# Slightly Less Simple Mosquito Modeling

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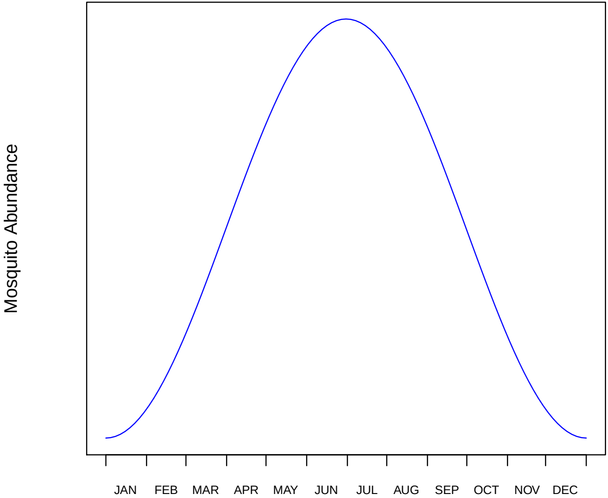
# What's this talk really about?

- finding low-hanging fruit,
- expression with models,
- simple analytical approaches,
- a little dimensional analysis,
- how to connect those with experiments and get higher up the tree, and
- a little about work habits and tools

# A Not Atypical Model of Vector Population



# But. . .

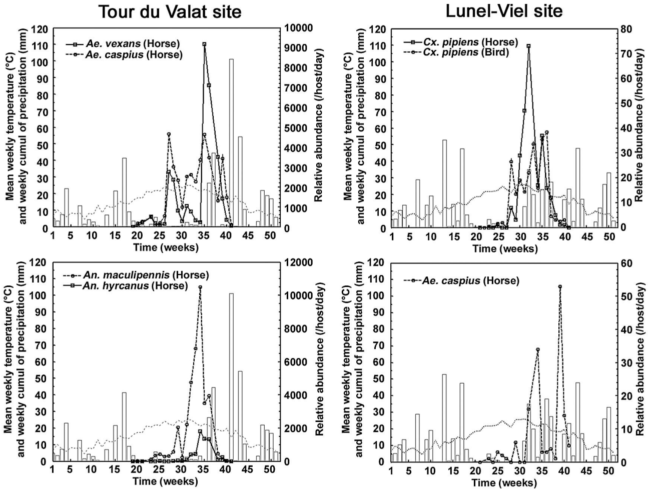



Figure: Bicout et al. "Horse-, Bird-, and Human-Seeking Behavior and Seasonal Abundance of Mosquitos in a West Nile Virus Focus of Southern France". J. Med. Entomol. 43(5): 936-946 (2006)

# So, a Disconnect.

Specifically, it is impossible to match features like peak population, total population over a year, and turnover rate with a functional form

$$M(t) = C \sin(\omega t + \theta)$$

. . . and these features can be critical to predicting transmission dynamics, and thus planning interventions.

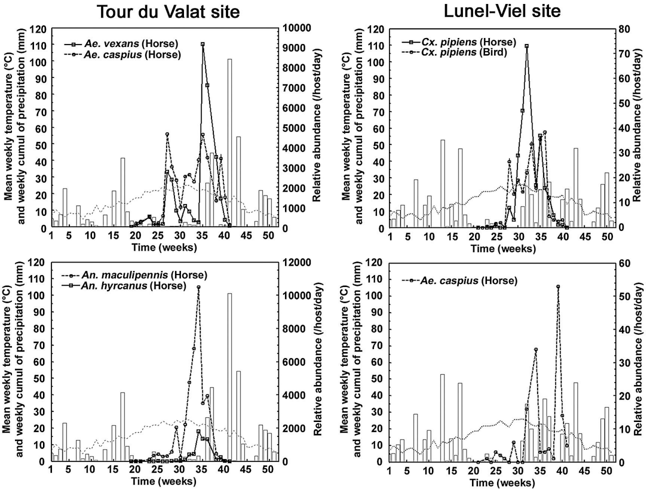
# Do Better, But Keep It Simple

What's appealling about this trigonometric representation?
Simplicity:

- two parameters
- no spatial features
- "easy" analytical form

Possible to identify alternatives that *can* match salient features, but still retain these features?

What are those salient features? Let's look again.



Tour du Valat site
Lunel-Viel site
Ae. vexans (Horse)
Ae. caspius (Horse)
Cx. pipiens (Horse)
Cx. pipiens (Bird)
An. maculipennis (Horse)
An. hyrcanus (Horse)
Ae. caspius (Horse)
Mean weekly temperature (°C) and weekly cumul of precipitation (mm)
Relative abundance (/host/day)
Time (weeks)

- every year,
- over a relatively short duration,
- the mosquito population rapidly increases,
- sits at a high level of activity,
- then rapidly declines,
- apparently connected with resource availability & environmental suitability

What's present in the trigonometric formulation?

- every year, **CHECK!** . . . *but not the rest of:*
- over a relatively short duration,
- the mosquito population rapidly increases,
- sits at a high level of activity,
- then rapidly declines,
- apparently connected with resource availability & environmental suitability

What does the last point tell us? That we need to stub out a connection to an external force. So, instead of just stating that mosquito populations oscillate, let's propose something else, $E(t)$, does and consider what that means for mosquito population*. *I.e.*, consider solutions to:

$$\dot{M}(t) = E(t) - \lambda M(t)$$

*and also just guess that mosquitos, like many other ecological phenomena, decay exponentially when their external resource supply is removed.

# Picking Candidates

We want to meet those criteria, which mostly amount to "spikey" function options, since the sharpness in $E(t)$ will carry over to $M(t)$. There are a variety of functions to satisfy that.
What else would need to ensure?

# Alternatives I

$$E(t) = \begin{cases} \dfrac{M_+}{\Delta t} & t \in \Delta t \\ 0 & \text{otherwise} \end{cases} \qquad \text{(Step)}$$

$$E(\rho, t) = \begin{cases} \dfrac{2M_+}{\Delta t(2-\rho)} & t \in \Delta t(1-\rho) \\ \dfrac{2M_+}{\Delta t(2-\rho)\rho}\left(1 - \dfrac{2|t|}{\Delta t}\right) & t \in \rho\Delta t \\ 0 & \text{otherwise} \end{cases} \qquad \text{(Modified Step)}$$

$$E(t) = \frac{2M_+}{\Delta t}\sqrt{\frac{2}{\pi}}e^{-\dfrac{8t^2}{\Delta t^2}} \qquad (\text{Approximate } \delta)$$

# Alternatives II

$$E(t) = \frac{M_+}{\Delta t}\sqrt{\frac{2}{\pi}}e^{-\frac{\sin^2 \omega t}{\omega^2 \Delta t^2}} \quad (\omega = \frac{\pi}{T}) \quad \text{(Trig. Approximate } \delta)$$

$$E(t) = \frac{M_+}{T}\left(1 + \cos\left(\frac{2\pi}{T}t\right)\right) \qquad \text{(Trig.)}$$

$$E(t) = \frac{(2^n n!)^2}{(2n)!}\frac{M_+}{T}\cos^{2n}\left(\frac{4\pi}{T}t\right) \quad (n = \lfloor 2^{-1}\sin^{-2}\frac{\pi \Delta t}{2T}\rfloor) \qquad \text{(Proper Trig.)}$$

$$E(c,t) = \frac{M_+}{\Delta t}\left[\frac{1}{1+e^{-c(t+\Delta t/2)}} - \frac{1}{1+e^{-c(t-\Delta t/2)}}\right] \qquad \text{(Double Logistic)}$$

# Aside: Dimensional Analysis

Those equations have a lot of parameters, as do the resulting integral solutions.

Fortunately, everything you learned in engineering coursework can apply here as well.

So, how can remove the scales?

# Scale-free Alternatives I

$$\tilde{E}(\rho,\tau) = \begin{cases} \frac{1}{\rho} & |\tau| \leq \rho/2 \\ 0 & \text{otherwise} \end{cases} \qquad \text{(Step)}$$

$$\tilde{E}(\rho,\rho_\Delta,\tau) = \begin{cases} \frac{2}{\rho(2-\rho_\Delta)} & \tau \in \rho(1-\rho_\Delta) \\ \frac{2}{\rho(2-\rho_\Delta)\rho_\Delta}\left(1-\frac{2|\tau|}{\rho}\right) & \tau \in \rho\rho_\Delta \\ 0 & \text{otherwise} \end{cases} \qquad \text{(Modified Step)}$$

$$\tilde{E}(\rho,\tau) = \frac{2}{\rho}\sqrt{\frac{2}{\pi}}e^{-\frac{8}{\rho^2}\tau^2} \qquad \text{(Approximate } \delta\text{)}$$

# Scale-free Alternatives II

$$\tilde{E}(\rho,\tau) = \frac{1}{\rho}\sqrt{\frac{2}{\pi}}e^{-\dfrac{\sin^2 \pi\tau}{\pi^2\rho^2}} \qquad \text{(Trig. Approximate } \delta\text{)}$$

$$\tilde{E}(\tau) = (1+\cos 2\pi\tau) \qquad \text{(Trig.)}$$

$$\tilde{E}(\rho,\tau) = \frac{(2^n n!)^2}{(2n)!}\cos^{2n} 4\pi\tau \quad (n = \lfloor 2^{-1}\sin^{-2}\frac{\pi\rho}{2}\rfloor) \qquad \text{(Proper Trig.)}$$

$$\tilde{E}(\tilde{c} = cT, \rho, \tau) = \frac{1}{\rho}\left[\frac{1}{1+e^{-\tilde{c}(\tau+\rho/2)}} - \frac{1}{1+e^{-\tilde{c}(\tau-\rho/2)}}\right] \qquad \text{(Double Logistic)}$$

# The Resulting Mosquito Populations

The analytical work to get exact $M(t)$ is... tedious. Thankfully, there are numerical integrators!

Which gives us a window to qualify these alternatives rapidly, and then decide which to thoroughly investigate.

# TODO insert poster figs

# Thoughts?

What do *you* think about the options?

# Back To Oversimplification Question

Are these alternatives still too simple?

They are all built assuming a stable driver, which is inaccurate.

But: this framework presents an easy way to consider $E(t)$ changes as perturbations. That is, given the stable solution at the start of a period, how do changes to the driver in that period transform the end-of-period outcome?

# So What?

What does this basic analysis give us?

- rough boundaries as input to other models,
- where more complex approaches are needed (agent-based, spatially explicity, *etc.*)
- a cog for ranges where this kind of model is good (or good enough [for now])

# Seque: Need "New" Habits and Tools

New challenges to getting science done:

- lashing together methods from different fields,
- getting genuine peer-review, and
- the purely mechanical handling of different people simultaneously working on the same "thing"

How can we address these issues?

# Solutions from Software Industry?

What tools and habits can we adopt from this field?

What risks are associated with that?

What's still missing?

# The Good

- version control systems,
- collaborative tools on top of those,
- preference for code documentation leading to
  - bite-sized parts,
  - modularity,
  - re-usability, and
  - verifiability (a/k/a unit testing)
- open availability of all source,
- combines with version control to provide complete history of work product

# The Bad

- openness can make for opportunity to be “scooped”,
- can focus more on process than product,
- learning curve for most scientists

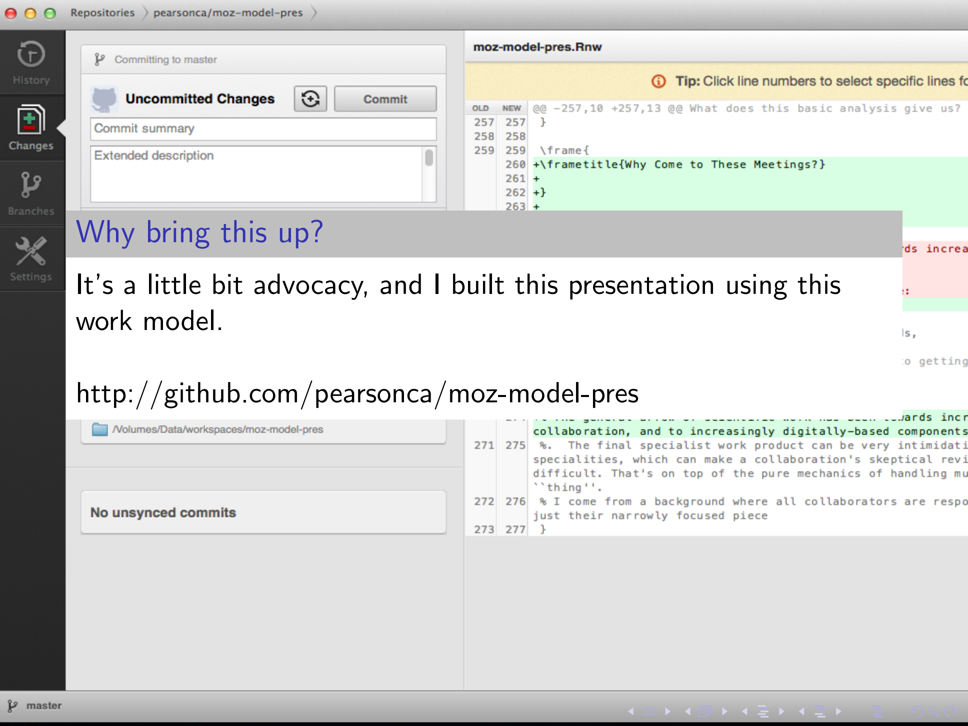
# The Ugly

- university contracts' intellectual property clauses,
- academic institutions don't "get" these tools,
- community adoption?

# Why bring this up?

It's a little bit advocacy, and I built this presentation using this work model.

http://github.com/pearsonca/moz-model-pres



# Why Come to These Meetings?