

Supplementary Information for “Evaluating the Mosquito Weather Index: A simple tool for predicting and communicating mosquito activity”

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ABSTRACT

This document contains the Supplementary Tables and Supplementary Figures accompanying “Evaluating the Mosquito Weather Index: A simple tool for predicting and communicating mosquito activity.”

MWI value	Classification	Interpretation
MWI = 0	No activity	At least one factor is outside its favourable range: temperature $\leq 15^{\circ}\text{C}$ or $> 30^{\circ}\text{C}$, relative humidity $< 40\%$ or $> 95\%$, or wind speed $> 21.6 \text{ km h}^{-1}$.
$0 < \text{MWI} \leq 0.33$	Low activity	Weather is only marginally favourable for mosquito activity.
$0.33 < \text{MWI} \leq 0.66$	Moderate activity	Weather is moderately favourable for mosquito activity.
$0.66 < \text{MWI} < 1$	High activity	Temperature, humidity and wind are all close to their optimal ranges.
MWI = 1	Very high activity	The index is at its maximum value: temperature, humidity and wind are simultaneously in their most favourable ranges.

Table S1. MWI classification thresholds.

Trap	HOBO logger	Data availability
BG_1	—	Trap counts and station/reanalysis weather
BG_2	Yes (from 8 Aug 2018)	Trap counts, station/reanalysis weather, and on-site HOBO temperature and humidity
BG_3	Yes (HOBO until 10 Oct 2019)	Trap counts, station/reanalysis weather, and on-site HOBO temperature and humidity
BG_4	Yes (from 8 Aug 2018)	Trap counts, station/reanalysis weather, and on-site HOBO temperature and humidity
BG_5	Yes (from 8 Aug 2018)	Trap counts, station/reanalysis weather, and on-site HOBO temperature and humidity
BG_6	—	Trap counts and station/reanalysis weather

Table S2. Data availability by trap. All six BG-Sentinel traps have mosquito counts and matched gridded/station weather; on-site HOBO temperature and relative-humidity loggers were installed at four traps (BG_2–BG_5) from 8 August 2018.

Trap	Valid 30-min readings	Missing (%)	Relative humidity (%)			Temp. (°C)	
			HOBO	ERA5	Diff. (pp)	HOBO	ERA5
BG 2	20,126	7	61.4	66.7	−5.3	20.2	19.4
BG 3	19,932	3	59.6	66.9	−7.3	20.9	19.4
BG 4	20,921	3	65.1	67.2	−2.1	20.2	19.4
BG 5	20,922	3	67.1	67.2	−0.1	20.7	19.4
All	81,901	4	63.4	67.0	−3.7	20.5	19.4

Table S3. On-site HOBO logger readings compared with ERA5-Land hourly reanalysis at the four instrumented traps over the study period. “Valid 30-min readings” counts distinct 30-minute logger records with a non-missing relative-humidity value (after removing overlapping-file duplicates and discarding the BG 2 sensor malfunction); “Missing (%)” is the shortfall relative to the number of 30-minute slots expected across each logger’s deployment span. The relative-humidity and temperature columns are means over the hours in which both the logger and ERA5-Land hourly have valid readings, and “Diff.” is the mean HOBO–ERA5 relative-humidity difference in percentage points. The loggers run systematically drier and slightly warmer than ERA5, though the humidity bias varies markedly across sensors (from −7.3 pp at BG 3 to essentially zero at BG 5).

Species	Component	Term	Estimate	90% CrI
<i>Ae. albopictus</i>	Count (log-mean)	Intercept	−0.08	(−1.22, 1.06)
		MWI	3.43	(2.39, 4.48)
		Trapping effort	0.10	(0.04, 0.17)
	Zero-inflation (logit)	Intercept	3.55	(2.52, 4.88)
		MWI	−18.16	(−26.25, −12.92)
<i>Cx. pipiens</i>	Count (log-mean)	Intercept	−0.26	(−1.23, 0.59)
		MWI	2.75	(2.17, 3.29)
		Trapping effort	0.09	(0.04, 0.15)
	Zero-inflation (logit)	Intercept	−1.34	(−4.74, −0.31)
		MWI	−5.03	(−9.60, −0.54)

Table S4. Posterior median estimates and 90% credible intervals for every coefficient in the primary zero-inflated negative binomial models (24-hour maximum MWI). Count-component estimates are on the log scale and zero-inflation-component estimates are on the logit scale. The MWI coefficient is credibly positive in the count component for both species and credibly negative in the zero-inflation component for *Ae. albopictus*; for *Cx. pipiens* the zero-inflation MWI coefficient is also negative at the 90% level (posterior probability ≈ 0.96), though the wider 95% credible interval would include zero.

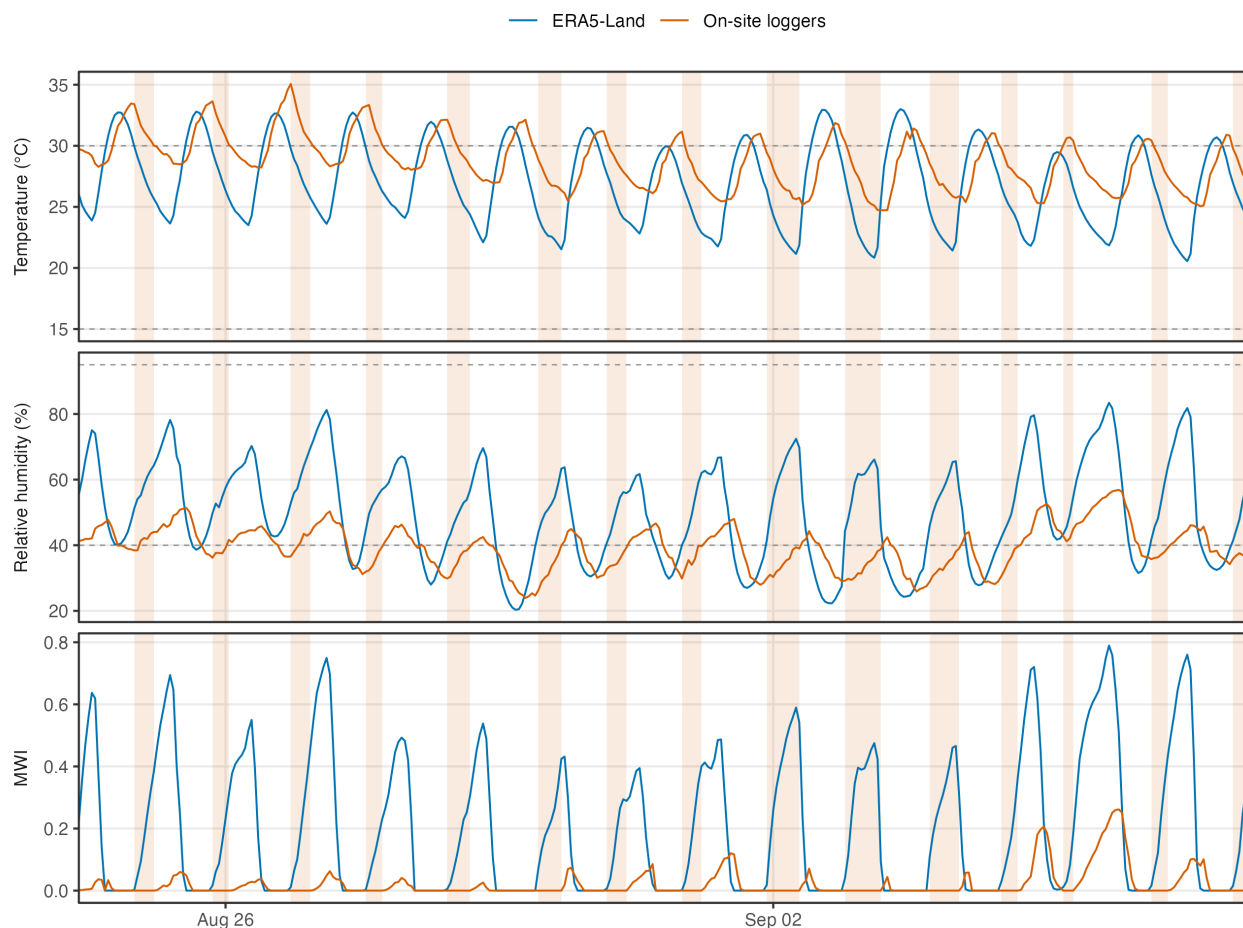


Figure S1. Hourly weather and Mosquito Weather Index from the ERA5-Land reanalysis and from the on-site HOB0 loggers, 24 August to 8 September 2019. The three panels share a time axis: air temperature (top), relative humidity (middle), and the resulting MWI (bottom). Logger traces are means across the instrumented traps reporting in each hour (two to four of BG 2–BG 5), with the readings from the BG 2 sensor malfunction excluded; because the loggers do not measure wind, the logger MWI takes its wind response from ERA5. Dashed lines mark the breakpoints of the index: 15 and 30°C, outside which the temperature response is zero, and 40 and 95% relative humidity, outside which the humidity response is zero. Shaded bands mark the hours in which the logger readings drive MWI to zero while the ERA5 values keep it positive. The loggers run warmer and markedly drier than the reanalysis, so their humidity trace sits on or below the 40% threshold through most afternoons and the index collapses even as ERA5 registers moderate activity. This fortnight was chosen as the one containing the most such hours and is not representative: 49% of the ERA5-positive hours here are forced to zero, against 12% across the full logger record.

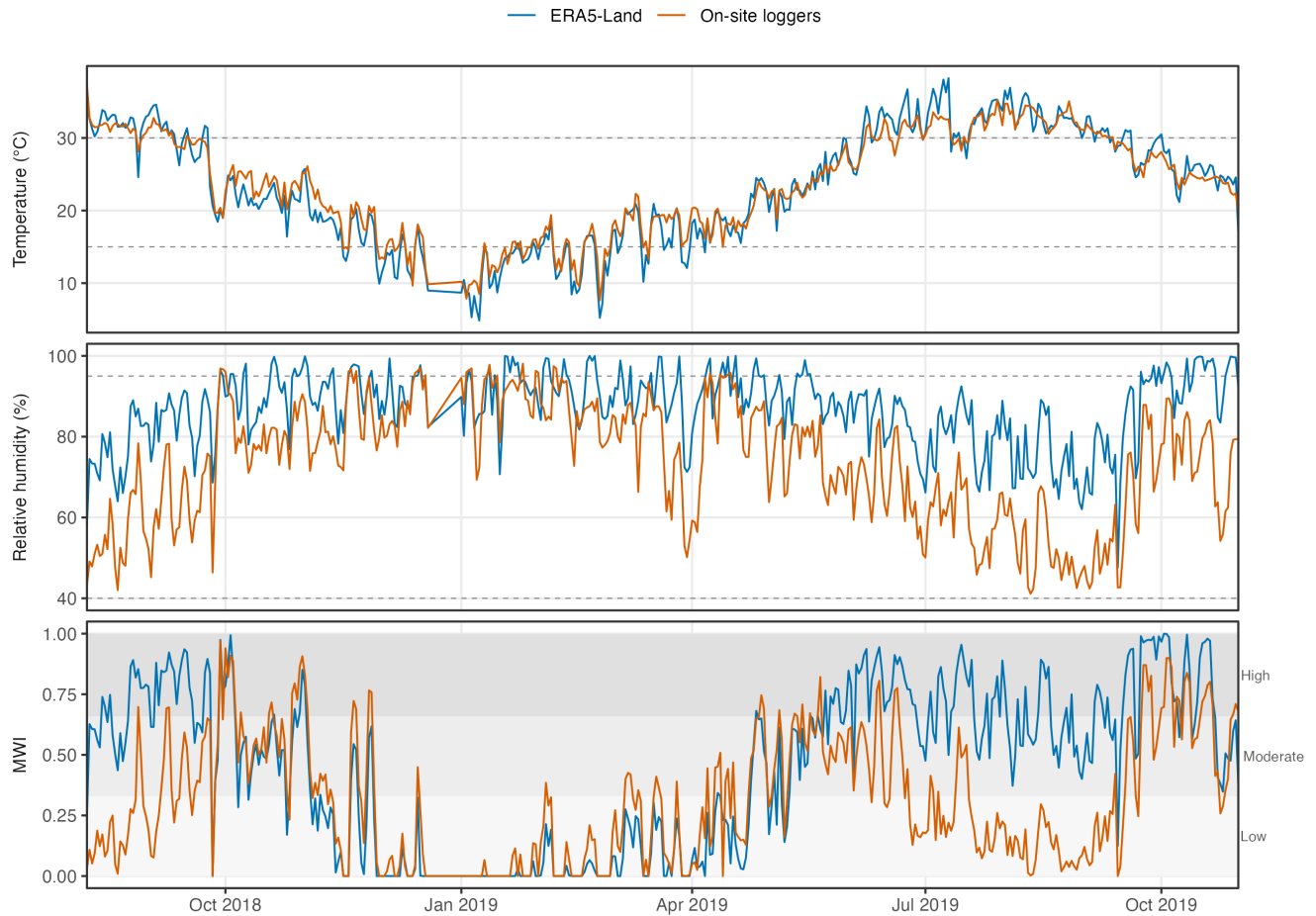


Figure S2. Daily maximum weather and Mosquito Weather Index from the ERA5-Land reanalysis and from the on-site HOBO loggers over the whole study period. Panels, colours, dashed breakpoint lines and logger processing are as in Supplementary Figure S1. Grey bands in the MWI panel mark the index’s operational activity classes, deepening with increasing activity: low ($0 < \text{MWI} \leq 0.33$), moderate ($0.33 < \text{MWI} \leq 0.66$) and high ($0.66 < \text{MWI} < 1$). The remaining two classes are single values rather than intervals and so cannot be drawn as bands: $\text{MWI} = 0$ is “no activity” and $\text{MWI} = 1$ is “very high activity”. Summarising to a daily maximum before plotting removes most of the threshold behaviour that is visible at hourly resolution, because the daily maximum relative humidity seldom approaches 40% for either source; this is why the mechanism is easier to see in the hourly view. What remains visible is the persistent offset between the two sources: logger temperatures track the reanalysis closely, whereas logger humidity runs well below it from spring through autumn, and the logger MWI is correspondingly depressed through the warm season, when trap catches are highest.

Species	Model	Weather predictors	ELPD	Δ ELPD vs. MWI
<i>Ae. albopictus</i>	Null	none (effort only)	−1119	−127 (11.3)
	MWI	MWI	−993	—
	Weather	$H + T + W$	−988	+4 (6.7)
	Weather ²	$\text{poly}_2(H, T, W)$	−968	+25 (7.8)
<i>Cx. pipiens</i>	Null	none (effort only)	−987	−45 (9.8)
	MWI	MWI	−943	—
	Weather	$H + T + W$	−928	+15 (5.6)
	Weather ²	$\text{poly}_2(H, T, W)$	−922	+21 (8.1)
Both (pooled)	Null	none (effort only)	−1305	−83 (12.1)
	MWI	MWI	−1222	—
	Weather	$H + T + W$	−1209	+13 (7.7)
	Weather ²	$\text{poly}_2(H, T, W)$	−1204	+18 (9.6)

Table S5. Leave-one-out predictive accuracy (ELPD) of the primary zero-inflated negative binomial specification (24-hour daily maximum, no seasonal term) when the weather term is (i) absent (the trapping-effort-only null), (ii) the single MWI value, (iii) the three raw weather variables—relative humidity H , temperature T and wind speed W —entered linearly, or (iv) the same three variables as second-degree polynomials. Higher (less negative) ELPD is better; Δ ELPD is relative to the MWI model, with the standard error of the difference in parentheses. All three weather-based models far exceed the null, while the single-parameter MWI predicts about as well as the three raw weather variables and only modestly worse than their second-degree polynomial expansion, indicating that MWI captures most of the count-relevant information in the weather variables using far fewer degrees of freedom.

Species	MWI weather source	ELPD	Δ ELPD vs. ERA5
<i>Ae. albopictus</i>	None (effort-only null)	−744	−85 (9.4)
	HOBO on-site loggers	−716	−57 (8.7)
	ERA5-Land hourly	−659	—
<i>Cx. pipiens</i>	None (effort-only null)	−661	−21 (7.5)
	HOBO on-site loggers	−660	−21 (7.7)
	ERA5-Land hourly	−639	—

Table S6. Leave-one-out predictive accuracy (ELPD) of the primary zero-inflated negative binomial specification (24-hour daily-maximum MWI, no seasonal term) fitted on the subset of trap-periods with on-site logger coverage ($n = 234$), with MWI computed either from the ERA5-Land hourly or from the on-site HOBO loggers, alongside a trapping-effort-only null. Higher (less negative) ELPD is better; Δ ELPD is relative to the ERA5 model, with the standard error of the difference in parentheses. MWI computed from ERA5-Land hourly predicts substantially better than MWI computed from the HOBO loggers for both species; the HOBO-based MWI improves only modestly over the null for *Ae. albopictus* and negligibly for *Cx. pipiens*.

Species	Trapping-effort term	MWI count coef. (90% CrI)	MWI zero-infl. coef. (90% CrI)	ELPD	Δ ELPD
<i>Ae. albopictus</i>	Linear (primary)	3.43 (2.39, 4.48)	−18.16 (−26.25, −12.92)	−993	—
	log effort, covariate	3.46 (2.40, 4.49)	−18.32 (−26.13, −13.12)	−993	−0.3 (0.4)
	log effort, offset	3.46 (2.40, 4.48)	−18.20 (−26.08, −12.89)	−991	+1.3 (0.9)
<i>Cx. pipiens</i>	Linear (primary)	2.75 (2.17, 3.29)	−5.03 (−9.60, −0.54)	−943	—
	log effort, covariate	2.77 (2.18, 3.33)	−4.91 (−9.52, 0.39)	−944	−1.0 (0.9)
	log effort, offset	2.80 (2.20, 3.34)	−4.92 (−9.76, 0.40)	−942	+0.3 (0.8)
Both (pooled)	Linear (primary)	4.07 (3.49, 4.65)	−6.57 (−11.08, −3.29)	−1222	—
	log effort, covariate	4.10 (3.52, 4.68)	−6.66 (−11.15, −3.30)	−1224	−1.5 (1.3)
	log effort, offset	4.10 (3.54, 4.70)	−6.53 (−11.09, −3.25)	−1222	+0.7 (1.0)

Table S7. Sensitivity of the primary zero-inflated negative binomial specification (24-hour daily-maximum MWI, no seasonal term) to how trapping effort is handled: as the linear covariate used throughout the main text, as a log-transformed covariate, or as a log offset. Δ ELPD is relative to the linear-covariate model, with the standard error of the paired difference in parentheses. The MWI coefficient shifts by at most 0.05 on the log scale and predictive accuracy by at most 1.5 ELPD units against standard errors of comparable size, so the choice is immaterial to the conclusions. The one visible difference is that the zero-inflation coefficient for *Cx. pipiens*, whose 90% interval excludes zero under the linear specification, includes zero under both log-effort variants.

Species	MWI construction	MWI count coef. (90% CrI)	ELPD	Δ ELPD vs. ERA5
<i>Ae. albopictus</i>	ERA5 hourly, then daily max	3.43 (2.39, 4.48)	−993	—
	Helix daily max, then indexed	0.24 (−0.42, 0.91)	−1042	−48.9 (9.1)
	None (effort-only null)	—	−1119	−126.6 (11.3)
<i>Cx. pipiens</i>	ERA5 hourly, then daily max	2.75 (2.17, 3.29)	−943	—
	Helix daily max, then indexed	−0.88 (−1.49, −0.27)	−979	−36.5 (10.2)
	None (effort-only null)	—	−987	−44.5 (9.8)
Both (pooled)	ERA5 hourly, then daily max	4.07 (3.49, 4.65)	−1222	—
	Helix daily max, then indexed	0.40 (−0.20, 0.98)	−1288	−65.3 (11.9)
	None (effort-only null)	—	−1305	−83.2 (12.1)

Table S8. Effect of reversing the order of operations when building MWI. In the ERA5-Land rows the index is evaluated hourly and only then summarised to a daily maximum, as throughout the main text; in the Helix rows the daily maximum of each weather variable is taken first and the index computed from those daily values. All models use the primary zero-inflated negative binomial specification. Δ ELPD is relative to the ERA5 model, with the standard error of the paired difference in parentheses. Aggregating before indexing removes the count-component association entirely—the coefficient is indistinguishable from zero for *Ae. albopictus* and the pooled total, and credibly negative for *Cx. pipiens*—and costs 37 to 65 ELPD units. The daily index nonetheless still beats the weather-free null, because its zero-inflation component continues to identify periods with no catch.

Species	Weather term	ERA5 ELPD	HOB0 ELPD	HOB0 – ERA5
<i>Ae. albopictus</i>	MWI	−674	−743	−69.1 (11.2)
	$T + H$ linear	−689	−683	+6.3 (11.2)
	$T + H$ second-degree polynomials	−660	−664	−3.5 (9.5)
	$T + H$ splines	−659	−658	+0.8 (6.4)
<i>Cx. pipiens</i>	MWI	−640	−662	−21.8 (7.7)
	$T + H$ linear	−631	−630	+0.6 (2.1)
	$T + H$ second-degree polynomials	−629	−633	−4.5 (3.7)
	$T + H$ splines	−629	−632	−2.1 (2.7)

Table S9. On-site logger weather compared with ERA5-Land reanalysis, with and without the MWI. All models are zero-inflated negative binomial fits to the trap-periods with logger coverage ($n = 228$ for *Ae. albopictus*, 224 for *Cx. pipiens*), controlling for trapping effort and trap random effects. Wind is excluded from both sources, because the loggers do not measure it, and the zero-inflation component is an intercept only, so that the sole difference between cells is the count-component weather term. The final column is the paired ELPD difference with its standard error. Passing the logger readings through the MWI costs 69 and 22 ELPD units relative to ERA5; entering the same readings as raw temperature and relative humidity removes the gap entirely, at every level of flexibility. For reference, the trapping-effort-only null scores −745 and −661.

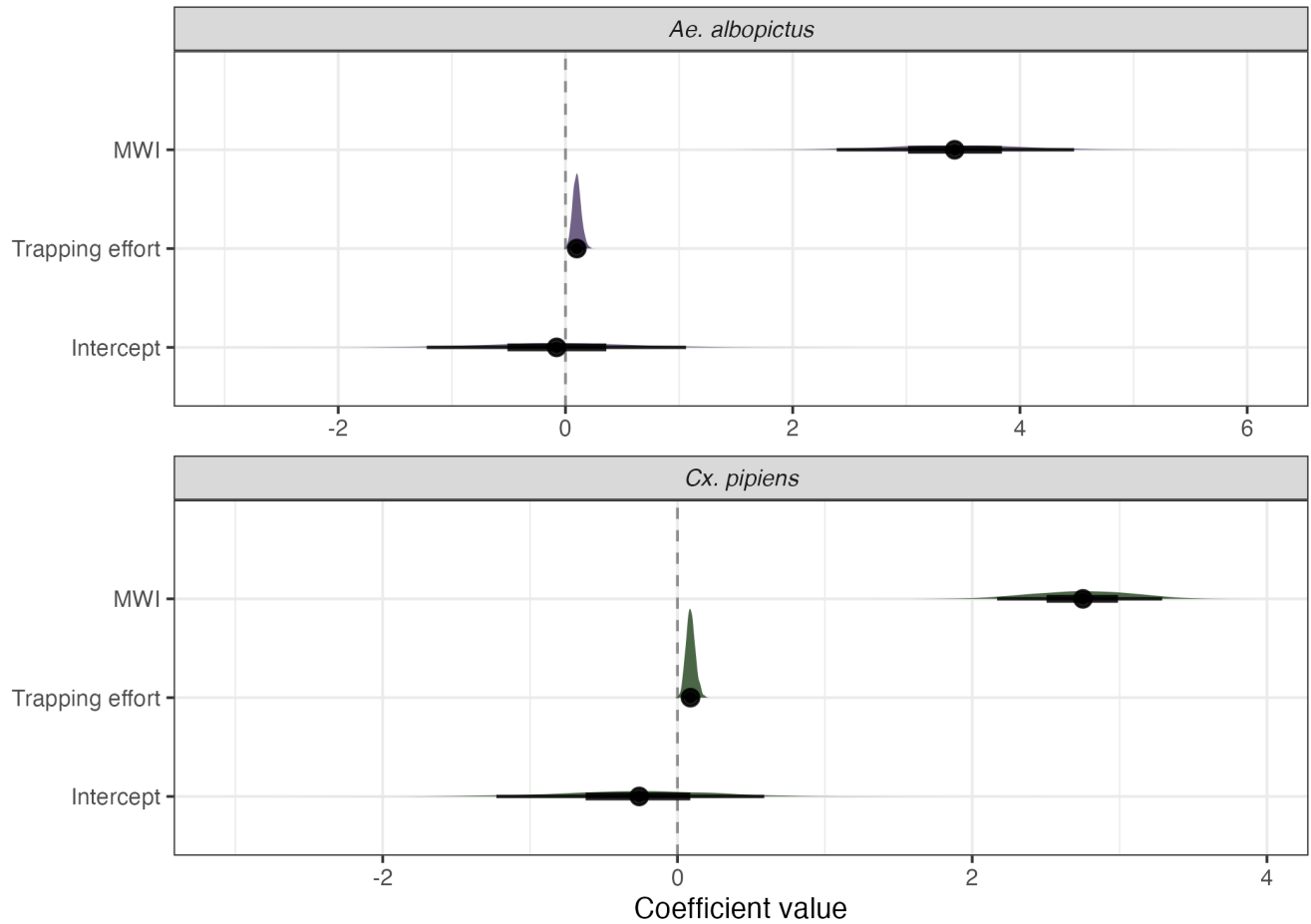


Figure S3. Posterior distributions of the count component (log-mean) coefficients of the primary zero-inflated negative binomial models for *Ae. albopictus* (top) and *Cx. pipiens* (bottom). Points show the posterior median and horizontal bars the 50% and 90% credible intervals; the dashed line marks zero. The coefficient on MWI is credibly positive for both species.

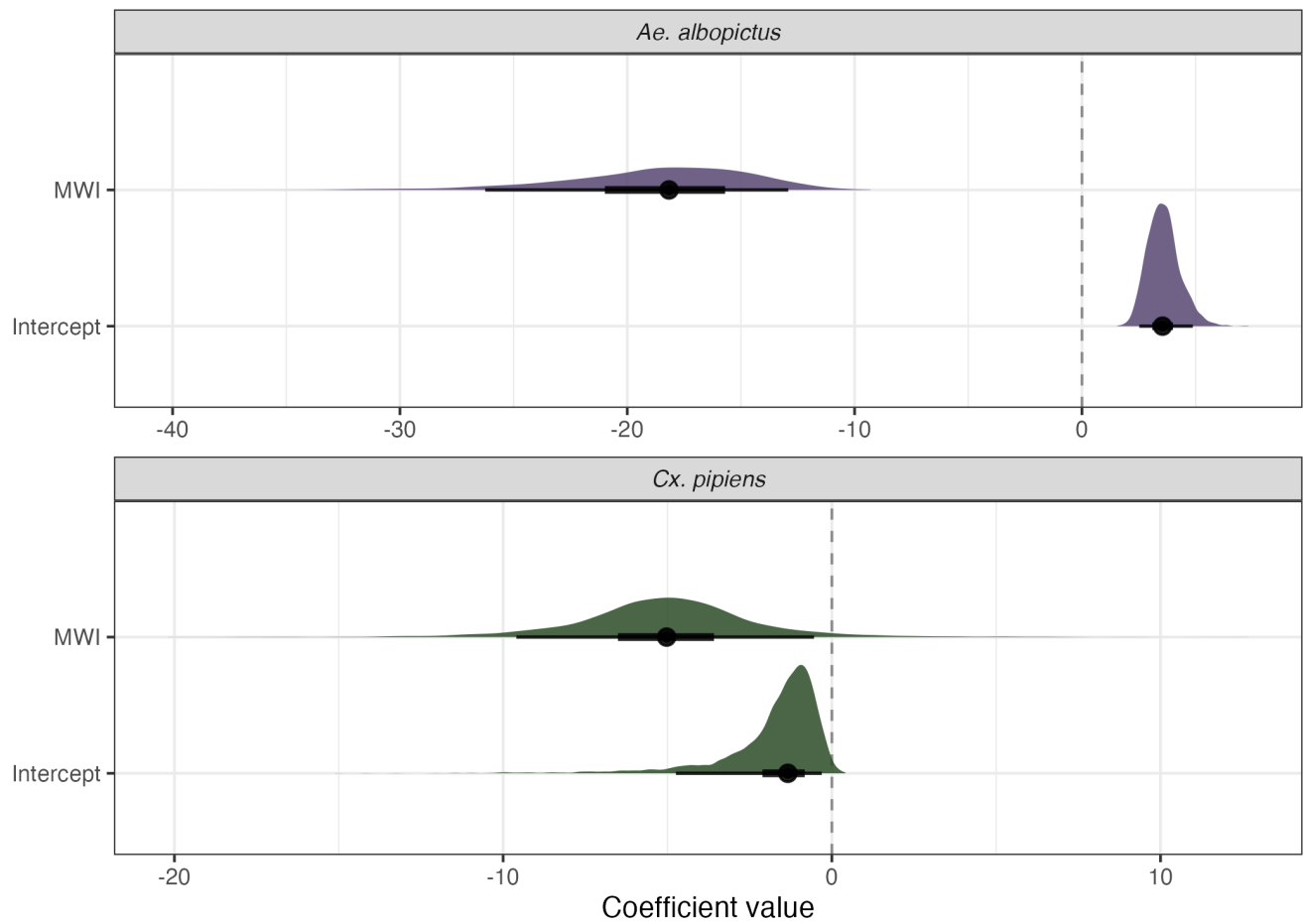


Figure S4. Posterior distributions of the zero-inflation-component (logit) coefficients of the primary zero-inflated negative binomial models for *Ae. albopictus* (top) and *Cx. pipiens* (bottom). Points show the posterior median and horizontal bars the 50% and 90% credible intervals; the dashed line marks zero. A negative coefficient on MWI means that higher MWI lowers the probability of a structural zero (no mosquitoes in the trap); this effect is credibly negative for *Ae. albopictus*, and also for *Cx. pipiens* at the 90% level, though more weakly (the wider 95% credible interval would include zero).

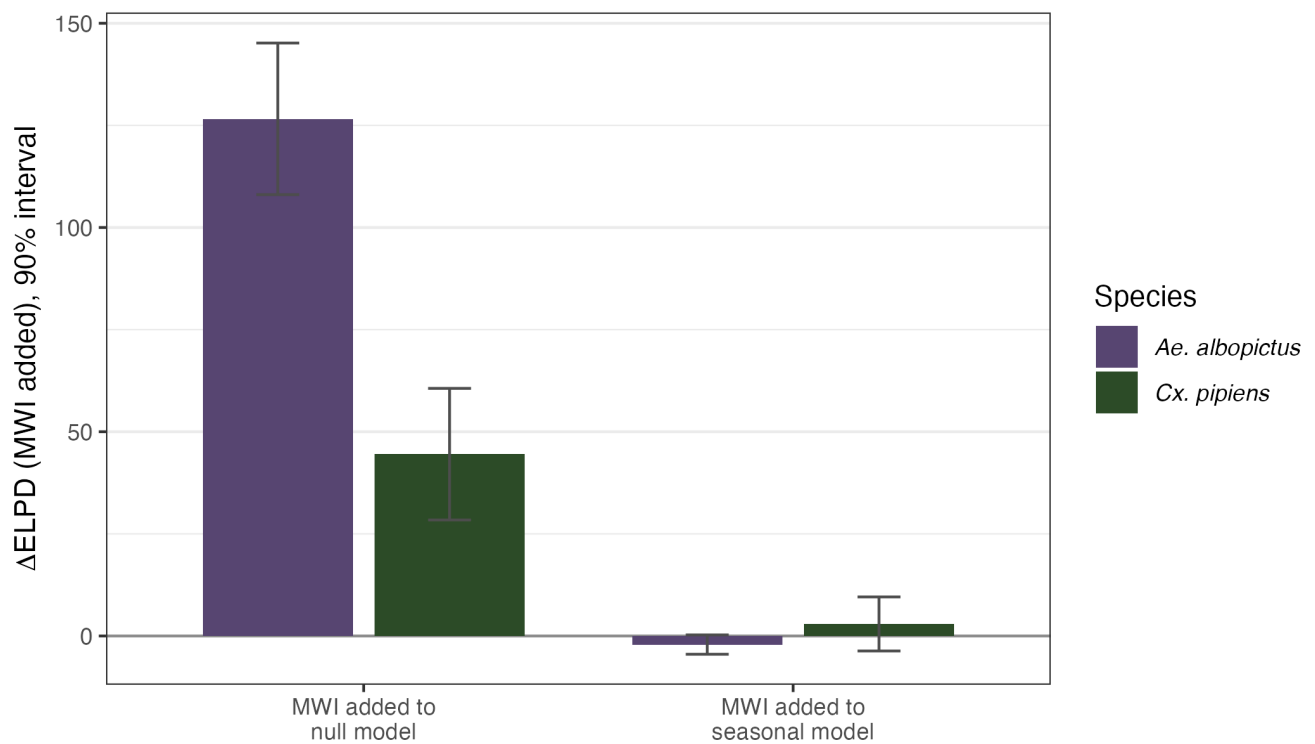


Figure S5. Improvement in leave-one-out predictive accuracy (ΔELPD) from adding MWI to models with only trapping effort and trap random effects, with and without a seasonality term. Bars are coloured by species and error bars show 90% credible intervals ($\Delta\text{ELPD} \pm 1.645 \cdot \text{SE}$). Adding MWI helps substantially for both species, but adds little once seasonality is present.

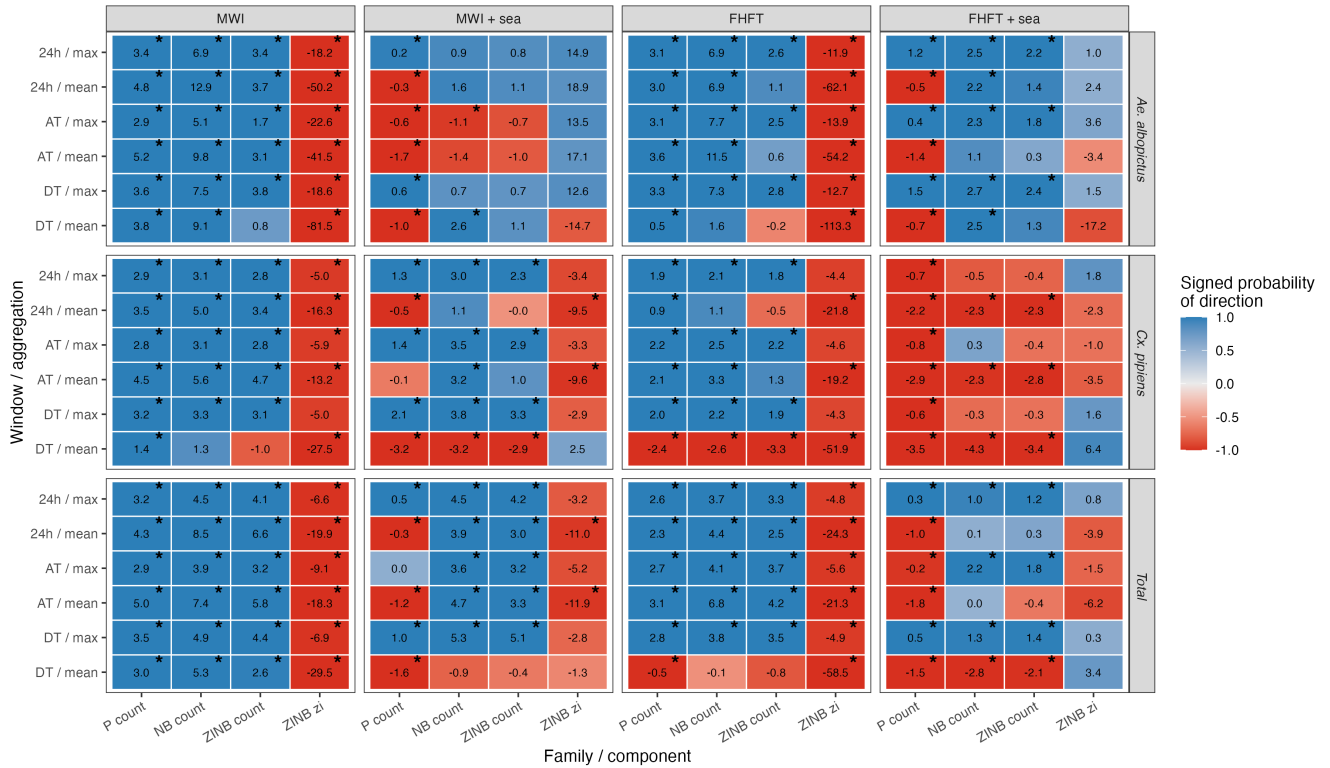


Figure S6. Index (MWI/FHFT) coefficient across the full set of models, including the FHFT index (the temperature–humidity index, i.e. MWI computed without the wind-speed factor) alongside MWI (the MWI-only subset is shown in the main text, Figure 2). Cell fill is coloured based on the signed probability of direction (blue positive, red negative; colour saturation reflects certainty), and an asterisk marks cells whose 90% credible interval excludes zero. The value labels show the posterior median coefficient on the model’s native link scale (log for the count component, logit for the zero-inflation component). Each row shows a different combination of daily aggregation window—full 24 hour vs. two-hours right after sunrise and two-hours right before sunset (AT) vs. full daylight hours (DT)—and aggregation statistic—maximum vs. mean. Columns show model outcome—MWI vs. FHFT—and whether or not a seasonality term is included; facet rows are species—*Ae. albopictus*, *Cx. pipiens*, and both species pooled.

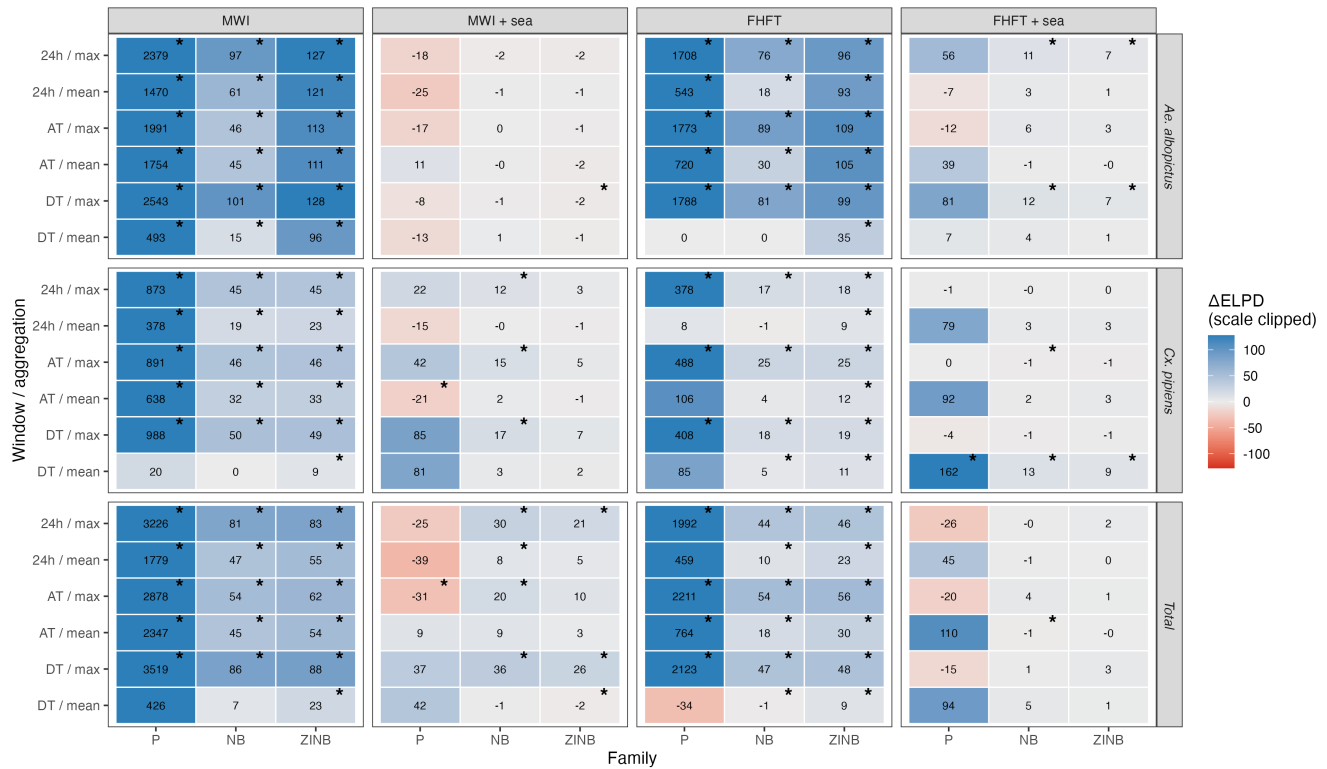


Figure S7. Leave-one-out predictive gain (ΔELPD) of each index model relative to its matched no-index version, across the full set of model specifications including the FHFT index (the MWI-only subset is shown in the main text, Figure 3). Blue indicates the index improves held-out prediction and red indicates it worsens it; asterisks mark cells whose 90% intervals ($\Delta\text{ELPD} \pm 1.645 \cdot \text{SE}$) exclude zero. Because the Poisson models produce artificially large values, the fill scale is clipped to the non-Poisson range (Poisson cells are shown at the extreme colour); cell labels show the actual ΔELPD values. Rows are aggregation window—24 hour, daylight hours (DT), or 2 hours after sunrise and before sunset (AT)—and aggregation statistic (mean or max); columns are model distribution family (Poisson, negative binomial, or zero-inflated negative binomial); facet rows are species and facet columns are index type (MWI or FHFT) crossed with seasonality.

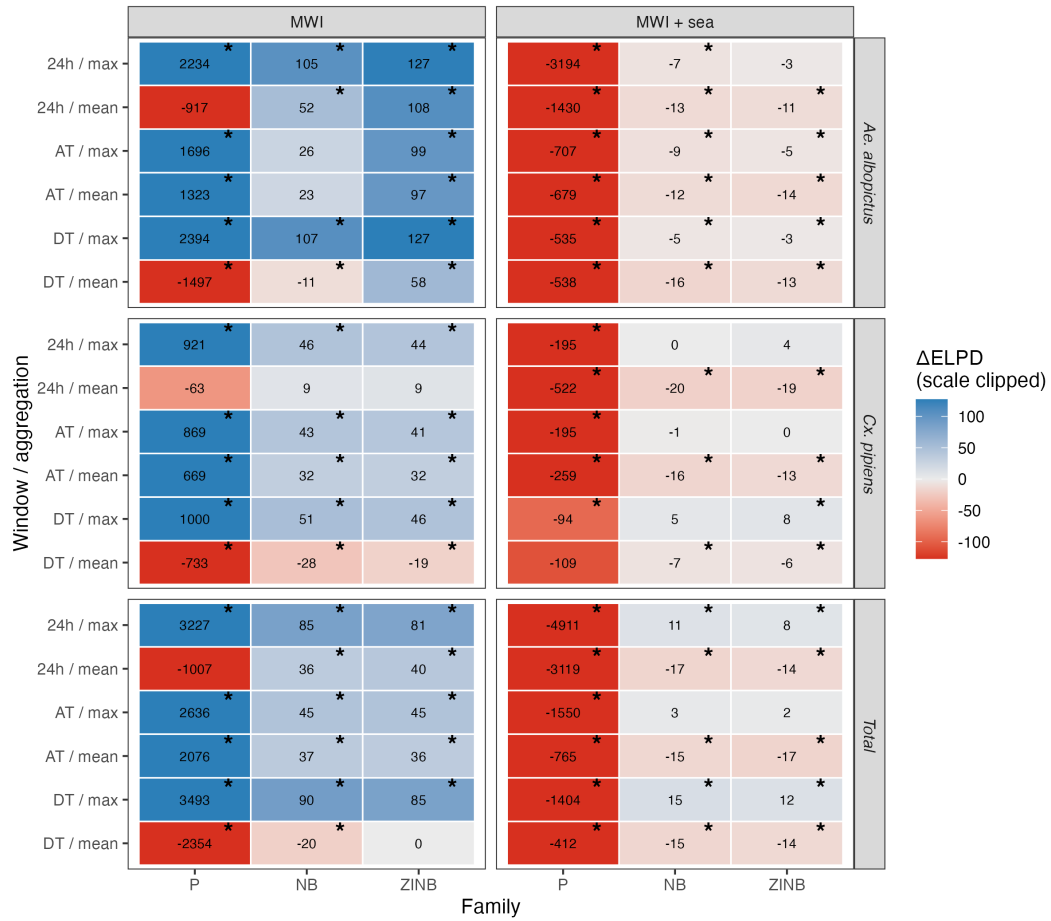


Figure S8. Leave-future-out forecasting gain (ΔELPD) of each MWI model relative to its matched no-MWI version, pooled across the 12 monthly forecast origins, for the same grid of specifications as Figure 3 of the main text. Blue indicates MWI improves the forecast and red indicates it worsens it; the colour scale is clipped to the non-Poisson range (Poisson cells shown at the extreme colour) and cell labels give the actual ΔELPD . Rows are aggregation window and statistic; columns are distribution family; facet rows are species and facet columns are MWI with and without a seasonal term.