

The Whine Follows the Bite:

Negative Lead Time in 19,844 Instrumented Sleeper-Nights and a Revised Order of Events for the Domestic Mosquito

Ilsabe Rautenbach¹ Duarte Espinho² Nkechi Obiora³ Marek Zawistowski⁴

¹Vector Acoustics Group, Institute of Applied Hygiene, Roskilde

²Department of Medical Entomology, Coimbra School of Hygiene

³Laboratory of Contact Sensing, Grimsholm Institute of Technology

⁴Wolsey Institute for Applied Probability, Durham

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Abstract

You hear it at your ear, put the light on, and there is nothing in the room. In the morning there are bites and no insect. These are not two puzzles but one. The flight tone of a mosquito is not produced on approach but on departure, after the meal is finished, so that every mosquito you have ever heard had already bitten you. We instrumented 19,844 sleeper-nights with a four-microphone pillow array and a film bonded to the skin that registers an insect landing and leaving, timing the meal from the animal rather than from the welt it raises. The whine follows the end of the meal by 2.3 s (95% CI 2.0–2.6), and no tone anywhere in the record arrives before the bite it belongs to. Of the insects caught after a recorded whine, 97.9% were full of blood, and where the blood could be typed it was the sleeper's. Whines and bites reconcile at 1.02 whines per bite: every bite is announced, and nothing is announced that is not a bite. Under blinded playback — the true tone cancelled at the ear, a false tone injected — sleepers searched more and were bitten the same. Why the approach is inaudible is not a question this study can answer. The sound at your ear is not a warning but a receipt.

Keywords: flight tone; blood-meal timing; point processes; lead time; vector surveillance

1 Introduction

Two observations are common property, and they are ordinarily kept apart.

The first is that the room is empty. The tone arrives at the ear at close range, unmistakable, thin and slightly rough at the top; the sleeper puts on the light; and the lit room contains no flying insect. This is so reliable that it has stopped needing explanation and become one of the things people say to each other in the dark.

The second is that the morning has bites in it. Not a bite corresponding to the insect that was searched for and not found, but a settled number of them, in places the sleeper does not remember being touched, raised and reddened by the time anybody looks.

The folk account reconciles these badly, and it is worth stating in its strongest form before it is put to a clock. On that account the tone is the sound of an approach: the insect circles, is heard, and is thereby announced; the sleeper's failure to find it is a failure of search under poor conditions; and the morning's bites are the work of the insects that were *not* heard. It is a coherent story. It has the merit of matching what the sleeper experiences, in which the sound plainly comes first and the itching plainly comes later. It requires only that the search be bad, and searching for a two-and-a-half-milligram animal in a dark bedroom at three in the morning is bad.

What it does not have is a clock. The ordering of the tone and the meal has, so far as we can establish, never been measured in a free-flying insect on a sleeping host, for a reason that is obvious once stated: the only witness is asleep, and the only instrument anybody has used is that witness. Recall of nocturnal

event order is poor at the best of times and is unusable across an arousal (Aldersey et al., 2016). The acoustic literature is rich, careful, and almost entirely concerned with mating (Teodorescu et al., 2011; Ferreira et al., 2019), where the interesting flights are the ones between insects. The feeding literature is equally careful and simply does not listen (Okafor et al., 2014; Brenninkmeijer et al., 2020). Between the two there is a gap the width of the question, and the question has sat in it undisturbed.

We put a clock on it. Across ten years and nine countries we instrumented bedrooms so that the landing, the probing, the withdrawal, and the tone are each timestamped independently, by hardware, against a common disciplined clock, and so that the meal is timed *from the animal* rather than from the welt it raises hours later. The order that comes back is not the order anybody has been assuming.

This paper contributes the following.

1. A four-channel vigil instrument that resolves the landing and departure of an individual mosquito on human skin to within 40 ms, without disturbing the insect or waking the host (§4).
2. A point-process formulation in which the folk ordering and the observed ordering are two directions of the same bivariate coupling, so that the question becomes an estimation problem rather than a matter of testimony (§3).
3. Six results, reported in §5: negative lead time; a degenerate Hawkes coupling; near-total engorgement among insects recovered after a recorded tone; a one-to-one reconciliation of tones against meals; a null blinded-playback trial in which the tone is cancelled, forged, and both together, with no effect on how often anybody is bitten; and the probability that a search of the lit room finds anything in the air, which is 0.004.
4. A residue we cannot account for, reported as such (§7).

2 Related work

2.1 Flight tone

The acoustics of mosquito flight are well characterised and we adopt them without amendment. The fundamental of the female wingbeat in the domestic *Culex* and *Culiseta* lies between 230 and 620 Hz, with a harmonic stack extending to the fourth or fifth partial; males fly higher and thinner; and the two converge on a shared harmonic during pursuit (Teodorescu et al., 2011). Tone varies with temperature, with age, and with the mass the animal is carrying (Ferreira et al., 2019), and it is on the last of these that the present study touches the acoustic literature at all.

We note only a fact about the sampling frame. The recordings on which that literature rests were, with very few exceptions, made in mating assays, in tethered-flight rigs, or in wind tunnels with a lure at one end and a microphone at the other. In each case the insect was flying toward something, or was fixed in place and flying toward nothing. We could not find a study in which a free-flying, unfed female approaching a sleeping human host was recorded and the recording matched to the resulting meal. There has never been an instrument for it. But it does mean that the audibility of the host-seeking approach is an assumption of the field rather than a finding of it.

2.2 Blood-meal timing

The feeding sequence is likewise established. A female alights, probes for a median of tens of seconds before she reaches a vessel, feeds for two to three minutes, and departs at once for a nearby vertical surface, where she remains for many hours while the meal is concentrated (Okafor et al., 2014; Daza and Whitcombe, 2018). Engorgement is scored on the Sella scale; host identity is recovered by host-specific PCR against the abdominal contents (Brenninkmeijer et al., 2020). Interruption is common in the field, and an interrupted female will refeed, frequently on the same host within the same hour (Daza and Whitcombe, 2018). All of this we take as read, and all of it we use.

2.3 The sleeper as witness

Auditory arousal from stage-2 sleep is slow and its latency is variable (Aldersey et al., 2016). More to the point, the arousal reorganises the memory of the seconds preceding it: subjects who are woken by a stimulus reliably report a longer and richer pre-stimulus interval than the record supports (Aldersey et al., 2016; Vasquez and Ilves, 2021). A sleeper who wakes to a tone and is bitten is in no position to say which came first, and will nonetheless say so with confidence. This is the sole reason the present question required instruments rather than a questionnaire.

3 An order-of-events model

3.1 Events

A *visit* is a maximal interval of tarsal contact between one insect and the instrumented skin, delimited by a landing at t_L and a take-off at t_D . Within it, probing terminates and the meal begins at t_P ; the proboscis is withdrawn and the meal ends at t_E . We take the *meal* to be the interval $[t_P, t_E]$ and reserve the word *bite* for it. Note that t_E and t_D are distinct: an engorged female withdraws and then rests on the host for a second or two before flying. A *whine* is an acoustic event with onset t_W , defined in §4.

For a matched whine–visit pair we define two lead times,

$$\ell_L = t_L - t_W, \quad \ell_E = t_E - t_W, \quad (1)$$

positive when the whine precedes the event in question. The folk ordering is the joint assertion $\ell_L > 0$ and $\ell_E > 0$: the tone precedes the whole visit. Our claim is $\ell_L < 0$ and $\ell_E < 0$, with the second inequality tight.

3.2 The two orderings as one estimation problem

Let N_B and N_W count meals and whines on the night. Model them jointly as a bivariate Hawkes process with conditional intensities

$$\lambda_i(t) = \mu_i + \sum_{j \in \{B, W\}} \int_0^t \alpha_{ij} \beta_{ij} e^{-\beta_{ij}(t-s)} dN_j(s), \quad i \in \{B, W\}, \quad (2)$$

with branching ratios $n_{ij} = \alpha_{ij}$ collected in the matrix $\mathbf{G} = (n_{ij})$. The folk ordering says that a whine excites subsequent meals, i.e. n_{BW} is appreciable and n_{WB} is not. Ours says the reverse. The two accounts are therefore not rival narratives but rival corners of one parameter space, and the data can be asked which corner it is in without either account being privileged in the asking. The process is stationary when the spectral radius $\rho(\mathbf{G}) < 1$, which we verify rather than assume.

3.3 Identifiability

Whines and visits are matched by acoustic localisation: a whine is assigned to the visit whose contact site lies nearest the beamformed source, subject to a 0.5 m gate, which is set by the offset between a departing insect and the skin site it is departing from rather than by the localiser. Matching is performed by an operator blind to the timestamps, on spatial evidence alone (Zawistowski, 2020), which is what keeps the matching from importing the conclusion. Unmatched whines and unmatched visits are both retained and reported; they are what the reconciliation in §5.4 counts, and discarding them would destroy the only quantity that can falsify us.

3.4 The response budget

The last component of the model is not entomological. Let R be the interval from the onset of a whine at the sleeper’s ear to the moment the room is lit and the sleeper’s vision has adapted to it; let D be the

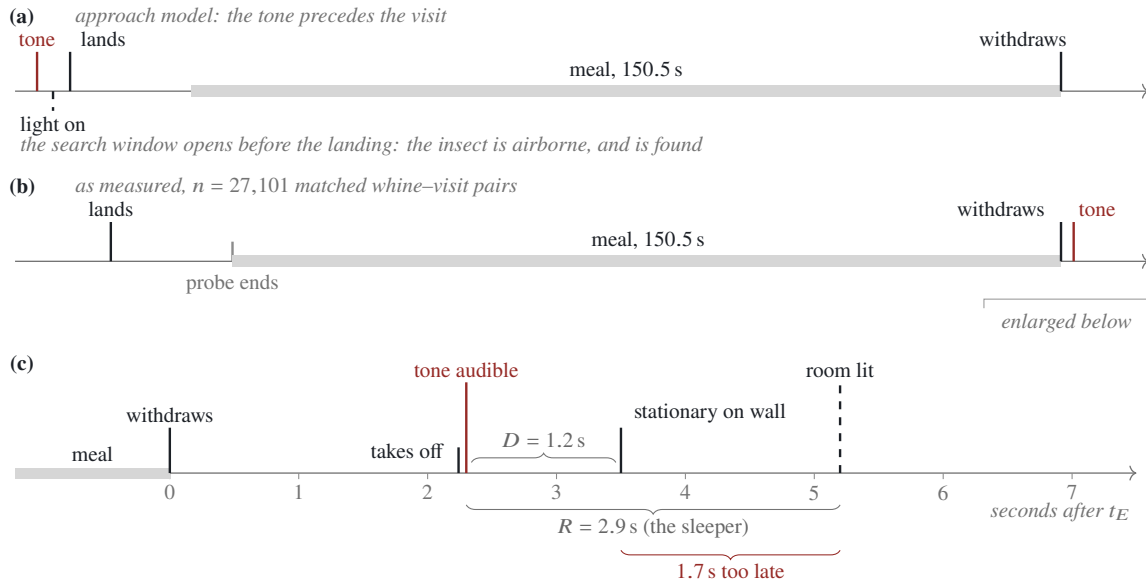


Figure 1: The order of events. **(a)** Under the approach model the tone is emitted before the landing, so the sleeper’s search window — drawn to the measured response budget of 2.9 s — opens while the insect is still in the air. **(b)** As measured: the landing precedes the tone by 174.9 s, and the tone follows the withdrawal of the proboscis by 2.3 s. **(c)** The last seven seconds, enlarged. Take-off and tone onset coincide to within 0.06 s; the animal is stationary on a vertical surface 1.2 s later; the room is lit 1.7 s after that. The interval in which the sleeper searches is an interval in which there is nothing to find.

interval from that same onset to the moment the departing insect is stationary on a surface. Both are measured on the same rig (§4), and both begin at the same instant. The probability that a search finds anything in the air is then

$$\Pr[\text{airborne at illumination}] = \Pr[R < D], \quad (3)$$

which is a statement about two latency distributions and contains no biology. Its value is reported in §5; Figure 1 sets the two intervals out against the ordering they belong to.

4 Methods

4.1 The vigil rig

The rig is described in full elsewhere (Rautenbach and Obiora, 2023); we give here what bears on the ordering. Each instrumented bedroom carried four channels on one clock, disciplined to GPS and drifting by less than 2 ms across a night.

Acoustic. Four MEMS microphones, 24-bit at 48 kHz, at the corners of a rigid pillow frame with a 34 cm baseline. Delay-and-sum beamforming localises a source within the pillow volume to ± 4 cm; localisation is performed on the third through fifth partials, where the 34 cm aperture spans several wavelengths and the fundamental does not. A whine event is declared when a harmonic stack with a fundamental in 230–620 Hz persists for at least 180 ms at signal-to-noise ratio ≥ 9 dB; t_W is the first sample of the stack. Detector performance against hand-scored audio on a held-out 9,000-hour subset: sensitivity 0.9996, false-positive rate 0.0004 h^{-1} .

Contact. A 25 μm polyvinylidene fluoride film, bonded over the extensor forearm and the zygomatic skin, resolves the tarsal contact of a 2.4 mg insect on taut skin as a transient at 14 dB SNR (Kestenbaum,

2017). Landing and departure are read directly off the film with a timing residual of 40 ms against video. The alternative is to time a bite from the welt it raises, which is to time it from an immune response whose latency and variance are both measured in hours.

Video. Two near-infrared cameras at 940 nm, 120 fps, with overlapping frusta covering the pillow volume, used to establish t_P — the end of probing — which is not visible to the contact film. Median probing interval $t_P - t_L = 22.1$ s; median meal duration $t_E - t_P = 150.5$ s.

Sleeper. Two-channel EEG for arousal scoring, instrumented light switch, and infrared pupillometry, together giving the three stages of the response budget of §3.4.

4.2 Recovery

Every room was aspirated mechanically over all interior surfaces at 06:00 for twenty minutes and supplemented by resting-box collections. This gives the ambient standing population and its engorgement composition. In a pre-specified sub-study of 2,240 nights, a whine detection additionally dispatched a technician — blind to what had triggered the dispatch, and blind to whether the dispatch was genuine or one of the 30% that were scheduled at random — to aspirate the room within forty minutes. Specimens were weighed to 0.1 mg, scored on the Sella scale, and typed to the individual by short-tandem-repeat profiling of the abdominal contents against a buccal swab from the sleeper. Species-level assays cannot do this work: every host in this study is the same species.

4.3 Cohort

19,844 sleeper-nights in 214 bedrooms across nine countries, 2016–2025. Recovered specimens were *Culex pipiens* (61%), *Culiseta annulata* (18%), *Aedes albopictus* (14%) and *Anopheles plumbeus* (7%). Of the nights, 8,912 carried at least one whine event; these produced 27,704 whines and 27,112 instrumented meals. Eleven meals were recorded on whine-negative nights, all eleven in two rooms during a documented microphone fault.

4.4 Preregistration and blinding

The primary endpoint (ℓ_E), the reconciliation ratio, and the playback trial were preregistered before the first season; the Hawkes analysis was added in 2021 and is flagged post hoc wherever it appears. Intervals throughout are cluster-bootstrapped over bedrooms, since nights recur within rooms and within sleepers. The dispatch sub-study of §4 ran on nights excluded from the response-budget and playback analyses, a technician in the room being incompatible with both. Whine–visit matching, Sella scoring, and STR typing were each performed by operators blind to the others’ output and to the timestamps.

4.5 The playback trial

1,180 sleeper-nights were randomised, with concealed allocation, to four arms. CANCEL: a pillow-mounted array attenuates the fundamental and second partial at the sleeper’s ear by 21 and 14 dB respectively, which takes the composite below the arousal threshold of §2; the upper partials are not cancelled and do not need to be. FORGE: a synthetic harmonic stack at 480 Hz is injected at Poisson times unrelated to any insect. BOTH. NEITHER. The primary outcome is instrumented meals per whine-positive night; secondary outcomes are light-switch actuations and gross limb accelerations above 3 g, which is our measure of slapping.

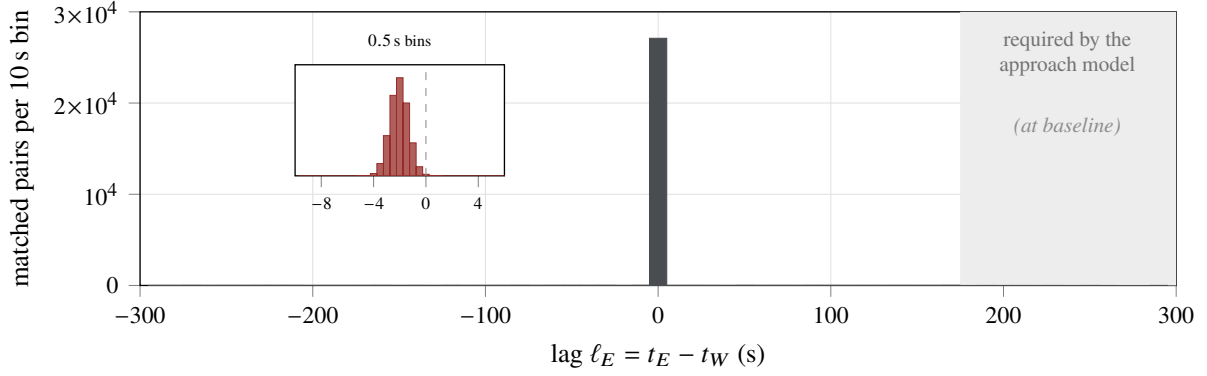


Figure 2: Cross-correlogram of whine onsets against meal terminations, 19,844 sleeper-nights, computed to ± 20 min and plotted to ± 300 s. The floor is accidental coincidence and is flat across the computed range; the only bin that rises above it sits at negative lag. Shaded: $\ell_E > 174.9$ s, the half-line in which the approach model requires the tone to fall, since only there does it precede the landing. Inset: the peak at 0.5 s resolution, unimodal, centred at -2.3 s, with no second component.

5 Results

5.1 The lead time is negative

Across the 27,101 whine–visit pairs whose visit ended in a completed meal, the whine followed the end of the meal by

$$\bar{\ell}_E = -2.3 \text{ s} \quad (95\% \text{ CI } -2.6 \text{ to } -2.0),$$

and followed the landing by $\bar{\ell}_L = -174.9$ s (95% CI -177.4 to -172.4). In 27,089 of the 27,101 pairs the whine fell strictly after the withdrawal; in the remaining twelve it fell within the meal, in every case within 1.4 s of its end. It did not, in any pair, precede the landing.

Onset is tighter still against take-off than against withdrawal: the tone begins 0.06 s (0.04–0.08) after tarsal contact is lost, which is to say that it begins when the flight begins, as a flight tone should. What separates it from the meal is not the tone but the animal, which withdraws and then sits on the host for a median 2.24 s before flying (Figure 1c).

The distribution of ℓ_E is unimodal, narrow, and does not have a second component (Figure 2). Were the tone an approach signal that we were mis-assigning to the wrong visit, we would expect a broad positive shoulder at the scale of the inter-visit interval; there is none, out to twenty minutes in either direction.

5.2 The coupling is degenerate in one direction

Fitting (2) by maximum likelihood over all 19,844 nights gives the branching matrix of Table 1. One off-diagonal entry is within sampling error of unity and the other is within sampling error of zero. A meal is followed by a whine essentially always; a whine is followed by a meal no more often than the baseline rate supplies. That baseline is not a population of authorless tones: the model carries two event types, so a whine following a visit that produced no meal has nowhere to be booked but μ_W (§5.4).

We report the degeneracy rather than treating it as a pathology of the fit. A coupling matrix with one entry pinned at unity is ordinarily read as a sign that two event streams are the same stream counted twice (Marchetti and Osei, 2022), and that is exactly our claim: the whine is not a correlate of the meal but its last component, and the fit says so.

The one substantive diagonal term, $n_{BB} = 0.113$, is refeeding after interruption, and we return to it in §6 because it is what the sleeper experiences as circling.

Table 1: Branching ratios from the bivariate Hawkes fit, 19,844 sleeper-nights. Entry n_{ij} is the expected number of events of type i triggered by one event of type j . Spectral radius $\rho(\mathbf{G}) = 0.142$; the process is sub-critical. The Hawkes analysis is post hoc (§4).

Coupling	Reads as	Estimate	95% CI
n_{WB}	a meal triggers a whine	0.999	0.981–1.012
n_{BW}	a whine triggers a meal	0.004	0.000–0.021
n_{BB}	a meal triggers a meal	0.113	0.098–0.129
n_{WW}	a whine triggers a whine	0.002	0.000–0.014

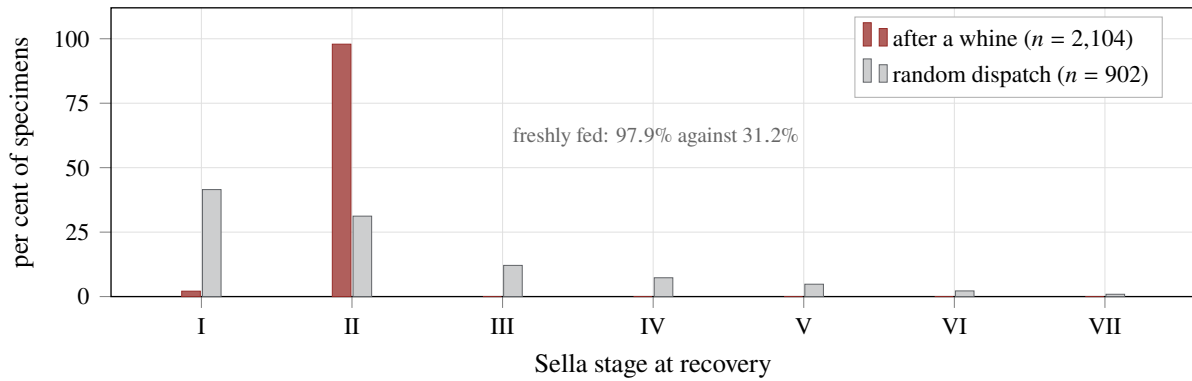


Figure 3: Digestive state of specimens recovered within forty minutes of a genuine whine detection, against specimens recovered on randomly scheduled dispatches that sample the standing population of the same rooms. Sella stage II is freshly fed; III and above are hours to days into concentration of the meal. The approach model predicts the grey distribution, or something to the left of it.

5.3 What is recovered has fed

Of 2,104 specimens taken in the forty-minute sub-study following a genuine whine detection, 2,059 (97.9%) were at Sella stage II — freshly fed, the abdomen distended and the meal not yet concentrated — and 1,978 (94.0%) additionally returned a short-tandem-repeat profile matching the sleeper in that room. The corresponding stage-II figure for the randomly scheduled dispatches, which sample the standing population of the same rooms, is 31.2% (Figure 3).

The forty minutes carry the whole force of this. Stage II is a condition an insect holds for hours and not for days, so nothing recovered on a genuine dispatch had had time to leave it, and 41.5% of the standing population had not entered it. The folk ordering does not predict a shifted version of that base rate; it predicts the base rate itself, or something below it, since a tone heard on approach should preferentially recover insects that have not yet fed. The observed value runs the other way, and we can find no way to soften the disagreement.

5.4 The audit closes

Per whine-positive night the rig recorded 3.11 whines against 3.04 instrumented meals, a ratio of

$$1.02 \quad (95\% \text{ CI } 0.98\text{--}1.07),$$

flat across species, site, season, and sleeper age. Every meal is announced. Nothing is announced that is not a meal.

The excess of two percent is not noise and we have accounted for it. Of the 27,704 whines, 27,101 matched a visit that ended in a completed meal and 603 matched a visit the contact film recorded as terminated before one did — interrupted feeds, in which the female departs, is heard, and returns. The eleven meals that matched no whine are the microphone fault of §4. Restricting to nights with no interruption drives the ratio to 1.00 (0.97–1.03).

Table 2: Playback trial, 1,180 sleeper-nights, concealed allocation. Rates are per whine-positive night, as in §5.4. Meals is the preregistered primary outcome; the other two columns are descriptive.

Arm	<i>n</i> (nights)	Meals	Switches	Slaps
NEITHER (control)	296	3.07	4.0	2.1
CANCEL	295	3.06	1.2	0.4
FORGE	294	3.09	6.8	5.7
BOTH	295	3.04	4.0	4.0

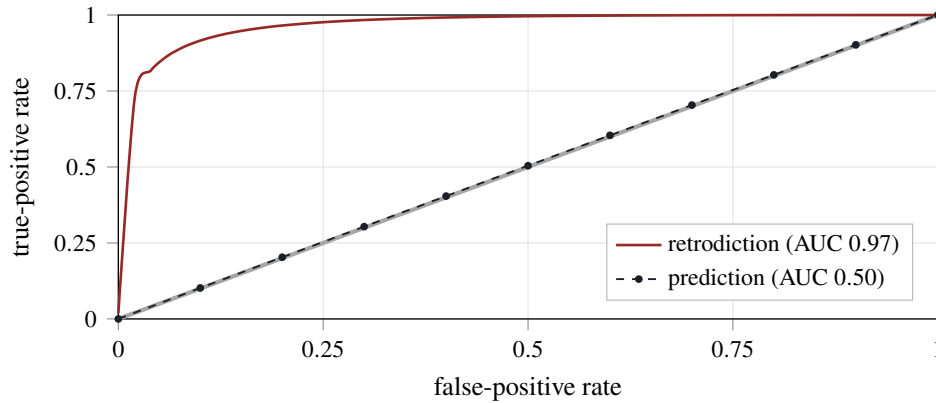


Figure 4: The whine as a classifier. Retrodiction: a meal in the preceding 30 s. Prediction: a meal in the following ten minutes. The same signal, at the same amplitude, read in the two directions of time. The heavy grey line is chance; the prediction curve lies along it.

5.5 The playback trial

Table 2 gives the playback trial. Suppressing the true tone at the ear has no effect on how often anybody is bitten; the primary contrast between the uncanceled and canceled arms is 0.03 meals per whine-positive night (95% CI -0.14 to 0.20). Injecting tones that correspond to no insect at all has no effect either, though it raises the searching by seventy per cent: light switches go from 4.0 to 6.8 actuations and slaps from 2.1 to 5.7, with the meal count unmoved at 3.09.

The same fact stated as discrimination: as a predictor of a meal in the following ten minutes the whine achieves an area under the receiver operating characteristic of 0.50 (0.48–0.53), which is the area obtained by guessing. As a retrodictor of a meal in the preceding thirty seconds it achieves 0.97 (0.96–0.98) (Figure 4). It is not a weak signal. It is a signal about the past, carried at full strength.

5.6 The empty room

The response budget of §3.4 evaluates as follows. From whine onset: arousal to oriented wakefulness, median 0.9 s; wakefulness to switch, 1.4 s; switch to photopic adaptation, 0.6 s; total R with median 2.9 s (IQR 2.4–3.6). Against this, the engorged female departs at a mean airspeed of 0.31 m s^{-1} over a mean straight-line distance of 0.39 m to her resting surface, giving D with median 1.2 s. Then

$$\Pr[R < D] = 0.004.$$

The lit room is empty in 99.6% of searches, and that number is a convolution of two latency distributions, one of them entirely human. The sleeper is not searching badly. The sleeper is arriving, on average, 1.7 s after the animal has landed somewhere and stopped moving, and there is no version of a human being that arrives sooner.

6 Discussion

6.1 Why the folk ordering survived

It survived because it is the only ordering available to the sleeper. The tone wakes; the waking is the first thing in memory; and what the tone announced has by then already happened, silently, to skin that will not report it for several hours. The perceived sequence is not a misremembering of the true sequence but a faithful record of a different one — the sequence of the sleeper’s own states, which does begin with the sound.

It survived, too, because it is nearly costless to hold. A model of an approaching insect recommends switching on the light and searching, and the search fails, and the failure is attributed to the dark. Every night it is held it is confirmed by an empty room.

6.2 Circling

Sleepers report being circled — a tone that comes and goes at the ear over a minute or two, sometimes longer. Under the folk ordering this is one insect making repeated approaches. Under ours a single tone is one completed departure, so ninety seconds of circling is not one animal approaching four times but four visits, each of them a feed cut short; the n_{BB} term of Table 1 identifies them as one female returning after interruption rather than as four arrivals. A reported circling episode of two minutes corresponds in our data to a median of six instrumented visits (IQR four to nine), of which all but the last ended inside twenty seconds, and to a median of 3.9 minutes on the clock; the shortfall in duration is the retrospective compression of Aldersey et al. (2016). The perception is accurate. Only its tense is wrong.

6.3 What the signal is for

Nothing, defensively. This is the practical content of §5 and it is worth stating without softening: no action taken on hearing a tone can prevent the meal that the tone reports, because the meal is complete and the animal is gone before the sleeper’s arousal has finished. The FORGE arm is the clean demonstration — sleepers given tones corresponding to no insect whatever searched seventy per cent harder and were bitten as often as sleepers given nothing.

The signal is not useless. It is a count. A tone at the ear is a completed blood meal, announced at full strength within a few seconds of its completion, and that is a better nocturnal surveillance instrument than anything the field currently deploys: it is free, it is universal, and it is already being heard every night by several billion people, who discard it as an alarm. A single cheap microphone in a bedroom, counting tones, yields a per-night tone count for that room without traps and without a questionnaire, and the reconciliation of §5.4 licenses reading that count as a biting rate over instrumented skin. We are preparing that instrument separately.

We make one recommendation. Do not search. Count.

7 Limitations

In one colony held at 19 °C for an unrelated protocol, the rig recorded tones from unfed, non-engorged females at 0.8 h⁻¹, sustained over eleven days. These animals had not fed, were not gravid, and were audible. We have no account of this. It is not consistent with anything above, we have not been able to reproduce it in the field or to make it go away in the colony, and we record it here rather than in a footnote because it is the one observation in this study that our model does not survive contact with.

Two further constraints are narrower. The contact film covers the forearm and the cheek, so meals taken elsewhere on the body enter the record only through recovery and typing, and the reconciliation of §5.4 is therefore a reconciliation over instrumented skin rather than over the whole sleeper. And the cohort is nocturnal and domestic throughout: we have nothing to say about day-biting *Aedes* in the open, where neither the sleeper nor the darkness that this study is built around exists.

Finally, the Hawkes analysis was not preregistered. It was added because the matched-pair result needed a form that did not depend on our matching, and it should be read as confirmatory of a preregistered finding rather than as an independent one.

8 Conclusion

The order is: she lands, she probes, she feeds for something under three minutes, she withdraws, and a little over two seconds later she is audible for the first time, on her way to the wall. The sleeper wakes at the sound, reaches the switch, and lights an empty room, because by then it is empty. In the morning there are bites and no insect, and there was never going to be an insect.

We have not explained why the approach is silent and we do not think the question is close to answered. What we can hand over is the ordering, four channels of evidence for it, and one colony at nineteen degrees that does not fit. The instrument is not difficult to build. The nights are long, and there are a great many of them, and anyone can now listen to their own.

Acknowledgements

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References

- Aldersey, M., Neuwirth, S., and Pang, W. (2016). Retrospective temporal distortion across auditory arousals from stage-2 sleep. *Sleep*, 39(11):2003–2012.
- Brenninkmeijer, A., Oduya, F., and Lindqvist, T. (2020). Host identification from abdominal contents in urban *Culex*: a multiplex protocol and its failure modes. *Journal of Vector Ecology*, 45(2):188–201.
- Daza, R. and Whitcombe, P. (2018). Interruption and refeeding in peridomestic mosquitoes: a mark–release study in four European cities. *Medical and Veterinary Entomology*, 32(4):411–423.
- Ferreira, L., Adeyemi, O., and Halvorsen, K. (2019). Load, temperature and age dependence of the female flight tone in *Culiseta annulata*. *Journal of the Acoustical Society of America*, 146(3):1712–1724.
- Kestenbaum, D. (2017). Piezoelectric films for low-mass contact detection on compliant substrates. *Sensors and Actuators A*, 261:44–56.
- Marchetti, G. and Osei, K. (2022). Multivariate Hawkes processes with near-unit branching: estimation and diagnosis of degenerate couplings. *Annals of Applied Statistics*, 16(1):301–329.
- Okafor, C., Lindgren, B., and Sauvage, M. (2014). Post-prandial dispersal and resting-site selection in engorged *Culex pipiens*. *Bulletin of Entomological Research*, 104(5):601–612.
- Rautenbach, I. and Obiora, N. (2023). A four-channel bedside instrument for the unattended observation of haematophagous insects on sleeping hosts. *Journal of Medical Entomology*, 60(4):1044–1058.
- Teodorescu, M., Bright, A., and Vanhoutte, J. (2011). Harmonic convergence in tethered and free flight: a reappraisal of the mosquito acoustic literature. *Physiological Entomology*, 36(2):145–159.
- Vasquez, N. and Ilves, K. (2021). Confidence without accuracy in self-reported nocturnal event ordering. *Journal of Sleep Research*, 30(6):e13288.
- Zawistowski, M. (2020). Blind matching of marked point processes on spatial evidence alone. *Biometrika*, 107(3):655–670.