Forecasting the relative abundance of *Aedes* vector populations to enhance situational awareness for mosquito control operations

Supplementary Material

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S1. Methods Details

S1.1. Spline interpolation

We used an interpolation technique to infer *Ae. aegypti* relative abundance per day from weekly observations. First, we assume that the weekly observations are smoothly distributed across the seven days of the week. Then, we used a spline interpolation over the cumulative time series of the observations. Specifically, the method encompasses by the following steps:

1. We calculated the weekly cumulative time series $C(w)$ of the target data (weekly relative abundance of *Ae. aegypti*, $c(w)$) on week w as $C(w) = \sum_{u=1}^{w} c(u)$, where $u = 1$ represents the earliest week of available data. By definition, we also set $C(0) = 0$.
2. We performed a cubic smoothing spline interpolation of $C(w)$. Smoothing means that the number of knots of the spline is set to the minimum possible while keeping the average square error under a given value s, where s was set at 0.01 for all years and study sites.
3. We sampled the spline function calculated in step 2 over a daily sequence of points, calculating the cumulative abundance time series $D(t)$ for each day t. By definition, we also set $D(0) = 0$.
4. We calculated the daily abundance $d(t)$ by taking the consecutive differences between the cumulative values $D(t)$, as $d(t) = D(t) - D(t-1)$ for $t = 1, 2, \dots t_{max}$.
5. As the spline interpolation does not necessarily preserve the strictly increasing aspect of the weekly series $C(w)$, it is possible that some values of $d(t)$ come off as negative, especially around low activity periods. For each day t in which this artifact occurs, we fix it by subtracting $|d(t) / 2|$ from each of the neighboring points $d(t-1)$ and $d(t+1)$ and then setting $d(t) = 0$. This process is repeated until no negative values are found in the data.

The method described above provides a daily relative abundance series $d(t)$ that we used to estimate the reproduction number $R(t)$.

S1.2. Training and testing datasets

To calculate the historical temporal trends of the reproduction number, we divided the mosquito surveillance data of each study site into two datasets (Dataset 1 and Dataset 2) each one containing roughly the same number of seasons. The years that were included into each dataset are reported in Table S1.

Table S1. Years of data included into the two analyzed datasets for each study site.

Study site	Dataset 1	Dataset 2
Los Angeles County	2018, 2019	2020, 2021
Maricopa County	2015, 2016, 2017	2018, 2019, 2020, 2021
Key West	2011, 2012, 2013, 2014, 2015	2016, 2017, 2018, 2019, 2020
Miami-Dade County	2019, 2020	2021, 2022

S2. Additional Results

S2.1. LHS parameter search

For the model calibration, we performed a Latin Hypercube Sampling (LHS)[2] search over two parameters that affect the forecast performance: the relative lowpass filter cutoff (γ_c) and the IQR of the estimated reproduction number ensemble that is used for forecasting (w_R). We explored 1,000 combination of parameters for each study site, and for each sampled pair (w_R, γ_c) of parameters, the forecast was executed and evaluated using the WIS. The results of each LHS parameter search show that each of the four study sites has a characteristic region on the parameter space in which the forecast performance is highest (Fig. S1). The optimal parameters identified by the LHS search for each location are shown in Table S2.

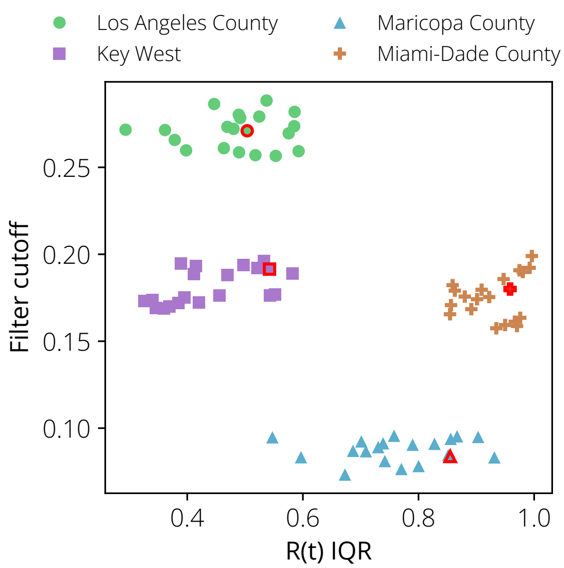

Figure S1. Top-20 parameters according to the forecast WIS. Scatter plot of the relative filter cutoff (γ_c) and interquantile range of the reproduction number used for the forecast (w_R). Each point represents one of the top-20 configurations (out of 1,000 LHS samples) according to the WIS of the associated forecasts. The red symbol represents the best configuration for each study site.

Table S2. Best parameters for each study site according to the WIS score of the associated forecasts.

Study site	Relative filter cutoff (γ_c)	Interquantile range of the reproduction number (w_R)
Los Angeles County	0.271	50.4%
Maricopa County	0.083	85.5%
Key West	0.191	54.2%
Miami-Dade County	0.180	95.8%

S2.2. Mosquito relative abundance over time for different forecast horizons

A comparison between the mosquito surveillance data and our forecasts for different time horizons is shown in Figures S2 (1-week ahead forecasts), S3 (3-week ahead forecast) and S4 (4-week ahead forecasts).

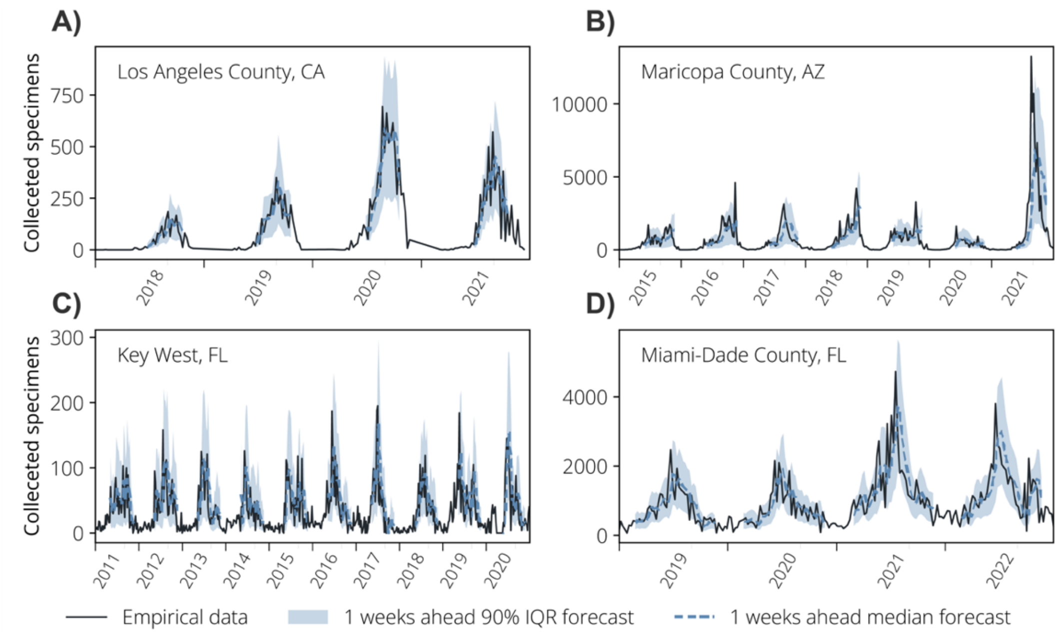

Figure S2. **Mosquito relative abundance over time and 1-week ahead forecasts. A** Observed and forecasted number of collected specimens over time in Los Angeles County, CA. The solid line represents the number of *Ae. aegypti* collected by the mosquito surveillance system per week, the dashed line represents the median of the 2-week ahead forecast, and the shaded areas are the 90% IQR of the 1-week ahead forecast. **B** As A, but for Maricopa County, AZ. **C** As A, but for Key West, FL. **D** As A, but for Miami-Dade County, FL, respectively.

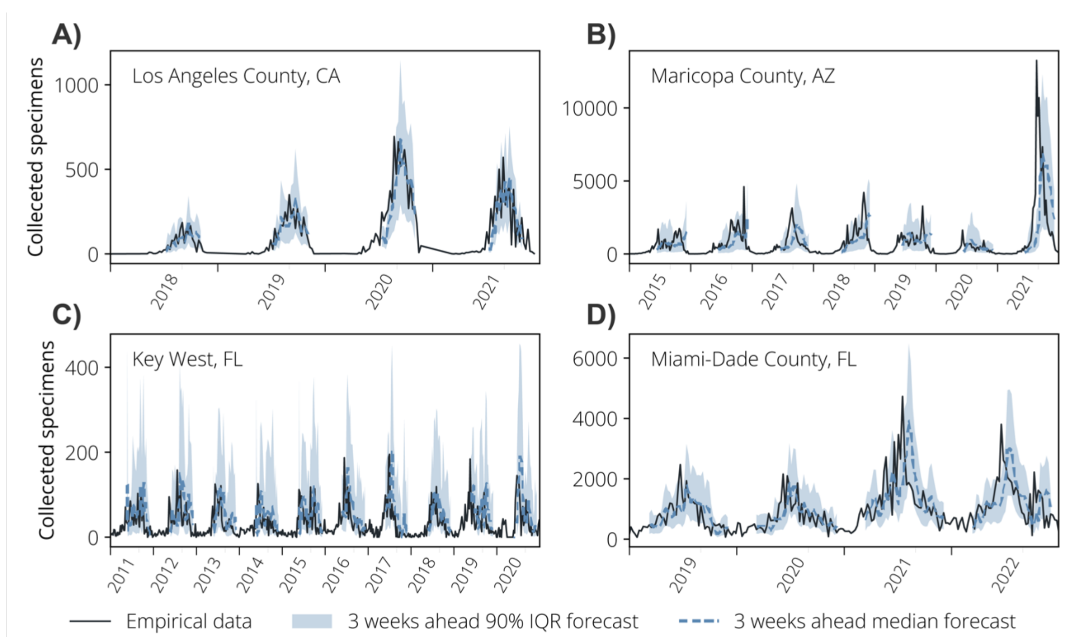

Figure S3. **Mosquito relative abundance over time and 3-week ahead forecasts. A** Observed and forecasted number of collected specimens over time in Los Angeles County, CA. The solid line represents the number of *Ae. aegypti* collected by the mosquito surveillance system per week, the dashed line represents the median of the 2-week ahead forecast, and the shaded areas are the 90% IQR of the 3-week ahead forecast. **B** As A, but for Maricopa County, AZ. **C** As A, but for Key West, FL. **D** As A, but for Miami-Dade County, FL, respectively.

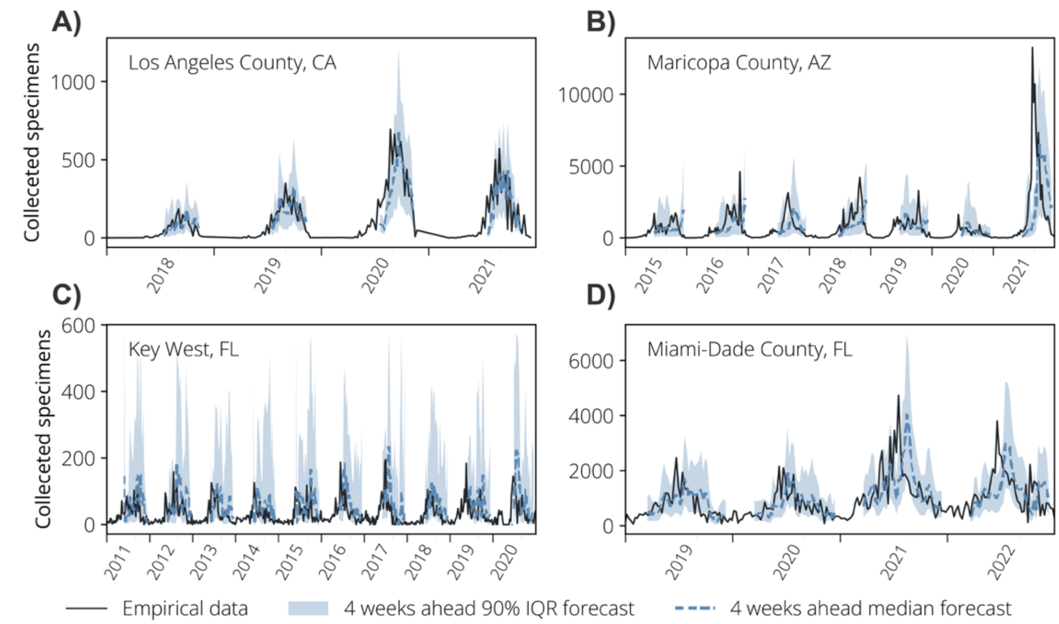

Figure S4. **Mosquito relative abundance over time and 4-week ahead forecasts. A** Observed and forecasted number of collected specimens over time in Los Angeles County, CA. The solid line represents the number of *Ae. aegypti* collected by the mosquito surveillance system per week, the dashed line represents the median of the 2-week ahead forecast, and the shaded areas are the 90% IQR of the 4-week ahead forecast. **B** As A, but for Maricopa County, AZ. **C** As A, but for Key West, FL. **D** As A, but for Miami-Dade County, FL, respectively.

S2.3. Additional forecast scores

Scoring metrics calculated independently for each season show how the performance of our method varies with the specificities of each location and year (Table S3). The Weighted Interval Score (WIS)[1], which account for both the precision and accuracy of the forecasts, was used to calibrate the model for each location; its season-normalized value ranged from 1.03 to 3.05, obtained respectively for the 2020 Los Angeles season and the 2017 Key West season. The coverage of the 90% IQR forecast showed its maximum value with Los Angeles in 2019 with 93% coverage, while the minimum was also obtained for Los Angeles in 2021 at 63% coverage. For the 50% IQR forecast, both the maximum and minimum coverages were obtained for Maricopa, with 56% in the 2020 season and 19% in 2021. The Average Outermost IQR, another metric of overall coverage, also had its minimum and maximum values with Maricopa's dataset, with 48% for the 2020 season (the most precise round, with a log score of -1.12) and 74% for the 2021 season (with a log score of -0.47). Among accuracy metrics of the median forecast, the MAPE score ranged from 31% (Los Angeles 2020) to 313% (Key West 2017), while the sMAPE score went from 35% (Los Angeles 2019 and 2020) to 93% (Key West 2017).

Table S3. Miscellaneous forecast scores, for different seasons in each study site.

Study site	Year	Season normalized WIS	50% coverage	90% coverage	Outermost IQR	MAPE score	sMAPE score	Log score
Key West	2011	2.35	0.48	0.90	0.51	1.17	0.63	-0.97
	2012	2.53	0.43	0.87	0.54	2.18	0.66	-0.98
	2013	2.37	0.45	0.90	0.53	1.23	0.65	-0.98
	2014	3.00	0.46	0.86	0.53	1.66	0.70	-0.87
	2015	2.65	0.47	0.89	0.52	1.32	0.66	-1.02
	2016	2.42	0.47	0.89	0.52	0.89	0.61	-1.16
	2017	3.00	0.33	0.65	0.64	3.13	0.93	-0.74
	2018	2.13	0.47	0.91	0.50	0.85	0.59	-1.09
	2019	2.65	0.34	0.80	0.60	1.24	0.68	-0.70
	2020	2.95	0.49	0.72	0.58	2.56	0.70	-0.99
Los Angeles County	2018	1.51	0.42	0.85	0.53	0.82	0.47	-0.88
	2019	1.08	0.50	0.93	0.50	0.37	0.35	-1.07
	2020	1.00	0.47	0.81	0.53	0.31	0.35	-1.10
	2021	1.71	0.28	0.63	0.68	0.93	0.58	-0.60
Maricopa County	2015	2.05	0.35	0.74	0.62	1.16	0.60	-0.68
	2016	1.87	0.43	0.81	0.54	0.56	0.50	-1.03
	2017	2.30	0.35	0.81	0.59	0.71	0.61	-0.79
	2018	1.99	0.36	0.67	0.63	0.60	0.59	-0.84
	2019	1.93	0.51	0.80	0.55	1.11	0.53	-0.86
	2020	1.79	0.57	0.91	0.48	0.66	0.49	-1.12
	2021	2.84	0.19	0.69	0.74	0.96	0.84	-0.47
Miami-Dade County	2019	1.26	0.49	0.80	0.54	0.56	0.39	-1.08
	2020	1.30	0.47	0.84	0.53	0.49	0.37	-0.98
	2021	1.52	0.31	0.75	0.62	0.45	0.39	-0.74
	2022	1.51	0.35	0.72	0.63	0.60	0.45	-0.74

References

1. Bracher, J., Ray, E. L., Gneiting, T. & Reich, N. G. Evaluating epidemic forecasts in an interval format. *PLOS Computational Biology* **17**, e1008618 (2021).
2. Marino, S. *et al.* Dendritic Cell Trafficking and Antigen Presentation in the Human Immune Response to Mycobacterium tuberculosis 1. *The Journal of Immunology* **173**, 494–506 (2004).