007–2008 dengue outbreak.

Materials and methods

Study site

Tryall Heights is a suburban, low socioeconomic status community situated approximately 3 miles north and on the outskirts of Spanish Town, the capital of St Catherine Parish. The community's population dwindled from 1889 to 1318 between the 1991 and 2001 census counts despite general population growth in Spanish Town and St Catherine.[14] The majority of residents own their homes, which are predominantly cement or concrete structures. The community receives an irregular supply of potable water from the Spanish Town water supply, which necessitates wide scale storage of water for domestic purposes. Solid waste removal sometimes occurs once or twice per month by the municipal garbage collection system, and open dumping and burning is common during gaps in service. The community does have access to public amenities, schools, health centers, and a hospital in Spanish Town. Residents generally seek employment in the nearby metropolitan areas of Kingston, Spanish Town, and Linstead; however, many generate income independently through taxi operation, backyard chicken farming, or other informal means. Tryall Heights was recommended as the study site by St Catherine Health Department officials familiar with water storage patterns and mosquito activity in the community.

Study instruments

Two instruments were used in this cross-sectional study. A KAP survey was used to collect demographic information and data on knowledge of dengue fever and prevention practices. The KAP survey began with categorization of age, gender, education, and occupation, and then continued with nineteen questions probing knowledge of dengue and its transmission, attitudes regarding responsibility for prevention, and household practices relevant to water storage and mosquito reduction. The KAP instrument was adapted for Jamaica from the work of Koenraadt and others in Kamphaeng Phet, Thailand,[8] and was reviewed by a senior public health inspector at the MOH Mosquito Control Section for wording and cultural appropriateness.

A standard container survey used by the Jamaican MOH Mosquito Control Unit was adapted to inventory water-holding and larvae-positive containers by type of container at each household, as well as global positioning system (GPS) location information. The survey form classifies each container as "found" (all identified containers), "wet" (containing any amount of water, with or without larvae), or "larvae-positive" (containing water and larvae). Only the numbers of wet and larvae-positive containers were recorded; dry containers were ignored for expediency. These counts were used to compute crude forms of the traditional *Stegomyia* indices used in Jamaica: the house index (HI, percentage of houses infested of houses inspected), container index (CI, percentage of larvae-positive containers of all wet containers), and Breteau index (BI, rate of larvae-positive containers per 100 houses inspected). Geographic coordinates were recorded in front yards using handheld GPS receivers, and household locations were georectified in a geographic information system (GIS) using high resolution IKONOS satellite imagery.

Both instruments and an informed consent form were approved with the study protocol by the University of the West Indies (UWI)/University Hospital of the West Indies Ethics Committee and the Institutional Review Board at San Diego State University. Administration of both the KAP and container surveys required about 10–20 minutes per household, depending on the number of containers present.

Sampling and data collection

Three survey teams were dispatched in Tryall Heights over two consecutive days. Surveying was performed at different times of the day to minimize household availability bias. Each team of 4–6 individuals was led by one or two Jamaican MOH officers, and was comprised of at least one UWI faculty member or public health graduate student (native Jamaican), and 2–3 visiting American public health graduate students. The MOH officer initiated contact at each household, and Jamaican team members sought informed consent with the head of household. The head of household was defined as the adult, age 18 or older, who was responsible for general upkeep around the premises and is familiar with water storage needs. If this person was unavailable, the team attempted to interview another adult resident familiar with the household's water use.

Houses were visited in one contiguous convenience sample with the intention of visiting as many of the approximately 300 households in Tryall Heights as possible. One revisit was attempted if a resident was not initially home, although general homogeneity of informal occupations across the community probably minimized this availability bias. Survey activities were ultimately cut short due to the approach of Hurricane Dean. A total of 91 households were visited, and complete container and KAP survey information was obtained for 68 households; the balance were excluded because no adults were home, or due to missing data.

Measures

The sociodemographic characteristics sex, age, occupation, and education were used as categorical measures for ease of interpretation and to smooth the effect of potential outliers. Age was stratified as 18–29, 30–49, and 50 or more years, while reported occupations were classified according to the subject's tendency to work away from the home during the day (non-home-based) or remaining home as a housewife, retiree, or due to unemployment (home-based). Education was stratified by the completion of at least the standard course of primary and secondary school (11 years or more) or not (10 or fewer years).

A participant's dengue knowledge score was computed as the sum of correct responses to three unprompted questions that captured awareness of dengue fever. Subjects received one point for each correctly recalled symptom of dengue fever, breeding site of *A. aegypti*, and preventive action. Every participant accumulated a score ranging from zero (no valid responses given) to a hypothetical 22 if all symptoms, breeding sites, and preventive practices on the KAP survey were named.

The number and type of wet and larvae-positive containers were recorded at each household. Dry containers, which also represent potential breeding sites, were ignored. Particular attention was given to definition of container types for proper analysis of the most productive *A. aegypti* breeding containers.

Data analysis

Wilcoxon rank-sum tests were used to assess overall differences in knowledge score across categories of each demographic measure. Multivariate negative binomial regression was performed to assess associations between demographic characteristics and the dengue knowledge score. Negative binomial regression was also used to model the knowledge score against household container counts. Numbers of immature mosquitoes per house are known to be skewed, and are often well accommodated by the negative binomial distribution.[15] Potential confounding was assessed by using a backwards elimination method to compare regression coefficients and rate ratios between models and eliminate multicolinearity; this and all regression analyses were performed using SAS® 9.1 (SAS Institute Inc, Cary, NC). Three spatial statistical methods measuring the degree of clustering or dispersion of the container counts were applied: Moran's I, the Getis-Ord G_i^*, and Ripley's K-function. Moran's I and G_i^* were tested over incremental distances using the ROOKCASE add-in for Microsoft Excel.[16] Ripley's K-function was computed using ArcGIS 9.2 (ESRI, Redlands, CA).

Results

Community characteristics

Table 1 shows demographic characteristics and knowledge scores for the 68 households. Age ranged from 18 to 77, with median 40.5 years, but most respondents tended to be

Table 1 Demographic characteristics and dengue knowledge score of participants derived from the knowledge, attitude, and practice (KAP) survey in Tryall Heights, Jamaica, with community-level *Stegomyia* indices

Characteristic	Participants (*n*)	Percentage (%)	*P*-value[a]
Sex (*n* = 65)			0.383
Female	42	64.6	
Male	23	35.4	
Age (years) (*n* = 62)			0.940
18–29	21	33.9	
30–49	15	24.2	
50–77	26	41.9	
Occupation (*n* = 64)			0.610
Housewife, retired, unemployed	34	53.1	
Other	30	46.9	
Education (*n* = 65)			0.073
Less than secondary	29	44.6	
At least secondary	36	55.4	
Dengue knowledge score[b] (*n* = 68)			–
0 correct responses	19	27.9	
1	16	23.5	
2	11	16.2	
3	6	8.8	
4	9	13.2	
5	2	2.9	
6	0	0	
7	3	4.4	
8	2	2.9	
House index		77.9	
Container index		46.3	
Breteau index (rate per 100 houses)		325.0	

Notes: [a]*P*-values from 2-sided Wilcoxon rank sum test of overall differences in knowledge score across each characteristic; [b]outcome of interest.

Table 2 Dengue symptoms, transmission mechanisms, breeding sites, and preventive practices named by 66 participants familiar with dengue fever during the knowledge, attitude, and practice (KAP) survey

Response	Participants (*n*)	Percentage (%)
Symptom		
Fever	17	25.8
Headache	4	6.1
Rash	3	4.5
Muscular pain	3	4.5
Nausea/vomiting	1	1.5
Bleeding	0	0
Shock	0	0
Do not know	44	66.7
Transmission		
Mosquitoes	46	69.7
Aedes (or striped mosquito)	4	6.1
Daytime biting	1	1.5
Do not know	17	25.8
Breeding sites		
Water drums	30	45.5
Tires	6	9.1
Animal drinking containers	6	9.1
Flower pots/vases	5	7.6
House drains	4	6.1
Garbage	3	4.5
Do not know	6	9.1
Preventive practices		
Covering containers	21	31.8
Changing stored water	9	13.6
Disposal of garbage	9	13.6
Repellent	6	9.1
Spraying	5	7.6
Mosquito coil	5	7.6
Mosquito nets	1	1.5
Fish in stored water	1	1.5
Adding abate to stored water	0	0
Do not know	19	28.8

much older or younger, probably due to sampling during business hours. Respondents were also more likely to be female (65%), with 31% of females reporting their occupation as "housewife". The majority of respondents (55.4%) had completed the standard 11 years of primary and secondary education. Of those who did not complete their secondary education, two reported no education, while the rest had between 4 and 10 years.

The dengue knowledge score ranged between 0 and 8 correct responses. Scores were generally low, with a median score of 1 response. Almost 28% of respondents were categorized as having no dengue knowledge after failing to name any dengue symptom, breeding site of *A. aegypti*, or preventive measure. Table 2 summarizes the specific responses during the KAP survey. While a majority of respondents could identify "mosquitoes" as the mode of transmission, subsequent knowledge was low. Most respondents (70.6%) could not name one symptom despite reference to "dengue fever" in preceding questions, and many could not name a breeding site or preventive practice (41.2% each). The most common symptom named was "fever" (25.8%), while "water drums" (45.5%) was the most-cited key breeding site, and "covering containers" (31.8%) was the most commonly named preventive practice.

Demographics and dengue knowledge

Overall differences in the dengue knowledge score across categories of the four demographic measures were assessed using Wilcoxon rank-sum tests (Table 1). Only education ($P = 0.073$) approached statistical significance; sex, age, and occupation did not demonstrate significant differences in knowledge score by category. The association between education and knowledge score was positive, as those completing secondary education were associated with higher scores.

Table 3 shows the results of multivariate negative binomial regression analysis assessing the association of all four demographic characteristics taken together with the dengue knowledge score. Education was significant (rate ratio 0.540, 95% confidence interval 0.313–0.931, $P = 0.027$), while controlling for sex, age, and occupation, meaning that the rate of higher dengue knowledge was about half as high for participants who did not complete secondary education. None of the covariates exhibited confounding characteristics.

Dengue knowledge and container counts

The distribution of households by number of wet and larvae-positive containers is presented in Table 4, while Table 5 contains the breakdown of wet and positive containers by type. Overall, 477 wet containers were inspected, and 221 (46.3%) were larvae-positive. The mean household had 7.0 wet containers of any variety, of which on average 3.3 were larvae-positive. The 55-gallon storage drums were the most common container type (202 wet, 88 with larvae), and households averaged 3.0 wet drums of which 1.3 were larvae-positive. Abandoned tires were most likely to contain larvae at 84.6% positive (39 wet, 33 with larvae). Storage drums, tires, and medium-size plastic containers (126 wet, 44 with larvae) accounted for 76.9% of all wet containers, and 74.7% of all larvae-positive containers. Three *Stegomyia* indices were calculated for the community: the house index (percentage houses infested) was 77.9%; the container index (percentage larvae-positive containers) was 46.3%; and the Breteau index (rate of larvae-positive containers per 100 houses) was 325.

Table 3 Multivariable negative binomial regression model of demographic characteristics associated with knowledge score among Tryall Heights residents ($n = 62$)

Variable	Rate ratio	95% CI
Education		
Less than secondary	0.540[b]	0.313–0.931
At least secondary[a]		
Sex		
Male	0.931	0.525–1.650
Female[a]		
Age		
18–29	0.754	0.406–1.400
30–49	0.748	0.386–1.448
50–77[a]		
Occupation		
Not home-based	1.018	0.592–1.751
Housewife, retired, unemployed[a]		

Notes: [a]Referent category; [b]$P < 0.05$.
Abbreviation: CI, confidence interval.

Table 4 Distribution of households (HHs) by wet and larvae-positive containers

Container count	All wet containers	All larvae-positive containers	All wet drums	All larvae-positive drums
	HHs (%)	HHs (%)	HHs (%)	HHs (%)
0	2 (2.9)	15 (22.1)	11 (16.2)	28 (41.2)
1	5 (7.4)	16 (23.5)	10 (14.7)	18 (26.5)
2	8 (11.8)	12 (17.6)	16 (23.5)	10 (14.7)
3	9 (13.2)	4 (5.9)	8 (11.8)	5 (7.4)
4	10 (14.7)	7 (10.3)	8 (11.8)	4 (5.9)
5	4 (5.9)	3 (4.4)	4 (5.9)	
6	4 (5.9)	1 (1.5)	5 (7.4)	2 (2.9)
7	3 (4.4)	2 (2.9)	1 (1.5)	1 (1.5)
8	5 (7.4)	1 (1.5)	1 (1.5)	
9	1 (1.5)		2 (2.9)	
10	4 (5.9)	1 (1.5)	1 (1.5)	
11	1 (1.5)	2 (2.9)	1 (1.5)	
12	2 (2.9)			
13	1 (1.5)	3 (4.4)		
14	1 (1.5)			
15	3 (4.4)			
16	1 (1.5)			
17				
18				
19	1 (1.5)			
20	1 (1.5)			
…				
27		1 (1.5)		
…				
34	1 (1.5)			
…				
39	1 (1.5)			
Total	68 (100)	68 (100)	68 (100)	68 (100)

The knowledge score was initially modeled separately against the counts of all wet containers and all larvae-positive containers in negative binomial regression. Two additional models were created for the subcounts of wet storage drums, and larvae-positive storage drums, as the 55-gallon storage drum was by far the most prevalent type of container. Table 6 shows the bivariate negative binomial regression models for each of the four container counts of interest; none displayed any significant associations with the knowledge score. The three components of the knowledge score, subscores for the number of correct symptoms, *Aedes* breeding sites, and prevention measures identified, were also individually modeled against each of the four container counts (Table 6, bivariate models). The symptom subscore was weakly associated with all larvae-positive containers ($P = 0.042$), and the prevention subscore approached significance for all larvae-positive containers. For the breeding site subscore, an additional 17 participants were excluded

Table 5 Distribution of wet and larvae-positive containers by type

Container type	Wet (% of total)	Larvae-positive (% of total)	Container index (% positive)
Storage drums	202 (42.3)	88 (39.8)	43.6
Plastic containers	126 (26.4)	44 (19.9)	34.9
Tires	39 (8.2)	33 (14.9)	84.6
Small tins/cans	20 (4.2)	14 (6.3)	70.0
Paint cans/larger tins	15 (3.1)	7 (3.2)	46.7
Water tanks	15 (3.1)	1 (0.5)	6.7
Pet water dish	14 (2.9)	5 (2.3)	35.7
Plant cuttings	14 (2.9)	5 (2.3)	35.7
Vases	8 (1.7)	6 (2.7)	75.0
Plant saucers	4 (0.8)	3 (1.4)	75.0
Bottles, glasses, jars	4 (0.8)	2 (0.9)	50.0
Watered plants	2 (0.4)	2 (0.9)	100.0
Total	477 (100)	221 (100)	46.3

from analysis (n = 51), as only respondents who correctly identified mosquitoes as the mechanism of dengue transmission were asked if they were aware of mosquito breeding sites. Surprisingly, the subscore for breeding sites was significantly, but negatively, associated with three of the four container counts: all wet containers (P = 0.014), all larvae-positive containers (P = 0.017), and all wet drums (P = 0.035). Respondents who named more correct *Aedes* breeding sites tended to have more unprotected containers in their yards.

Finally, the knowledge subscores for symptoms, breeding sites, and prevention were included in a multivariate model along with the four demographic characteristics for each of the four container measures. Sex and occupation exhibited no confounding characteristics and were dropped from the models, leaving the three subscores, education (completion of secondary education), and age (Table 6). Contrary to expectations, residents with less than a secondary education were associated with having fewer wet and larvae-positive containers (for all types and for drums) in their yard. The knowledge subscores and age were generally not associated with the four container measures, with the exception of the prevention subscore being negatively associated with all larvae-positive containers (P = 0.025). Residents who named more prevention methods generally had fewer larvae-positive containers (all types) in their yard.

Spatial patterns of knowledge and containers

Kernel density surfaces of the knowledge score and container counts were generated using ArcGIS and offered an initial qualitative visualization of the potential for spatial clustering or dispersion. Figure 1 shows the Moran's I statistic plotted by distance for both the knowledge score and all four container measures. No significant autocorrelation was present at low critical distances that could potentially be influenced by *A. aegypti* (less than 100 meters), and the observed clustering of both wet and larvae-positive storage drums between 100 and 175 meters disappeared at greater distances.

Ripley's K-function was computed for the knowledge score and container measures as a second global measure of spatial autocorrelation at multiple distances. The results of this test, which compares the actual distribution of a phenomenon to a series of spatially random permutations of the same phenomenon, indicated no significant spatial trends at low distances and marginal trends at higher distances (data not shown).

Table 6 Bivariate negative binomial regression models for the relationships between the dengue knowledge score and its component subscores with container counts, and multivariate model for the relationship between select characteristics with container counts (rate ratios and 95% confidence intervals presented)

Predictor	Dependent measure (total count)			
	Wet containers	Larvae-positive containers	Wet drums	Larvae-positive drums
Bivariate models				
Knowledge score	1.03 (0.95–1.13)	1.06 (0.95–1.19)	1.03 (0.95–1.14)	0.95 (0.83–1.10)
Symptom subscore	1.20 (0.94–1.53)	1.40[c] (1.01–1.94)	1.06 (0.81–1.38)	0.90 (0.60–1.34)
Breeding subscore	1.24[c] (1.05–1.47)	1.34[c] (1.05–1.70)	1.26[c] (1.02–1.55)	1.11 (0.80–1.54)
Prevention subscore	0.91 (0.72–1.15)	0.72[d] (0.50–1.05)	1.05 (0.83–1.33)	0.88 (0.62–1.26)
Multivariate model				
Age 18–29[a]	0.84 (0.51–1.38)	0.74 (0.37–1.47)	0.74 (0.42–1.31)	0.90 (0.39–2.05)
Age 30–49[a]	0.99 (0.55–1.80)	0.51 (0.22–1.18)	1.04 (0.52–2.04)	0.57 (0.19–1.71)
Less than secondary education[b]	0.58[c] (0.35–0.96)	0.39[c] (0.19–0.80)	0.45[e] (0.25–0.82)	0.30[c] (0.12–0.78)
Symptom subscore	1.23 (0.89–1.70)	1.39 (0.92–2.12)	0.95 (0.66–1.38)	1.05 (0.60–1.84)
Breeding subscore	1.16 (0.91–1.46)	1.20 (0.89–1.61)	1.25 (0.95–1.63)	1.10 (0.74–1.65)
Prevention subscore	0.75[d] (0.54–1.05)	0.59[c] (0.37–0.93)	0.94 (0.65–1.37)	0.87 (0.49–1.52)

Notes: [a]Referent category is Age 50–77; [b]referent category is At Least Secondary Education; [c]$P < 0.05$; [d]$P < 0.10$; [e]$P < 0.01$.

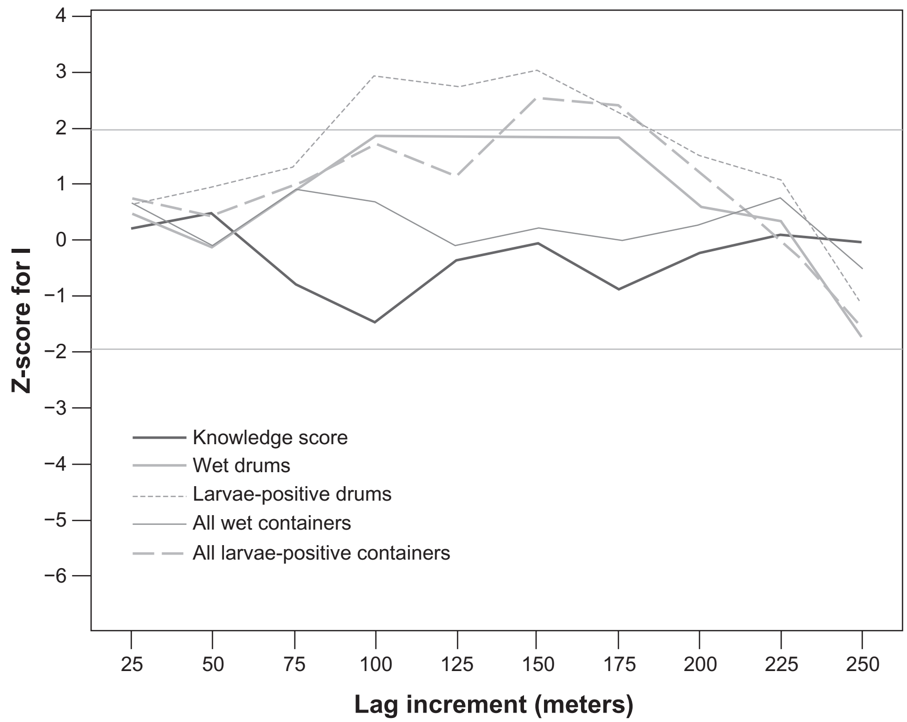

Figure 1 *Z*-scores for Moran's *I* plotted for knowledge score and container counts by distance lag. *Z*-score trajectories stabilizing beyond the 1.96 to −1.96 range would be considered statistically significant at $\alpha = 0.05$.

The Getis-Ord G_i^* was calculated to examine potential local clusters of high and low counts for the four container measures. Computed using a critical distance of $d = 50$ meters, the statistic suggested a small potential "hot spot", or cluster of high total wet and larvae-positive container counts in the northwest, and a possible "cold spot", or cluster of low wet drum counts in the center of the surveyed area. Figure 2 shows the mapped G_i^* values draped over kernel density surfaces also computed using a 50 meter window.

Discussion

Tryall Heights as a community demonstrated very little awareness about dengue fever while also exhibiting high levels of *A. aegypti* infestation as measured by a Breteau index of 325. The levels of dengue knowledge observed in Tryall Heights are slightly lower than previous KAP findings in Jamaica,[4,5] Thailand,[8] Brazil,[17] and Trinidad and Tobago,[6] though national dengue campaigns differ by country. Residents were almost universally aware of dengue fever, and most were aware of the mosquito's role in transmission. Knowledge of symptoms and suitable breeding habitat for *A. aegypti* was considerably lower. There was modest knowledge of prevention practices, but no participants recalled the larvicide Abate as a strategy, despite it being readily available from MOH officers. Jamaica experienced an imported *Plasmodium falciparum* malaria outbreak beginning in late 2006 (nearly 50 years after eradicating the endemic disease) that prompted a national awareness campaign to urge people to protect themselves against mosquitoes. Protective measures for malaria and dengue share some common recommendations (spraying, bed nets, covering skin, screens on windows), but residents of Tryall Heights did not demonstrate any greater awareness of prevention than of dengue symptoms and *Aedes* breeding habits.

From the four demographic factors examined, only secondary education was associated with higher dengue knowledge. Previous work using a similar KAP instrument in Thailand[8] demonstrated associations between sex, age, and education. The lack of associations with measures other than education may be due to the low levels of knowledge in general, which make it more difficult to vet small differences in a small sample. This low knowledge may be due to inexperience with dengue, a phenomenon observed in Puerto Rico[18] and especially common for diseases with infrequent outbreaks. The inclusion of nonhead of household females may also dilute the association with knowledge, since awareness of dengue and its control may not be a priority for these women. The absence of an association between age and knowledge might be due to the categorization of age, whereas a larger sample may have demonstrated

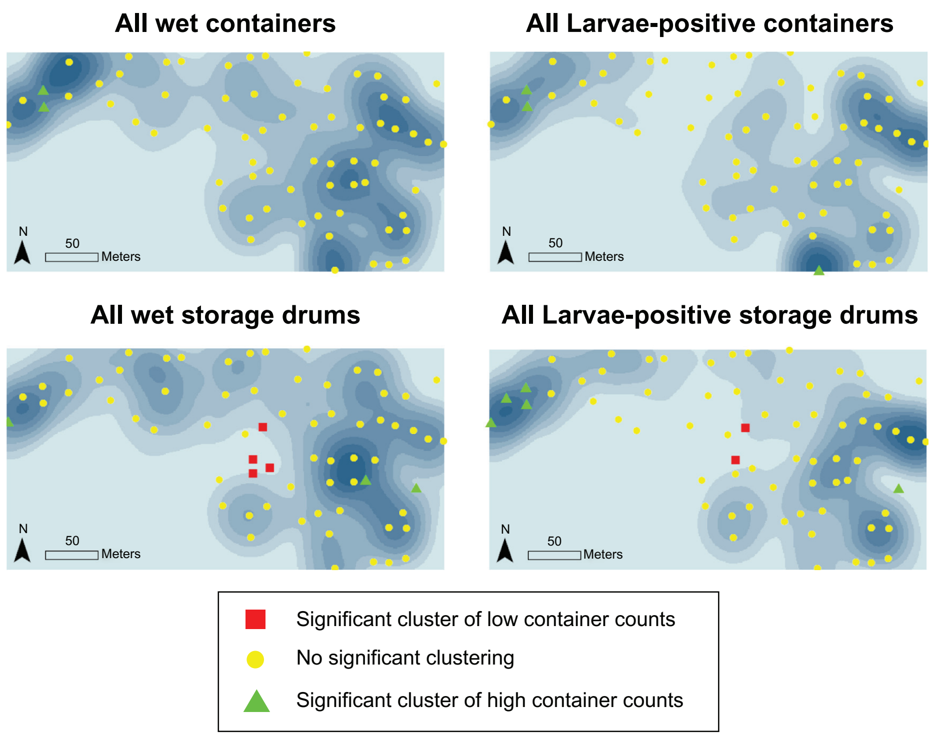

Figure 2 Visualization of the Getis-Ord G_i^* computed using a critical distance $d = 50$ m at $\alpha = 0.05$ to examine potential clusters of high and low counts of four container measures. Results are displayed over kernel density surfaces (darker tones represent higher container density), generated using a 50 m kernel ($n = 68$ houses).

a relationship. The association with education does signal that school-based instruction on dengue control may reach a larger percentage of residents in rural communities like Tryall Heights if offered at any early age.

The container survey resulted in very high infestation levels as measured by a Breteau index of 325, an average of over three larvae-positive containers per house. This high degree of breeding was concentrated in three key container types (drums, tires, and plastic containers), which accounted for 74.7% of larvae-infested containers, consistent with previous breeding habitat surveys for *A. aegypti* in Jamaica[19] and elsewhere.[10,20–24] The existence of key containers reinforces the potential impact of container-targeted vector control, and protection of these containers should serve as a strategic centerpiece of a vector control program.[25]

Knowledge of dengue fever demonstrated no association with the number of wet and larvae-positive containers found outside a home, a finding consistent with several studies.[6,8,17] Knowledge of symptoms and preventive practices were generally not associated with container counts in bivariate analysis, while knowledge of breeding sites was strongly associated with more unprotected containers. Similar patterns were demonstrated through multivariate associations with container counts in Thailand, and the authors suggest that perhaps residents became more familiar with mosquito breeding sites that are common on their premises.[8] However, in this study the individual effects of the knowledge components virtually disappeared in multivariate analysis, and the completion of a secondary education emerged as the strongest predictor of the container counts. The finding was counterintuitive, as residents who did not complete their secondary education tended to have fewer wet and larvae-positive containers and drums.

The unexpected association between education and containers probably does not reflect differences in socioeconomic status, since the community is fairly homogenous and poverty usually increases water storage needs and results in less-clean households. Educational achievement has attained gender-equality in Jamaica, although women now demonstrate higher literacy among youth (15–24 years) and are more likely to be enrolled in secondary school.[26] It is also possible that educated residents reporting any components of dengue knowledge continue to support container productivity on their premises via improper implementation of preventive measures. However the survey data support another explanation: storage drums, which were the most prevalent container type, were also the most-cited breeding site (45.5%) during the KAP survey, with no other sites coming close. While residents have some awareness of *Aedes* as container-breeders particularly in storage drums, they remain unaware of other productive containers in their community, and this inattention may have produced a spurious counterintuitive finding. Residents may indeed only be aware that mosquitoes breed in drums because drums are ubiquitous for water storage.

The three spatial statistics applied in this study are standard tools available in many GIS and statistical packages. The measures did not detect any strong spatial patterns in the overall distribution of knowledge levels or containers; although the G_i^* measure did identify small clusters of high and low larvae-positive container counts, demonstrating potential dependencies on immediate neighbors for vector reduction. The results at neighbor distances of 50 m or less were of primary interest, as recent work elsewhere has demonstrated very short flight ranges for *A. aegypti*. In Puerto Rico, *A. aegypti* rarely left the vicinity of the house they inhabited, and travel distances waned when housing was denser.[27,28] Spatial clustering of containers has been observed at distances of 10 m or less in communities with very dense living quarters, and is generally variable by both space and time,[29–31] with density of breeding sites thought to be a critical predictor for container productivity.[32] In Tryall Heights, where houses were spaced 10–50 m apart, it is unlikely that spatial patterns detected at neighbor distances beyond 50 m would be attributable to *Aedes*-driven processes. Given a sample of 68 houses, 2–3 clusters are expected just by chance at a significance level of $\alpha = 0.05$. While the results are not overwhelmingly significant, the methodology demonstrates how cluster analysis and data visualization enhance the utility of container surveys, particularly across multiple neighborhoods and seasons, and ultimately help MOH plan and target community-based interventions.

Some additional limiting factors affected the scope of this study. Survey activities were cut short due to the approach of Hurricane Dean, and the small sample size limits the generalization of findings. This study did not use random sampling, although many dengue-related assessments have employed continuous or sequential sampling methods to understand *A. aegypti* breeding.[12,22,29] In Tryall Heights, households were sampled in a continuous cluster in order to test spatial relationships of container counts at close distances. At a larger geographic scale (eg, multiple communities or Parish-wide), a multistep cluster sample would be an improvement, although simpler quadrat- and transect-sampling may suffice.[10] Random sampling would enable investigation of a broader geographic area using a much smaller sample size from each community.[33] This would also likely improve the variance of demographic characteristics and enable capture of measures that better reflect sociodemographic nuances, although incorporating highly detailed KAP questions requires a tradeoff with speed in the field. Given these caveats, the study shows the potential for larger-scale demographic modeling of dengue knowledge across multiple communities.

There are shortcomings to the traditional container survey methodology, and subsequent *Stegomyia* indices, that make them inadequate for determining transmission risk, and only somewhat useful for assessing control programs.[9,34,35] Containers are characterized as larvae-positive or -negative without recording the productivity of individual containers, and larval counts have been shown to be a poor predictor of adult mosquito populations relative to pupal assessments.[35] Despite these weaknesses, the results from more sophisticated pupal-demographic surveys in Latin America often correlate with the larval indices,[10–12] and the traditional container survey remains a common measurement tool in Jamaica. Pupal-demographic surveys represent a methodological improvement for vector control, although utility as a rapid assessment tool would be dependent upon numbers and availability of trained MOH staff.

Some container types were not inspected due to time constraints and the lack of protective equipment (eg, rooftop tanks), or for safety and logistical reasons (eg, indoor containers), thus narrowing our focus to the impact of outdoor environmental sanitation. This increased survey efficiency and ensured cooperation with Tryall residents; community objections have been an impediment to proper inspections elsewhere.[22,36] The lack of any strong clustering of containers may be attributable to omitted container data, as the effects of indoor water storage on mosquito breeding in St Catherine Parish are not as well understood.

Improving community knowledge of dengue fever and *A. aegypti* breeding habits is an important step toward effective vector source reduction,[37] and can be achieved through community involvement in the control program[7,38] despite difficulties measuring the contributions of human behavior.[39,40] This pilot utilizes standard tools that are inexpensive, easy to implement, and scalable for measuring community knowledge and mosquito breeding levels in larger geographical areas. In the absence of resources for a more methodologically robust vector assessment strategy, the use of simple surveys and GIS software can help MOH identify communities that are most deficient in dengue fever awareness and environmental sanitation practices, thereby building on recent work in Jamaica.[19] More research is needed to understand sociodemographic and geographic disparities in knowledge and container protection in Jamaica, so that MOH can target community education and mosquito control efforts toward regions with the most productive containers as part of a comprehensive socioecological control program.[13]

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Disclosure

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