Slightly Less Simple Mosquito Modeling

Carl A. B. Pearson

Emerging Pathogens Institute, University of Florida

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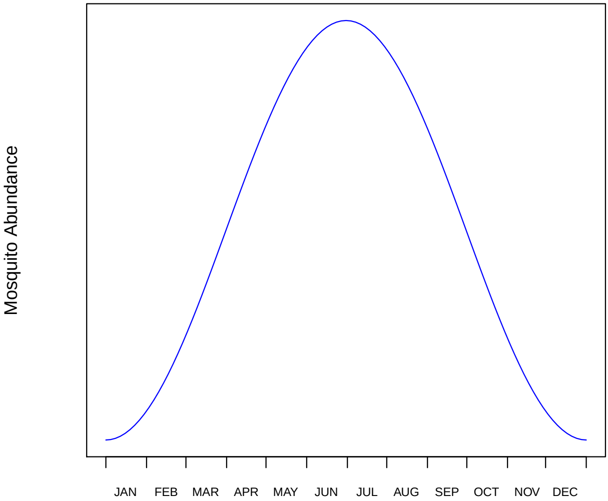
What Will I Talk About?

- finding low-hanging fruit,
- expression with models,
- value of simple analytical approaches (*e.g.*, dimensional analysis),
- how to build from simple models, and
- a little about work habits and tools

A Not Atypical Model of Vector Population



But. . .

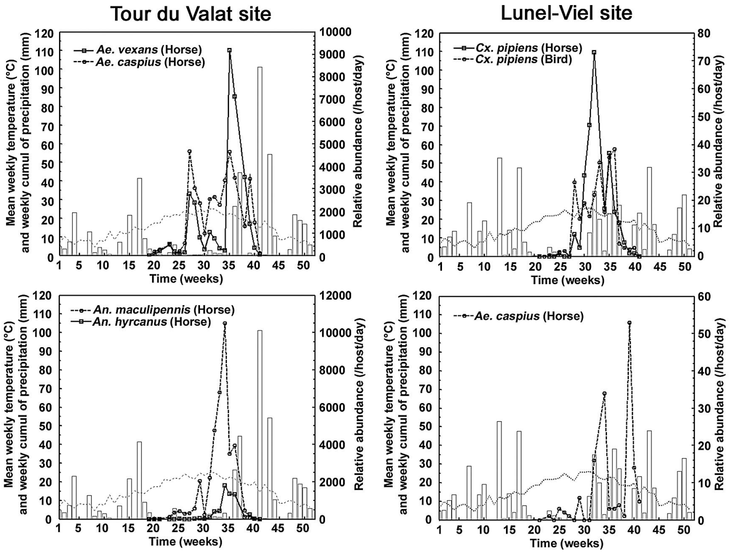


Figure: Bicout et al. J. Med. Entomol. 43(5): 936-946 (2006)

So, a Disconnect.

With

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

Impossible to match features like

- peak population,
- total population over a year, and
- turnover rate

These can be critical to predicting transmission dynamics.

Do Better, But Keep It Simple

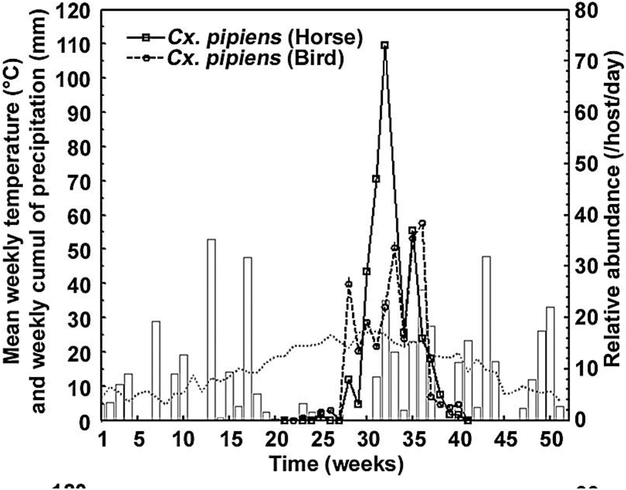
What's good about trigonometric representation? Simplicity:

- 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.

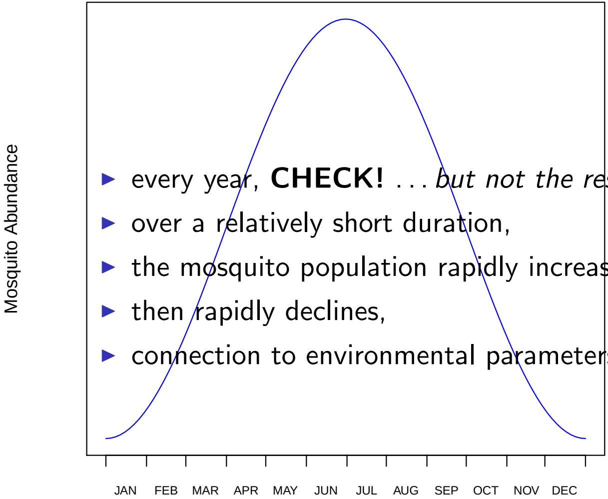
Lunel-Viel site



Salient Features

- every year,
- over a relatively short duration,
- the mosquito population rapidly increases,
- sits at a high level of activity,
- then rapidly declines,
- connection to environmental parameters

Salient Features in Trig. Representation



- every year, **CHECK!** . . . *but not the rest of:*
- over a relatively short duration,
- the mosquito population rapidly increases,
- then rapidly declines,
- connection to environmental parameters

Getting at the Other Points

Need:

- way to connect to external factors
- “spikey”
- oscillatory

Can get that with repeating boundary conditions on

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

and appropriate $E(t)$.

Appropriate $E(t)$

Most of the criteria boildown to a “spikey” function options.
Suggestions?

What else would we need to ensure?

Alternatives I

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

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

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

Alternatives II

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

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

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

$$\text{(Proper Trig.)}$$

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

$$\text{(Double Logistic)}$$

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

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

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

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

Scale-free Alternatives II

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

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

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

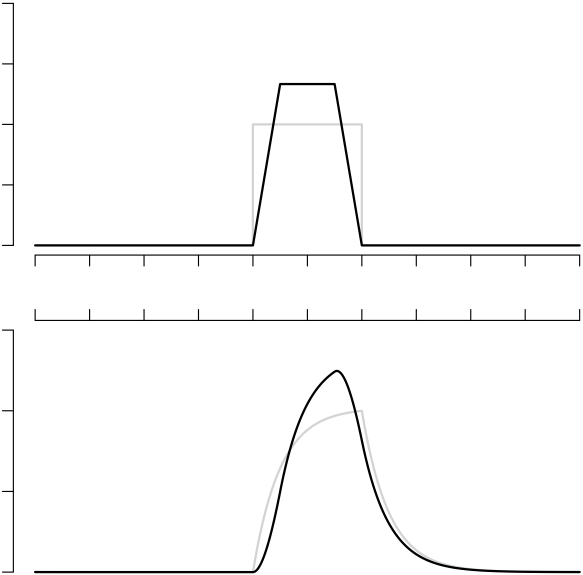
$$\tilde{E}(\tilde{c} = cT, \rho, \tau) = \frac{1}{\rho}\left[\frac{1}{1+e^{-\tilde{c}(\tau+\rho/2)}} - \frac{1}{1+e^{-\tilde{c}(\tau-\rho/2)}}\right] \qquad \text{(Double Logistic)}$$

The Resulting Mosquito Populations

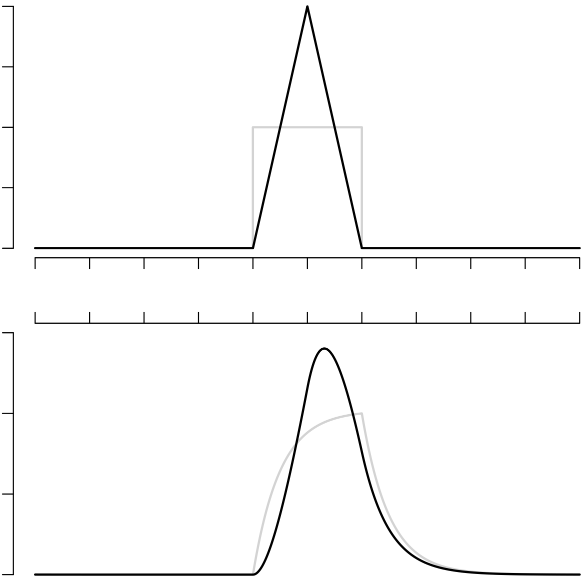
The analytical work to get exact $M(t)$ is... tedious. Thankfully, there are numerical integrators!

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

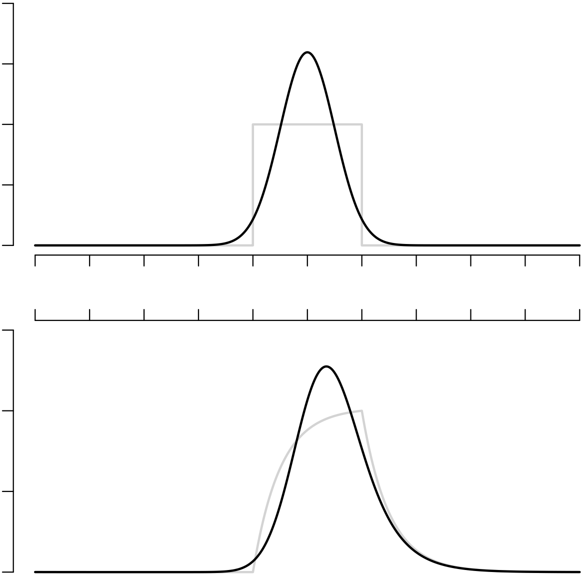
Modified Step (Trapezoid)



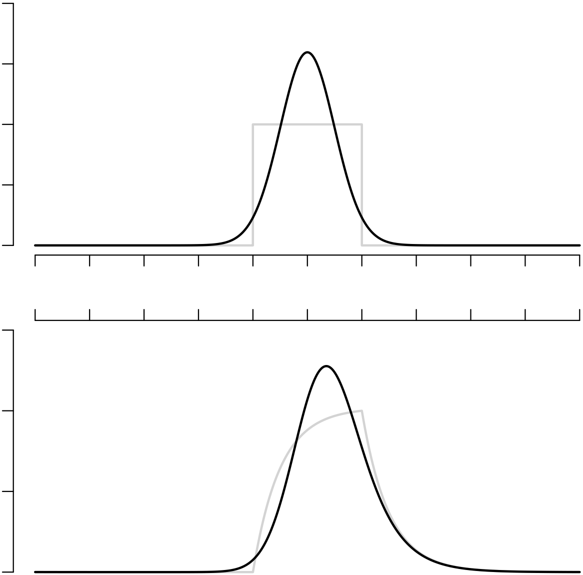
Modified Step (Triangle)



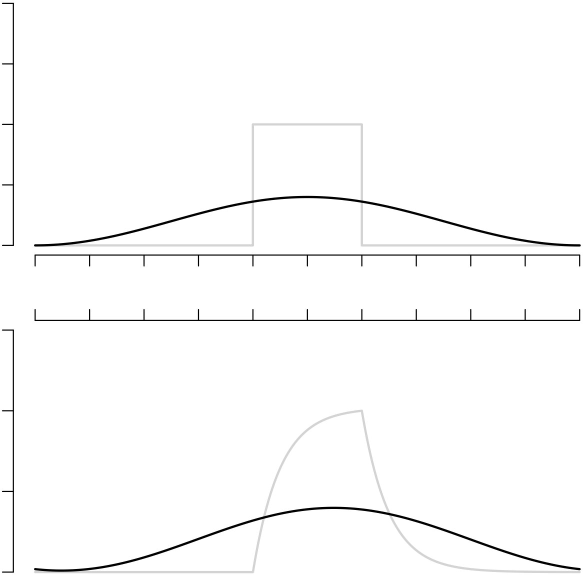
Approx. δ



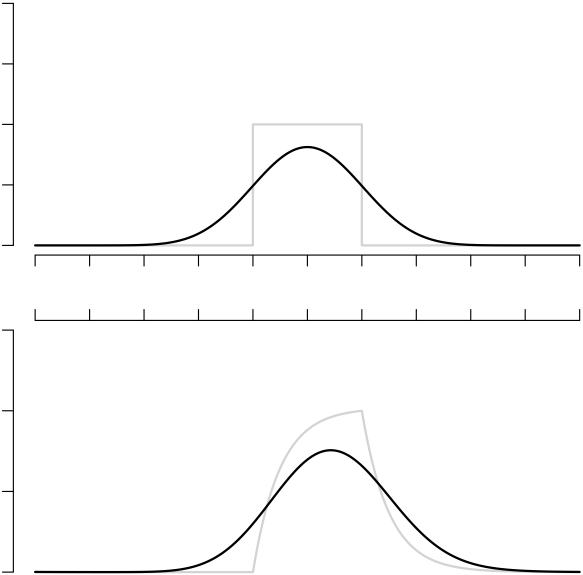
Trig. Approx. δ



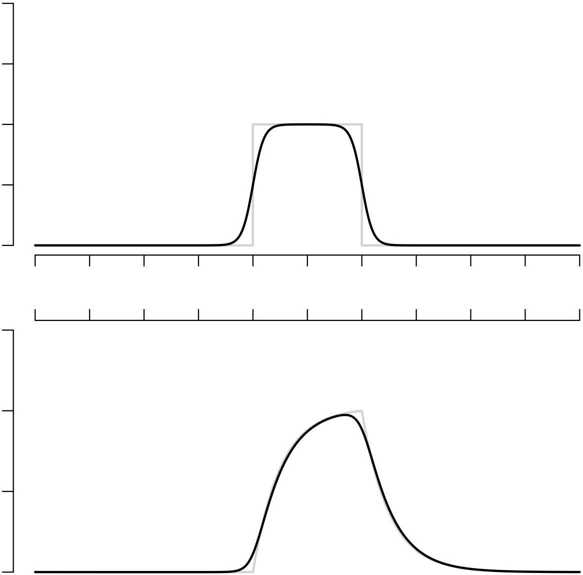
Trigonometric



Proper Trigonometric

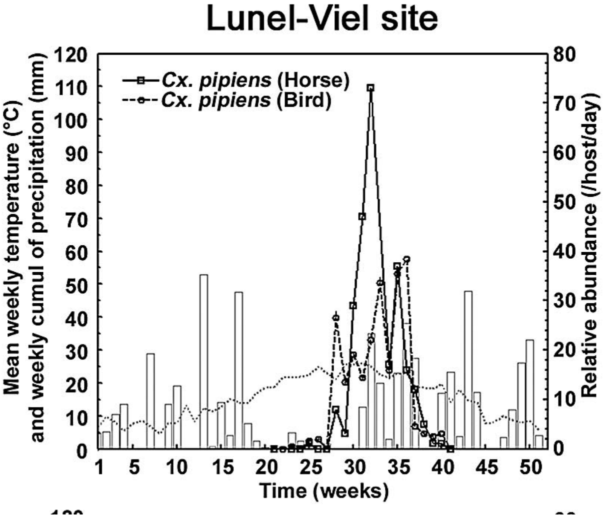


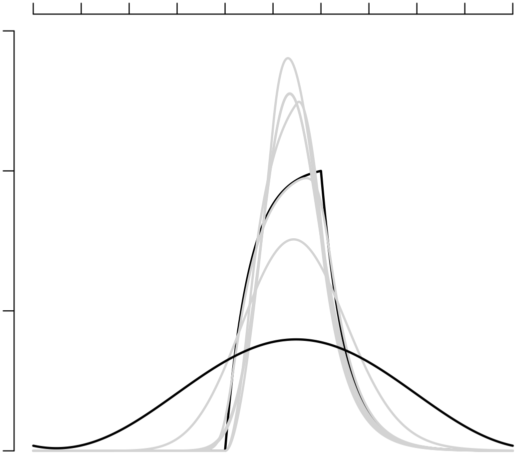
Double Logistic



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.

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 component connectable to other models

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

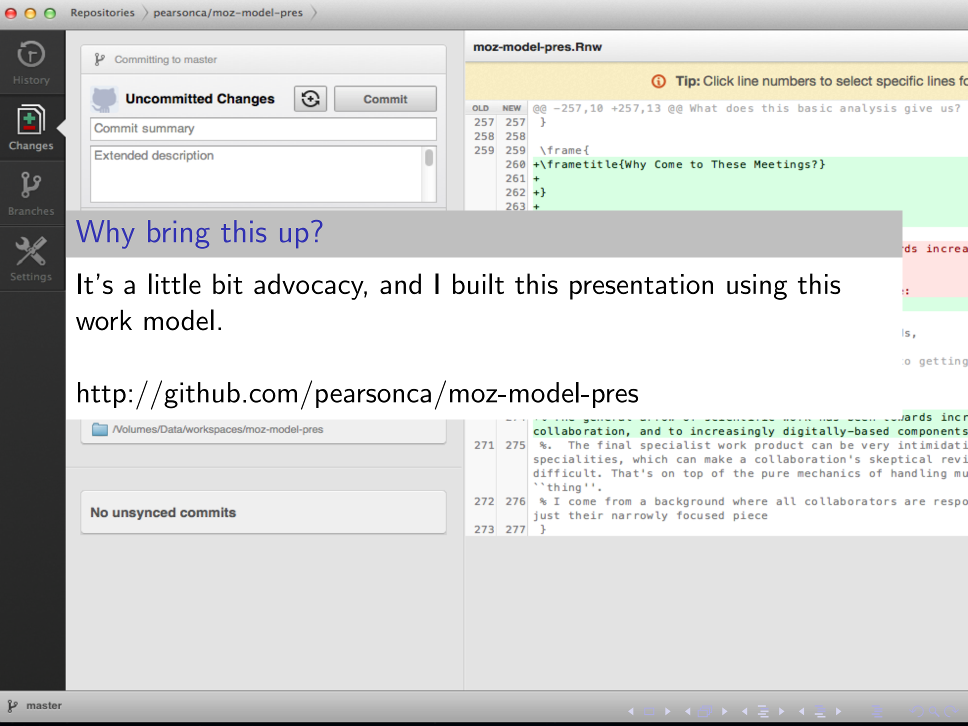
The Ugly

- university contracts' intellectual property clauses,
- hiring & retention don't (yet) "get" this model,
- critical community adoption level

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

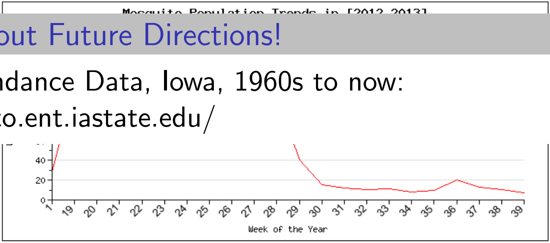


Let's Talk About Future Directions!

Mosquito Abundance Data, Iowa, 1960s to now:
http://mosquito.ent.iastate.edu/

Mosquito Surveillance in Iowa

During the summer months, the Iowa State University Medical Entomology Laboratory, in a cooperative project with the Iowa Department of Public Health and the University Hygienic Lab (Iowa City, IA), monitors mosquito populations and mosquito-borne disease in the State of Iowa. Mosquito surveillance efforts took place in the state from the late 1960's-2005 under the supervision of Professor Emeritus, Wayne Rowley, and now are supervised by Dr. Lyric Bartholomay. The resulting information on mosquito population dynamics (including numbers and types of mosquitoes trapped weekly in New Jersey Light Traps from the mid-1970's-2007) now is available through this site.



New Jersey light trap records for the state of Iowa are shown for the current and previous year. Data are shown as a weekly average that accounts for the number of traps running.
Records are shown according to the week of the year with week 1 being the first week in January. Roughly, the latter half of May = weeks 20-22, June = 23-26, July = 27-30, August = 31-35, September = 36-39, and the beginning of October =40.

Acknowledgements

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References

Much of the information contained herein is the subject of numerous publications on mosquitoes in Iowa authored by Dr. Rowley and colleagues.