Comparing the effectiveness of adulticide application interventions on mitigating local transmission of dengue virus

Supplementary Material

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Temperature-dependent parameters

Temperature-dependent development and mortality rates

Using data collected in previous studies (Farnesi et al., 2009; Yang et al., 2009; Yang et al., 2011), we performed a polynomial regression to assess the effect of temperature on the development rates for eggs, larvae, and pupae and the inverse of the gonotrophic cycle for the adult mosquitoes. As *Aedes aegypti* development/oviposition and mortality rates demonstrated parabolic trends in these studies, we fit the regressions with even degrees of the polynomial until we observed the best fit for the data. Then, we used the regression coefficients to predict the development/oviposition rates for temperatures between the minimum and maximum temperatures recorded in each study for each life stage. We repeated this method to assess the effect of temperature on the mortality rates for all life stages of *Ae. aegypti*. The best-fitting polynomials are shown in Fig. S1 and Table S1.

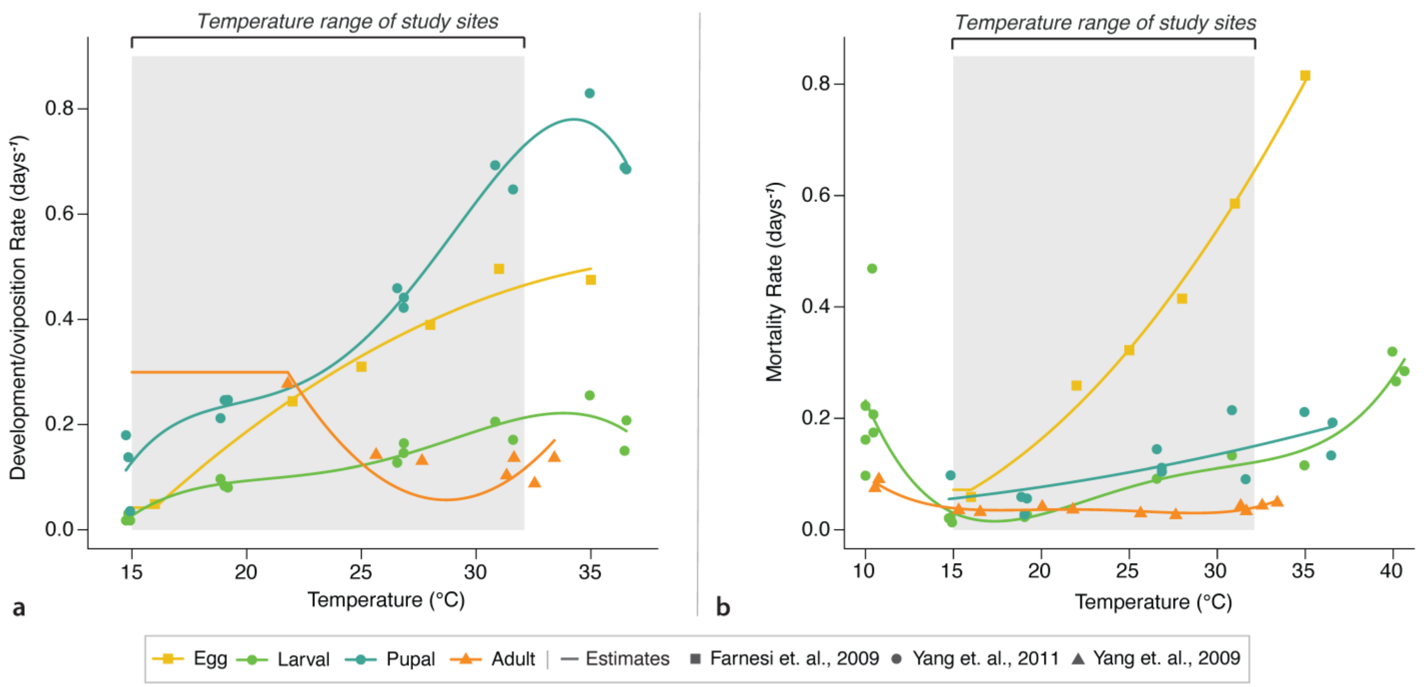

Figure S1. Temperature-dependent rates for *Aedes aegypti* during different mosquito life stages. a. Development/oviposition rates estimated during the egg, larval, pupal, and adult life stages. Symbols represent data obtained from previous literature (Farnesi et al., 2009; Yang et al., 2009; Yang et al., 2011), and lines represent the development/oviposition rates estimated from the polynomial regression. The shaded area represents the temperature range in the two study sites; **b.** Mortality rates estimated during the egg, larval, pupal, and adult life stages. Symbols represent data obtained from previous literature (Farnesi et al., 2009; Yang et al., 2009; Yang et al., 2011), and lines represent the development/oviposition rates estimated from the polynomial regression. The shaded area represents the temperature range in the two study sites.

Table S1. Polynomial equations for estimating temperature-dependent development and mortality rates for the life stages of *Aedes aegypti* from previous literature.

Symbol	Description	Value	Data from ref.
$\boldsymbol{d_E}$	Egg development rate (days^{-1})	$\begin{cases} -0.79 + 0.065T - 0.0008T^2, \text{if } 16.0°C \le T \le 32.1 \\ 0.04, \text{if } 16.0°C > T > 32.1 \end{cases}$	(Farnesi et al., 2009)
$\boldsymbol{d_L}$	Larva development rate (days^{-1})	$-3.3 + 0.6T - 3.5 \cdot 10^{-2}T^2 + 9.7 \cdot 10^{-4}T^3 - 9.7 \cdot 10^{-6}T^4, \text{if } 15.0°C \le T \le 32.1$	(Yang et al., 2011)
$\boldsymbol{d_P}$	Pupa development rate (days^{-1})	$-8.2 + 1.5T - 9.7 \cdot 10^{-2}T^2 + 2.8 \cdot 10^{-3}T^3 - 2.8 \cdot 10^{-5}T^4, \text{if } 15.0°C \le T \le 32.1$	(Yang et al., 2011)
$\boldsymbol{d_A}$	Inverse of the gonotrophic cycle (days^{-1})	$\begin{cases} 4.2 - 0.3T + 0.005T^2, \text{if } 21.8°C \le T \le 32.1 \\ 0.30, \text{if } 21.8°C > T > 32.1 \end{cases}$	(Yang et al., 2009)
$\boldsymbol{m_E}$	Egg mortality rate (days^{-1})	$\begin{cases} 0.04 - 0.02T + 0.001T^2, \text{if } 16.0°C \le T \le 32.1 \\ 0.07, \text{if } 16.0°C > T > 32.1 \end{cases}$	(Farnesi et al., 2009)
$\boldsymbol{m_L}$	Larva mortality rate (days^{-1})	$2.2 - 3.7T + 2.2 \cdot 10^{-2}T^2 - 5.7 \cdot 10^{-4}T^3 + 5.4 \cdot 10^{-6}T^4, \text{if } 15.0°C \le T \le 32.1$	(Yang et al., 2011)
$\boldsymbol{m_P}$	Pupa mortality rate (days^{-1})	$0.03 - 0.0003T + 0.0001T^2, \text{ if } 15.0°C \le T \le 32.1$	(Yang et al., 2011)
$\boldsymbol{m_A}$	Adult mortality rate (days^{-1})	$4 \cdot (8.6 - 1.5T + 1.1 \cdot 10^{-2}T^2 - 3.2 \cdot 10^{-4}T^3 + 3.5 \cdot 10^{-6}T^4), \text{if } 15.0°C \le T \le 32.1$	(Yang et al., 2009)

Model calibration

The loglikelihood (LL) of observing the weekly *Ae. aegypti* abundance collected in each study location given the number of *Ae. aegypti* estimated by the dengue transmission model was defined as follows:

$$LL = \sum_{t \in [\text{season}]} \log\big(NB(N_t, M_t, \sigma)\big)$$

Where:

- N_t refers to the number of *Ae. aegypti* collected on week t
- season for Miami-Dade County, FL, was defined as the period form from January 1, 2021, to December 31, 2021; the season for Brownsville, TX, was defined as the period from April 9, 2018, to November 4, 2018;
- M_t is number of *Ae. aegypti* estimated by the transmission model on week t;
- σ is the over-dispersion of the negative binomial distribution;
- $NB(n, m, \sigma)$ is the probability of observing n from a negative binomial distribution of mean m, and over-dispersion σ.

We used Metropolis-Hastings sampling to explore LL, and estimate the joint posterior distribution of 6 model parameters in Miami-Dade County (and 5 model parameters in Brownsville): the carrying capacity (K_E) for 4 time periods for Miami-Dade County (3 time periods for Brownsville), the initial number of eggs, and the over-dispersion parameter of the negative binomial. Chains consisted of 1 million iterations. We assessed convergence by visual inspection of the trace plots for multiple initial values for each parameter (Fig. S2 and S3). The estimated posterior distributions of model parameters are shown in Fig. S4 and S5.

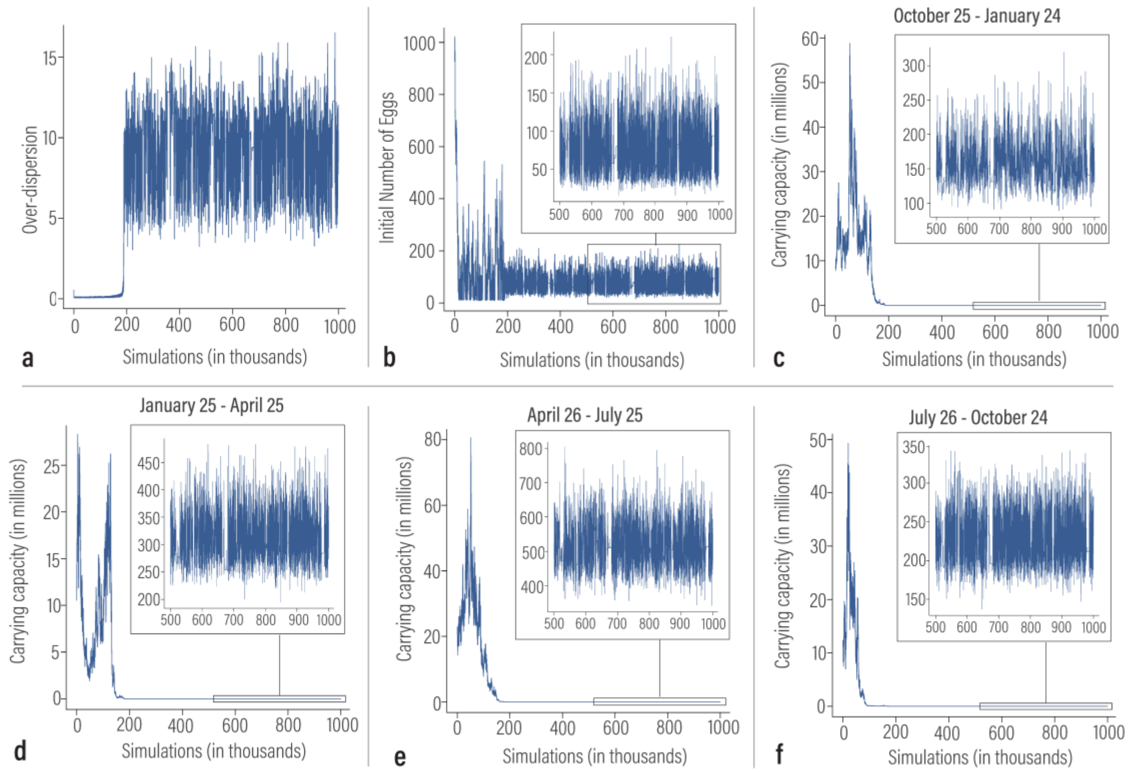

Fig. S2. Trace plots of the estimated model parameters in Miami-Dade County, FL; **a.** Over-dispersion parameter of the negative binomial distribution. **b.** number of *Aedes aegypti* eggs on January 1. **c.** October 25 to January 24; **b.** January 25 to April 25; **c.** April 26 to July 25. **d.** July 26 to October 24.

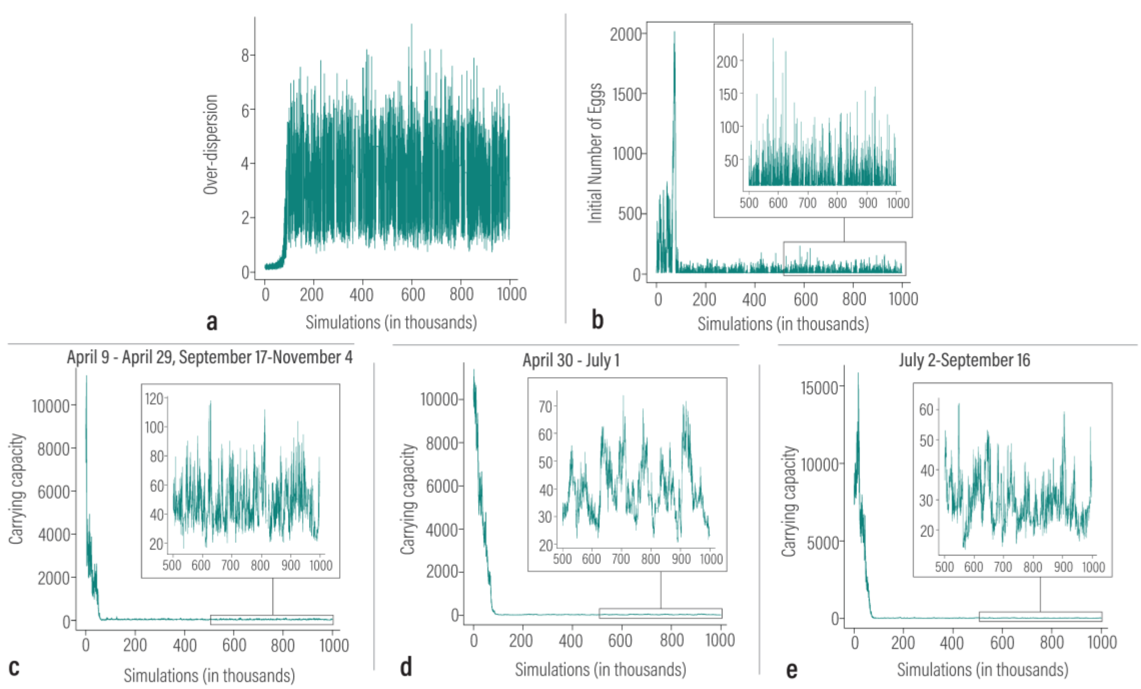

Fig. S3. Trace plots of the estimated model parameters in Brownsville, TX; a. over-dispersion parameter of the negative binomial distribution; **b.** number of *Aedes aegypti* eggs on April 4; **c.** April 9 to April 29 and September 17 to November 4; **e.** April 30 to July 1; and **f.** July 2 to September 16.

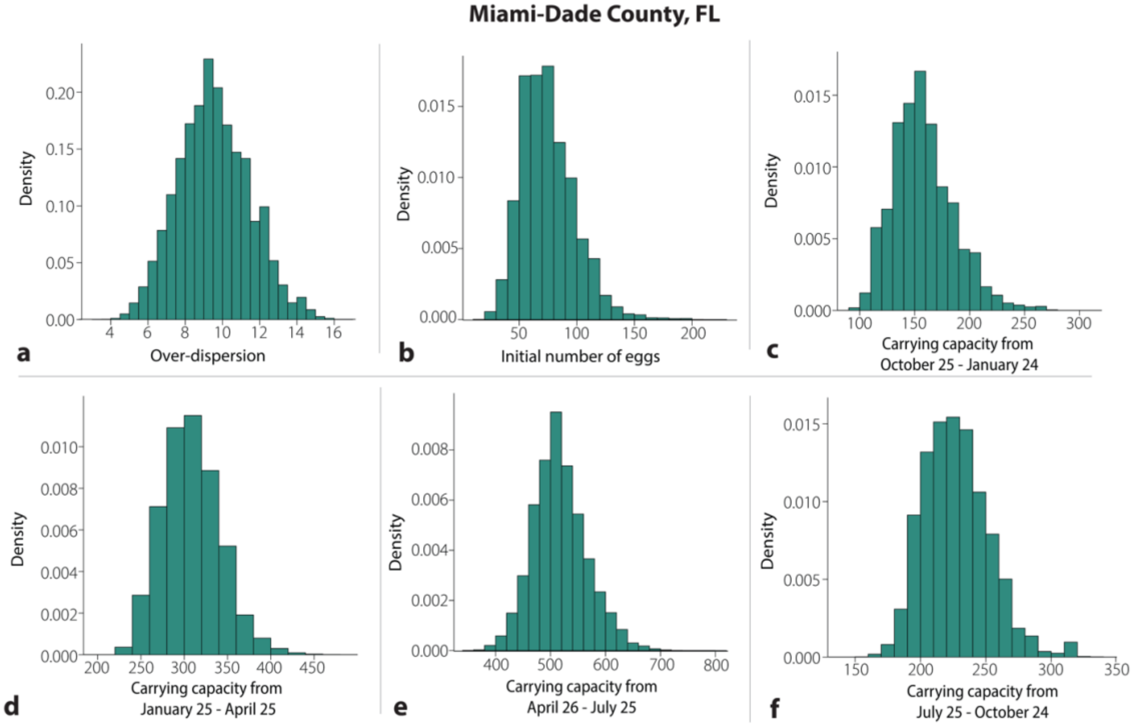

Fig. S4. Estimated posterior distributions of model parameters in Miami-Dade County, FL; **a.** Over-dispersion parameter of the negative binomial distribution. **b.** number of *Aedes aegypti* eggs on January 1. **c.** October 25 to January 24; **b.** January 25 to April 25; **c.** April 26 to July 25. **d.** July 26 to October 24.

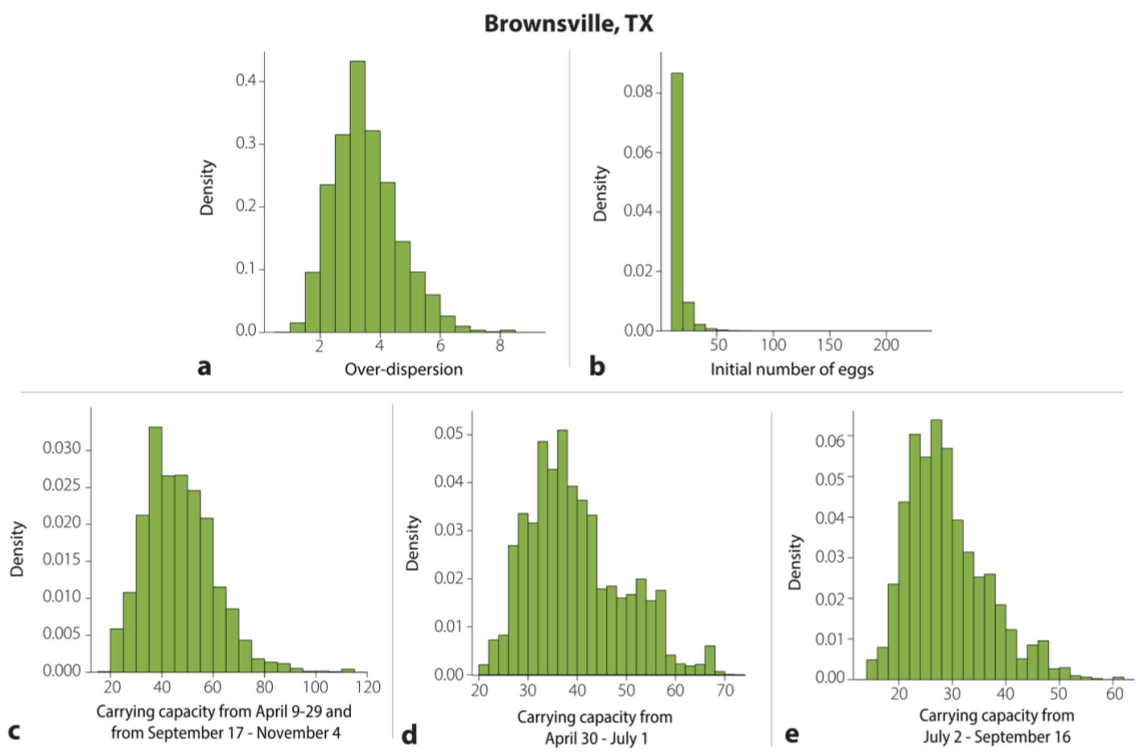

Fig. S5. Estimated posterior distributions of model parameters in Brownsville, TX; a. over-dispersion parameter of the negative binomial distribution; **b.** number of *Aedes aegypti* eggs on April 4; **c.** April 9 to April 29 and September 17 to November 4; **e.** April 30 to July 1; and **f.** July 2 to September 16.

Estimated DENV reproduction number

For both study sites, we estimated the weekly reproduction number of mosquitoes (Fig. S6), where the reproduction number was set to an average of 1.5 during the week when mosquito abundance was the highest (i.e., $R^* = 1.5$). For Miami-Dade County, the DENV reproduction number remained, on average, above the epidemic threshold from late-May to mid-September (Fig. S6). Brownsville showed a more complex pattern characterized by two periods where the DENV reproduction number was estimated to be above the epidemic threshold: from late-April and early-July and from late August to early October (Fig. S6).

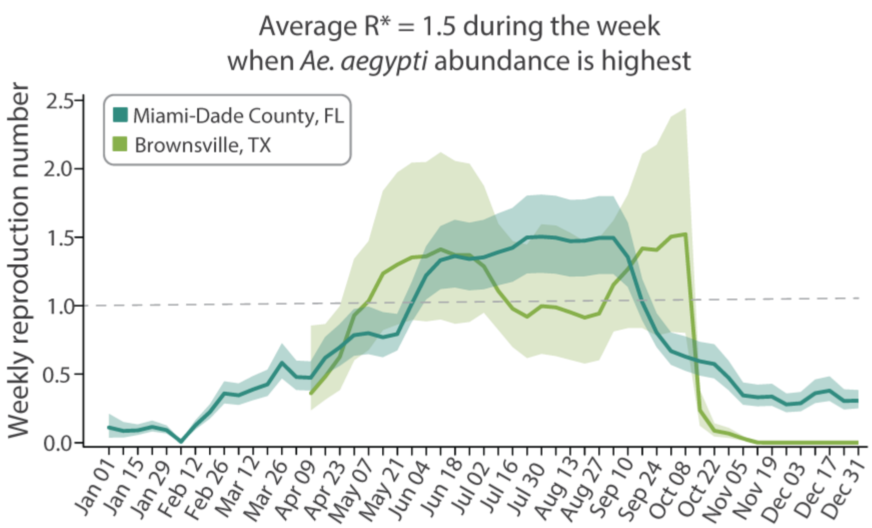

Figure S6. Weekly dengue virus reproduction number in Miami-Dade County, FL, and Brownsville, TX. Lines and shaded areas represent the means and 95% CI, respectively. The dotted line represents the epidemic threshold.

Sensitivity Analyses

Miami-Dade County, FL

Results from the sensitivity analyses for Miami-Dade County, FL, are shown in Tables S2-9.

Table S2. Estimated outbreak potential of a local dengue virus (DENV) outbreak in Miami-Dade County, FL, under different values of R^* for an importation of DENV in May.

Value of R^*	Number of symptomatic infections above the outbreak identification threshold	Probability (%)				
		No intervention	Adulticide spraying for 14 consecutive days			
			1 am	*7 am*	*3 pm*	*8 pm*
1.5	0-39	5.6	8.4	12.5	7.9	10.8
	40-119	6.5	5	0.4	5.5	0.1
	120-199	2.4	1.6	0.2	1.6	0
	200+	1.1	1.4	0	1	0
1.7	0-39	5.2	6.6	12.3	7	12.8
	40-119	5.5	6.7	1.1	6.7	0.5
	120-199	2.7	2.3	0.2	1.8	0
	200+	3.3	3.4	0.2	2.6	0
2.0	0-39	2	2.3	16.7	2.4	19.1
	40-119	4	5.5	3.5	5.3	1.4

	120-199	2.1	3.2	1.2	4.3	0.2
	200+	7.3	9.2	1.7	7	0.6

Table S3. Estimated outbreak size of a local dengue virus outbreak in Miami-Dade County, FL, under different values of R^* for an importation of dengue in May.

Value of R^*	**Median number of symptomatic infections above the outbreak identification threshold (IQR)**				
	No intervention	**Adulticide spraying for 14 consecutive days**			
		1 am	*7 am*	*3 pm*	*8 pm*
1.5	67 (25.5-103)	40 (15-85)	2 (1-6)	38 (14-81)	1 (0-2)
1.7	88 (28-198.25)	61 (27.5-149)	1 (0-6.5)	60 (23-136.5)	1 (0-2)
2.0	351 (115-623)	265.5 (99-492)	3 (1-37.5)	235.5 (91.25-591.75)	2 (1-5)

Table S4. Estimated outbreak potential of a local dengue virus outbreak in Miami-Dade County, FL, when an importation occurs during different times of the year.

Month of importation	Number of symptomatic infections above the outbreak identification threshold	Probability				
		No intervention	Adulticide spraying for 14 consecutive days			
			1 am	*7 am*	*3 pm*	*8 pm*
April	0-39	1.9	3.2	4.4	3.4	3.7
	40-119	3.4	1.9	0.1	1.8	0
	120-199	0.7	0.7	0	0.8	0
	200+	0.6	0.2	0	0.2	0
May	0-39	5.6	8.4	12.5	7.9	10.8
	40-119	6.5	5	0.4	5.5	0.1
	120-199	2.4	1.6	0.2	1.6	0
	200+	1.1	1.4	0	1	0
June	0-39	4.3	5.4	7.7	6.7	6.9
	40-119	4.6	3.3	0.1	2.1	0.2
	120-199	1.2	0.6	0	0.7	0
	200+	0.9	0.4	0	0.4	0
July	0-39	12.7	17.8	23.1	16.2	20.2
	40-119	8.8	7.6	0.2	9.2	0
	120-199	1.4	0.6	0.1	0.6	0
	200+	0.4	0.3	0	0.2	0
August	0-39	23.3	24.1	24.8	23	22.5
	40-119	6.4	5.6	0	6.5	0
	120-199	0.1	0	0	0.5	0
	200+	0	0	0	0	0
September	0-39	16.8	16.4	13.5	16.2	12.3
	40-119	0.6	0.2	0	0.3	0
	120-199	0	0	0	0	0
	200+	0	0	0	0	0

Table S5. Estimated outbreak size of a local dengue virus outbreak in Miami-Dade County, FL, when an importation occurs during different times of the year.

Month of importation	Median number of symptomatic infections above the outbreak identification threshold (IQR)				
	No intervention	Adulticide spraying for 14 consecutive days			
		1 am	*7 am*	*3 pm*	*8 pm*
April	54 (23.5-93.5)	23 (3-65)	1 (0-3)	33 (3-74)	1 (0-1)
May	67 (25.5-103)	40 (15-85)	2 (1-6)	38 (14-81)	1 (0-2)
June	54 (26.75-96.25)	34 (13-63)	2 (1-3)	27 (11-58)	1 (0-3)
July	38 (17-61)	28 (15-47)	3 (1-7)	30 (14-50)	1 (0-3)
August	20.5 (8.25-36)	18 (6-33.25)	2 (1-4)	18 (7.75-38)	1 (0-3)
September	11 (5-17)	7 (3-13)	2 (1-3)	7 (3-12)	1 (0-2)

Table S6. Estimated outbreak potential of a local dengue virus outbreak in Miami-Dade County, FL, using different outbreak identification thresholds.

Outbreak identification threshold	Number of symptomatic infections above the outbreak identification threshold	Probability				
		No intervention*	Adulticide spraying for 14 consecutive days			
			1 am	*7 am*	*3 pm*	*8 pm*
5	0-39	5.6	8.4	12.5	7.9	10.8
	40-119	6.5	5	0.4	5.5	0.1
	120-199	2.4	1.6	0.2	1.6	0
	200+	1.1	1.4	0	1	0
10	0-39	5	7.1	15.1	7.7	15.5
	40-119	7.6	5.9	0.6	5.1	0.2
	120-199	1.2	1.8	0	1.5	0
	200+	1.1	0.9	0	1.3	0
20	0-39	4.9	6.6	13.9	6.7	14.6
	40-119	6.7	5.1	0.8	5	0.1
	120-199	1.3	1.3	0	1.6	0
	200+	0.8	1.6	0	1.3	0

Table S7. Estimated outbreak size of a local dengue virus outbreak in Miami-Dade County, FL, using different outbreak identification thresholds.

Outbreak identification threshold	Median number of symptomatic infections above the outbreak identification threshold (IQR)				
	No intervention	Adulticide spraying for 14 consecutive days			
		1 am	*7 am*	*3 pm*	*8 pm*
5	67 (25.5-103)	40 (15-85)	2 (1-6)	38 (14-81)	1 (0-2)
10	62 (28-107)	44 (14.75-79.25)	8 (6-12)	39.5 (17.75-100.25)	7 (5-8)
20	52 (21-105.5)	45 (17.5-91.25)	20 (16-25)	46 (19-89.25)	18 (15-21)

Table S8. Estimated outbreak potential of a local dengue virus outbreak in Miami-Dade County, FL, for different durations of the intervention.

Days of adulticide spraying	Number of symptomatic infections above the outbreak identification threshold	Probability				
		No intervention	Adulticide spraying			
			1 am	*7 am*	*3 pm*	*8 pm*
No intervention	0-39	5.6	-	-	-	-
	40-119	6.5	-	-	-	-
	120-199	2.4	-	-	-	-
	200+	1.1	-	-	-	-
14 consecutive days	0-39	-	8.4	12.5	7.9	10.8
	40-119	-	5	0.4	5.5	0.1
	120-199	-	1.6	0.2	1.6	0
	200+	-	1.4	0	1.0	0
28 consecutive days	0-39	-	10.5	13.5	10.3	12
	40-119	-	6.7	0	6.3	0
	120-199	-	1.1	0	1.1	0
	200+	-	0.2	0	0.4	12

Table S9. Estimated outbreak size of a local dengue virus outbreak in Miami-Dade County, FL, for different durations of the intervention.

Outbreak identification threshold	Median number of symptomatic infections above the outbreak identification threshold (IQR)				
	No intervention	Adulticide spraying			
		1 am	*7 am*	*3 pm*	*8 pm*
No intervention	67 (25.5-103)	-	-	-	-
14 consecutive days	-	40 (15-85)	2 (1-6)	38 (14-81)	1 (0-2)
28 consecutive days	-	33.5 (7-57)	1 (0-3)	32 (11-55.75)	1 (0-2)

Brownsville, TX

Results from the sensitivity analyses for Brownsville, TX, are shown in Tables S10-17.

Table S10. Estimated outbreak potential of a local dengue virus outbreak in Brownsville, TX, under different values of R^* for an importation of dengue in May.

Value of R^*	Number of symptomatic infections above the outbreak identification threshold	Probability (%)				
		No intervention	Adulticide spraying for 14 consecutive days			
			1 am	*7 am*	*3 pm*	*8 pm*
1.5	0-9	4.6	5.2	7.5	6	6.4
	10-59	5.9	4.5	0.3	3.9	0.3
	60-99	1.3	0.7	0.1	0.3	0
	100+	0.6	0.1	0	0	0
1.7	0-9	4.6	4.9	8.8	5.9	9.2
	10-59	5.9	6.1	1.1	5.3	0
	60-99	1.5	0.9	0	0.8	0
	100+	2.4	1.1	0	1.5	0
2.0	0-9	2.7	3.3	10.2	4.2	11.1
	10-59	7.6	7.5	2.5	5.4	1
	60-99	2.4	1.9	0.2	2.2	0
	100+	4.1	2.9	0	3.3	0

Table S11. Estimated outbreak size of a local dengue virus outbreak in Brownsville, TX, under different values of R^* for an importation of dengue in May.

Value of R^*	Median number of symptomatic infections above the outbreak identification threshold (IQR)				
	No intervention	Adulticide spraying for 14 consecutive days			
		1 am	*7 am*	*3 pm*	*8 pm*
1.5	15 (7-33)	8 (3-21)	1 (0-3)	6 (2-22)	1 (0-2)
1.7	19 (6-60.5)	12 (2-36)	1 (0-3)	11 (3-37)	1 (0-1)
2.0	45 (19-140.75)	33 (11-86.5)	2 (1-5.5)	36 (7-100.5)	1 (0-2)

Table S12. Estimated outbreak potential of a local dengue virus outbreak in Brownsville, TX, when an importation occurs during different times of the year.

Month of importation	Number of symptomatic infections above the outbreak identification threshold	Probability				
		No intervention	Adulticide spraying for 14 consecutive days			
			1 am	*7 am*	*3 pm*	*8 pm*
April	0-9	2.1	2.3	4.4	2.5	4.6
	10-59	4	3.4	0.6	2.9	0.1
	60-99	0.5	0.3	0	0.2	0
	100+	0	0	0	0.4	0
May	0-9	4.6	5.2	7.5	6	6.4
	10-59	5.9	4.5	0.3	3.9	0.3
	60-99	1.3	0.7	0.1	0.3	0
	100+	0.6	0.1	0	0	0
June	0-9	3.4	5.4	4.9	4.9	3.6
	10-59	3.4	1.9	0.3	2.1	0
	60-99	0.3	0	0	0.2	0
	100+	0	0	0	0	0
July	0-9	3.8	3.5	2.8	3.6	2.5
	10-59	1.1	0.6	0	0.6	0
	60-99	0	0	0	0	0
	100+	0	0	0	0	0
August	0-9	7.9	9	6.7	9.6	6.9
	10-59	1.3	0.7	0	0.7	0
	60-99	0	0	0	0	0
	100+	0	0	0	0	0
September	0-9	2	2.5	2.4	2.5	2.3
	10-59	0	0	0	0	0
	60-99	0	0	0	0	0
	100+	0				

Table S13. Estimated outbreak size of a local dengue virus outbreak in Brownsville, TX, when an importation occurs during different times of the year.

Month of importation	Median number of symptomatic infections above the outbreak identification threshold (IQR)				
	No intervention	Adulticide spraying for 14 consecutive days			
		1 am	*7 am*	*3 pm*	*8 pm*
April	16 (4-39)	15 (7-26.5)	2 (1-4)	14 (6-31)	1 (0.5-2)
May	15 (7-33)	8 (3-21)	1 (0-3)	6 (2-22)	1 (0-2)
June	10 (5-10)	5 (2-10.5)	1 (0-3)	4 (1-15)	0 (0-1)
July	4 (2-8)	3 (1-7)	1 (0-2)	2 (1-5)	0 (0-1)
August	3 (1-8)	2 (1-4)	1 (0-2)	2 (1-5)	1 (0-1)
September	2 (0-3)	1 (0-3)	1 (0-2)	1 (0-2.75)	1 (0-1)

Table S14. Estimated outbreak potential of a local dengue virus outbreak in Brownsville, TX, using different outbreak identification thresholds.

Outbreak identification threshold	Number of symptomatic infections above the outbreak identification threshold	Probability				
		No intervention	Adulticide spraying for 14 consecutive days			
			1 am	*7 am*	*3 pm*	*8 pm*
5	0-9	4.6	5.2	7.5	6	6.4
	10-59	5.9	4.5	0.3	3.9	0.3
	60-99	1.3	0.7	0.1	0.3	0
	100+	0.6	0.1	0	0	0
10	0-9	4.3	7	11.6	7.9	12
	10-59	3.9	4.9	1.3	4.2	0.9
	60-99	1.2	0.7	0	0.7	0
	100+	0.6	0.3	0	0	0
20	0-9	1.7	5.1	5.1	5.1	5.1
	10-59	3.2	5.6	6.5	5.8	6.5
	60-99	0.2	0.7	0	0.5	0
	100+	0.6	0.2	0	0	0

Table S15. Estimated outbreak size of a local dengue virus outbreak in Brownsville, TX, using different outbreak identification thresholds.

Outbreak identification threshold	Median number of symptomatic infections above the outbreak identification threshold (IQR)				
	No intervention	Adulticide spraying for 14 consecutive days			
		1 am	*7 am*	*3 pm*	*8 pm*
5	15 (7-33)	8 (3-21)	1 (0-3)	6 (2-22)	1 (0-2)
10	13 (5-32)	10 (6-20)	6 (5.0-8)	9 (5-18.5)	6 (5.0-8)
20	18 (5-85)	13.5 (5-27)	13.5 (5-19)	13.5 (5-23.75)	13.5 (5-20)

Table S16. Estimated outbreak potential of a local dengue virus outbreak in Brownsville, TX, for different durations of the intervention.

Days of adulticide spraying	Number of symptomatic infections above the outbreak identification threshold	Probability				
		No intervention	Adulticide spraying			
			1 am	*7 am*	*3 pm*	*8 pm*
No Intervention	0-9	4.6	-	-	-	-
	10-59	5.9	-	-	-	-
	60-99	1.3	-	-	-	-
	100+	0.6	-	-	-	-
14 consecutive days	0-9	-	5.2	7.5	6	6.4
	10-59	-	4.5	0.3	3.9	0.3
	60-99	-	0.7	0.1	0.3	0
	100+	-	0.1	0	0	0
28 consecutive days	0-9	-	7.4	8.1	7.4	6.4
	10-59	-	2.5	0	2.5	0
	60-99	-	0.2	0	0.2	0
	100+	-	0	0	0	0

Table S17. Estimated outbreak size of a local dengue virus outbreak in Brownsville, TX, for different durations of the intervention.

Outbreak identification threshold	Median number of symptomatic infections above the outbreak identification threshold (IQR)				
	No intervention	Adulticide spraying			
		1 am	*7 am*	*3 pm*	*8 pm*
No intervention	15 (7-33)	-	-	-	-
14 consecutive days	-	8 (3-21)	1 (0-3)	6 (2-22)	1 (0-2)
28 consecutive days	-	4 (2-10)	1.0 (0-2)	4 (1-10)	1.0 (0-2)

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