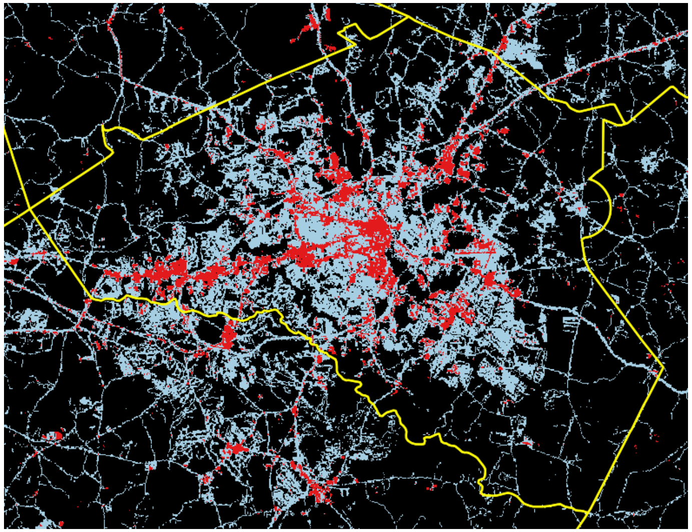
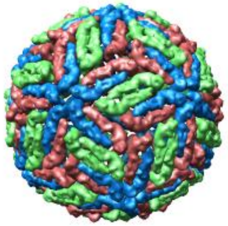
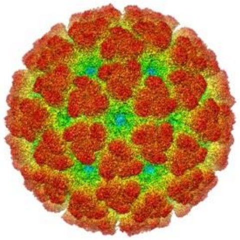






Variation in mosquito microclimate and implications for vector-borne disease transmission

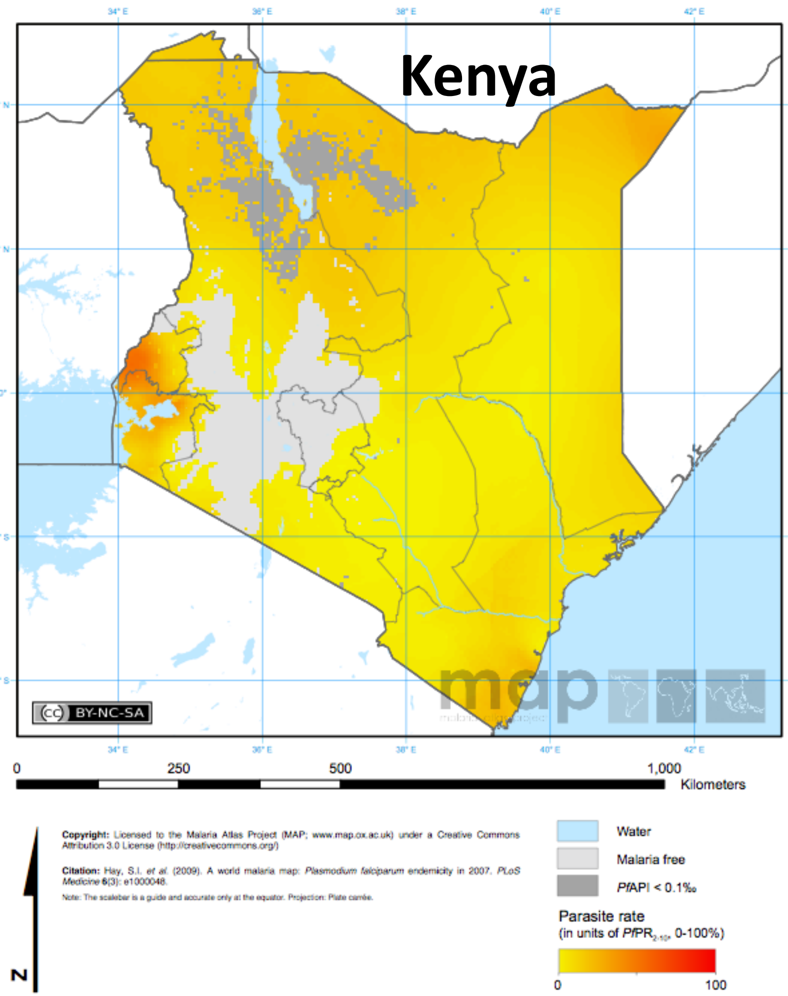
Courtney Murdock + many more

GMCA 2015

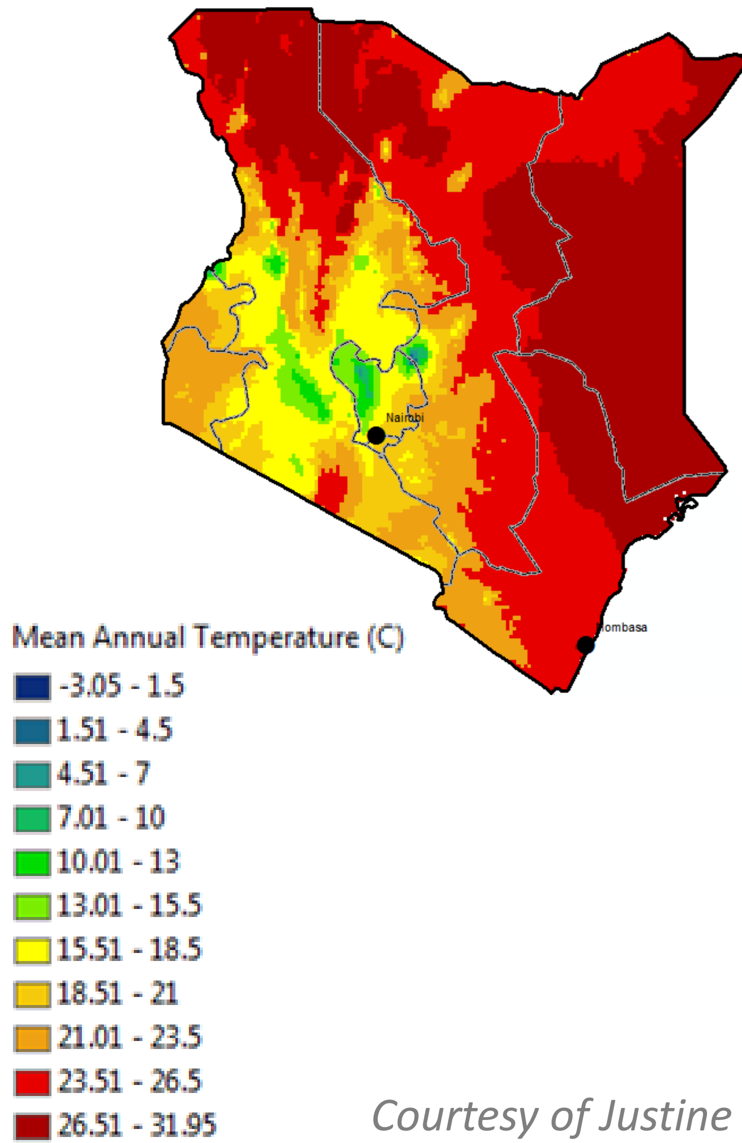
THE UGA® COLLEGE OF VETERINARY MEDICINE
Department of Infectious Diseases

Odum School of Ecology
The University of Georgia

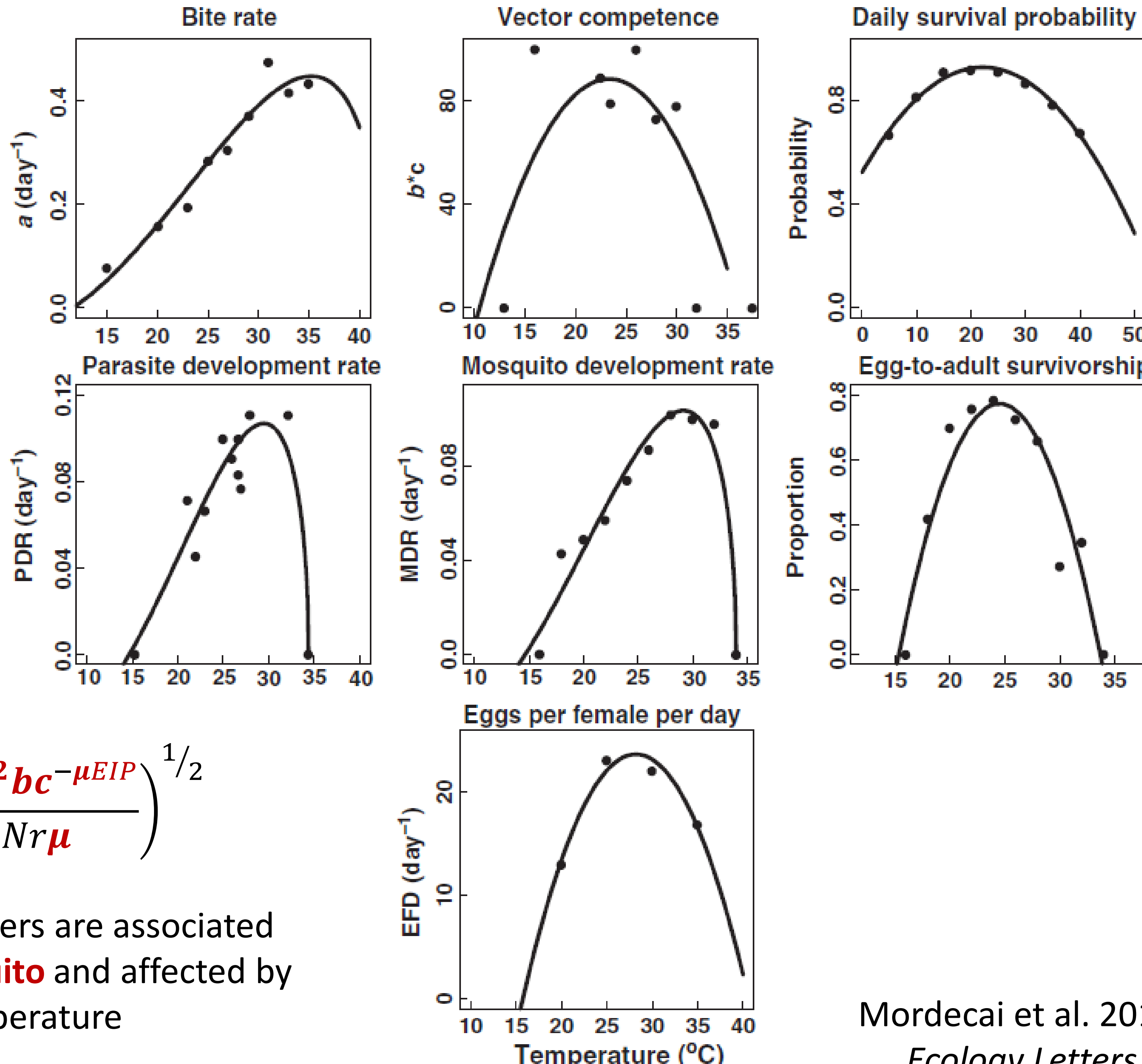
Distribution of vector-borne disease varies substantially, and largely can be explained by variation in temperature



Malaria Atlas Project



Courtesy of Justine Blanford

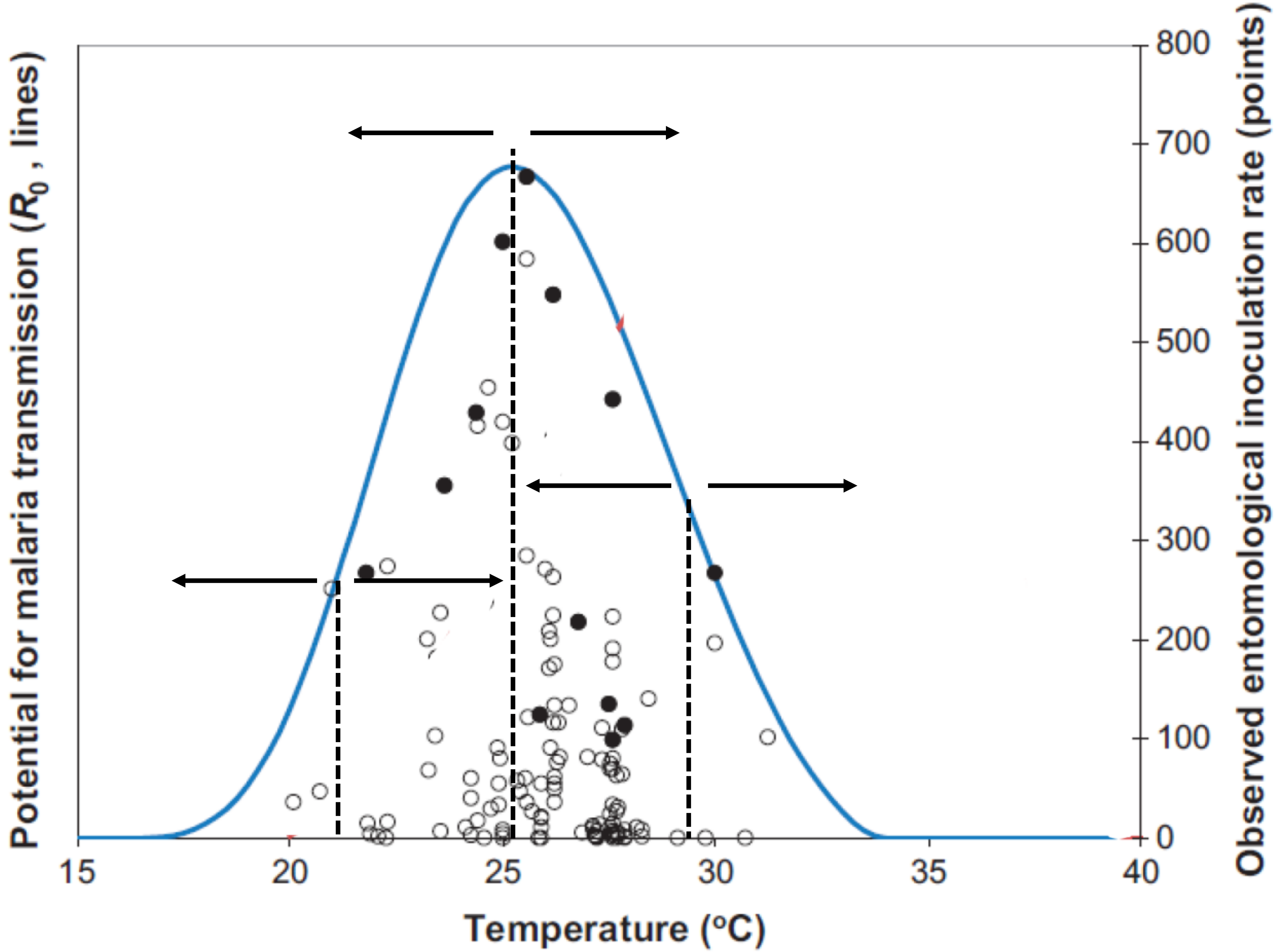


$$R_o = \left(\frac{Ma^2bc^{-\mu EIP}}{Nr\mu}\right)^{1/2}$$

many parameters are associated with the **mosquito** and affected by temperature

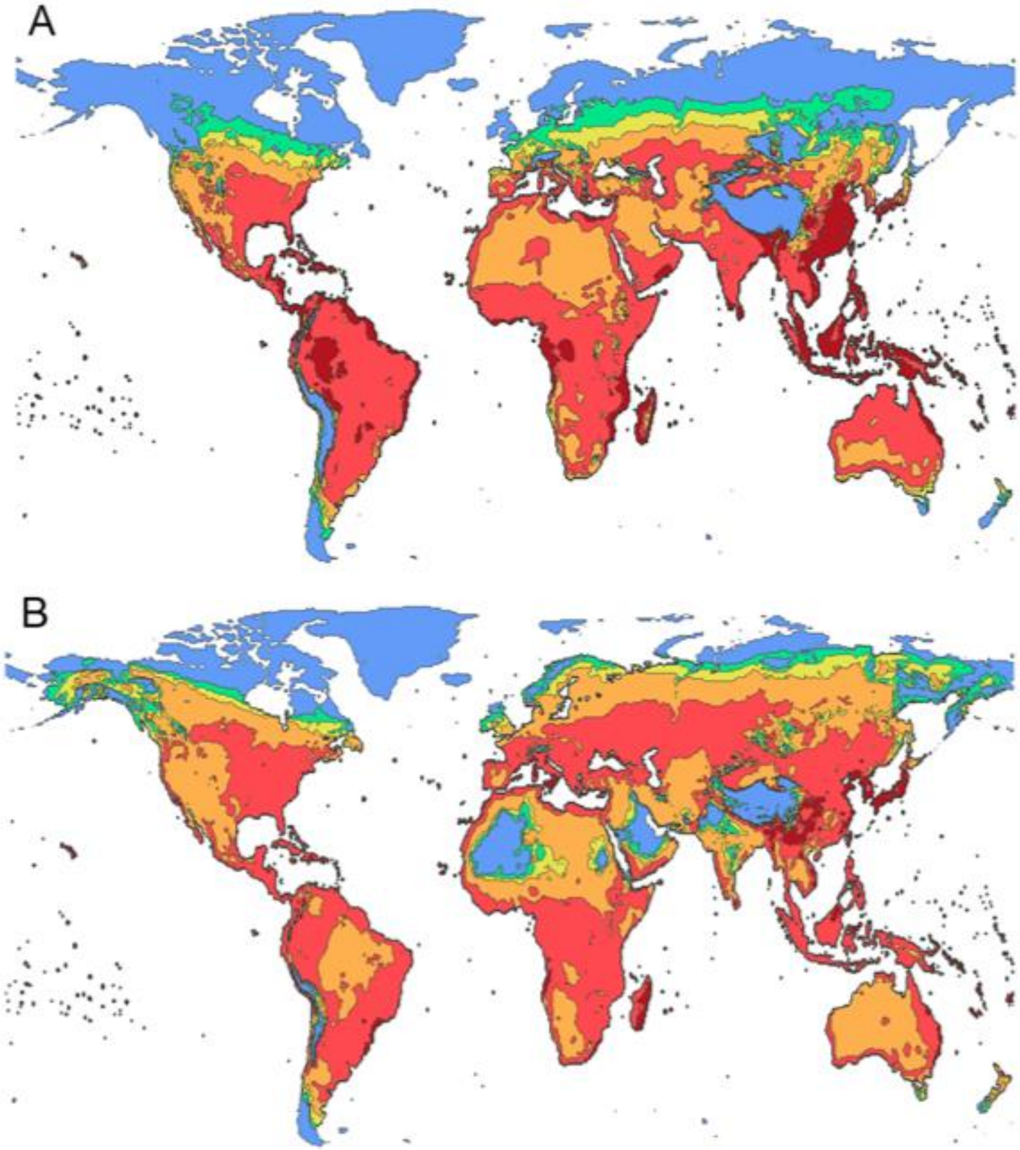
Mordecai et al. 2013 *Ecology Letters*

Diurnal temperature fluctuation will integrate with mean temperature to affect disease transmission

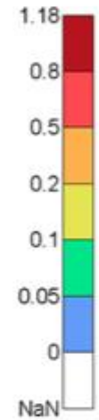


adapted from Mordecai et al. 2013
Ecology Letters

When we predict climate effects on vector borne disease transmission, we quickly run into problems with scale

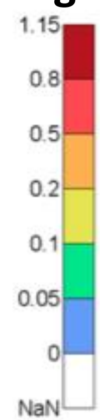


Dengue potential 1980-2009



CRU-TS v3.1 **mean monthly temperature** and **diurnal temperature ranges** were used for grid boxes of 0.5 by 0.5 degrees latitude and longitude (about **50 x 50 km** grid sizes at the equator)

Dengue potential 2070-2099



Most climate models collect data at much coarser scales than organisms experience

Liu-Helmersson et al. 2014 PLoS One

Heterogeneity in landscapes can significantly shape the microclimates vectors experience

Overall objectives for the summer 2015 field season:

1. Does mosquito microclimate vary across human – modified landscapes?

2. Does variation in mosquito microclimate translate into variation in mosquito traits?

3. If microclimate variation affects mosquito ecology, can we use local weather station data to predict relevant microclimate?

4. What are the implications for mosquito transmission potential?

A highly permissive vector: 27 different arboviruses, including chikungunya and dengue viruses

Asian tiger mosquito
Aedes albopictus

Overall objectives for the summer 2015 field season:

1. Does mosquito microclimate vary across human – modified landscapes?

2. Does variation in mosquito microclimate translate into variation in mosquito traits?

3. If microclimate variation affects mosquito ecology, can we use local weather station data to predict relevant microclimate?

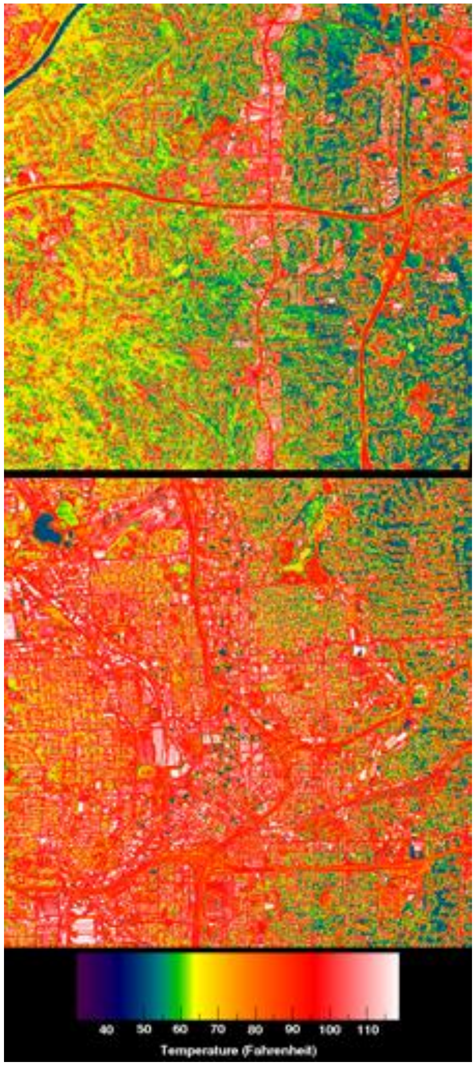
4. What are the implications for mosquito transmission potential?

A highly permissive vector: 27 different arboviruses, including chikungunya and dengue viruses

Asian tiger mosquito
Aedes albopictus

Overall objectives for the summer 2015 field season:

1. Does mosquito microclimate vary across human – modified landscapes, in particular across urban, suburban, and rural sites?



We predict that microclimate will vary across urban, suburban, and rural sites due to variation in impervious surface cover

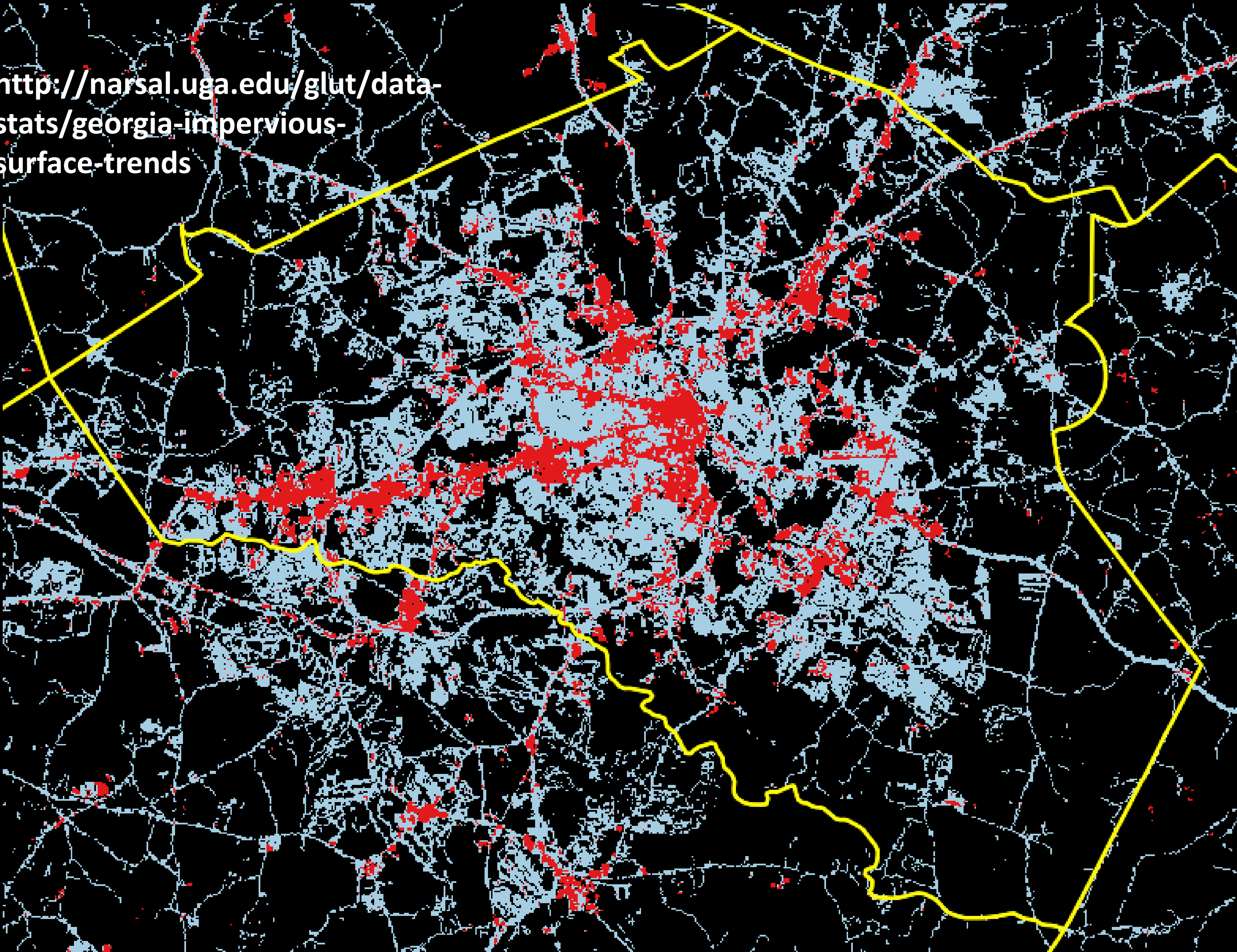
Due to urban heat island effects, we predict urban environments to have:

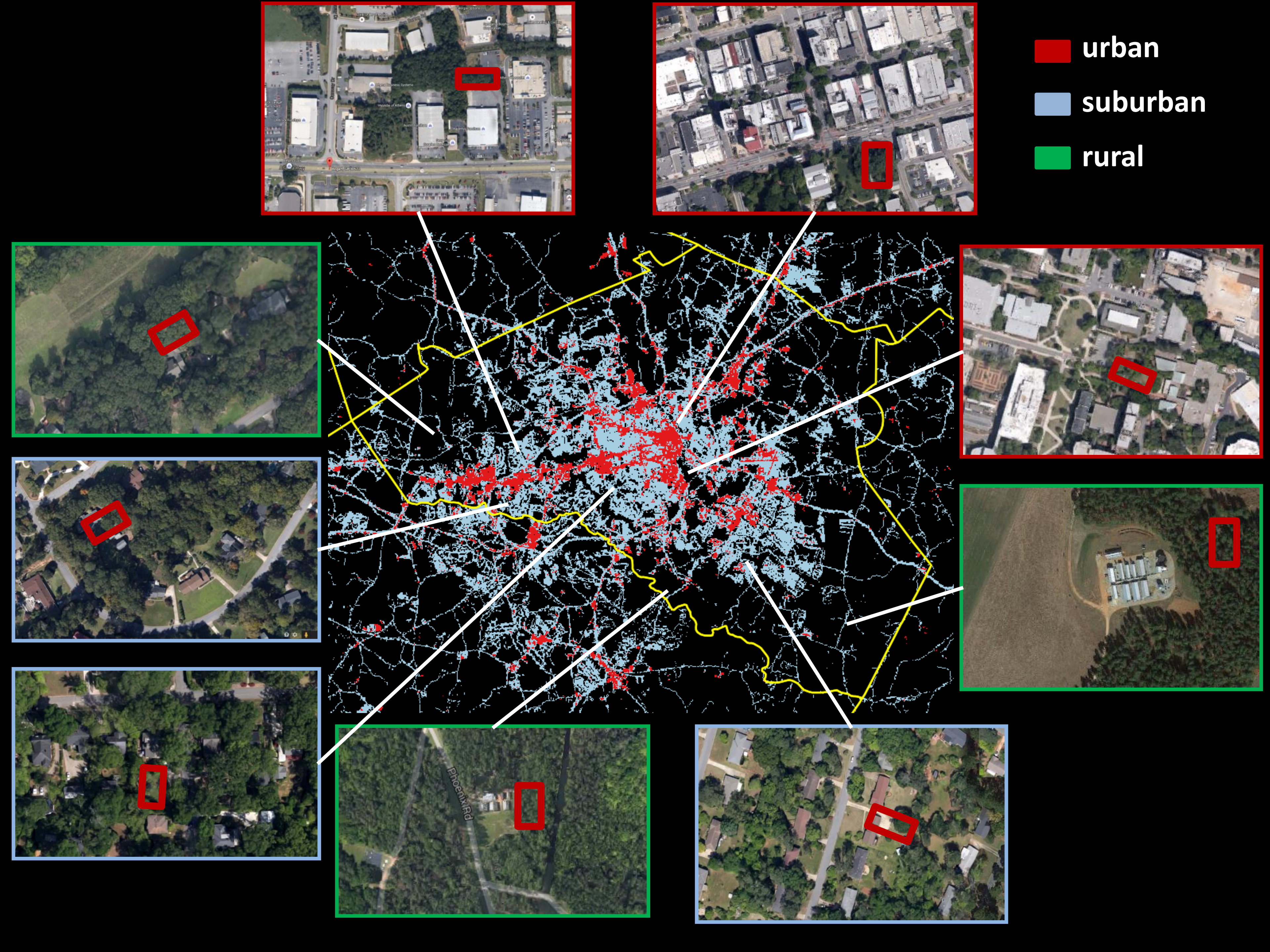
higher average temperatures, and

lower relative humidity

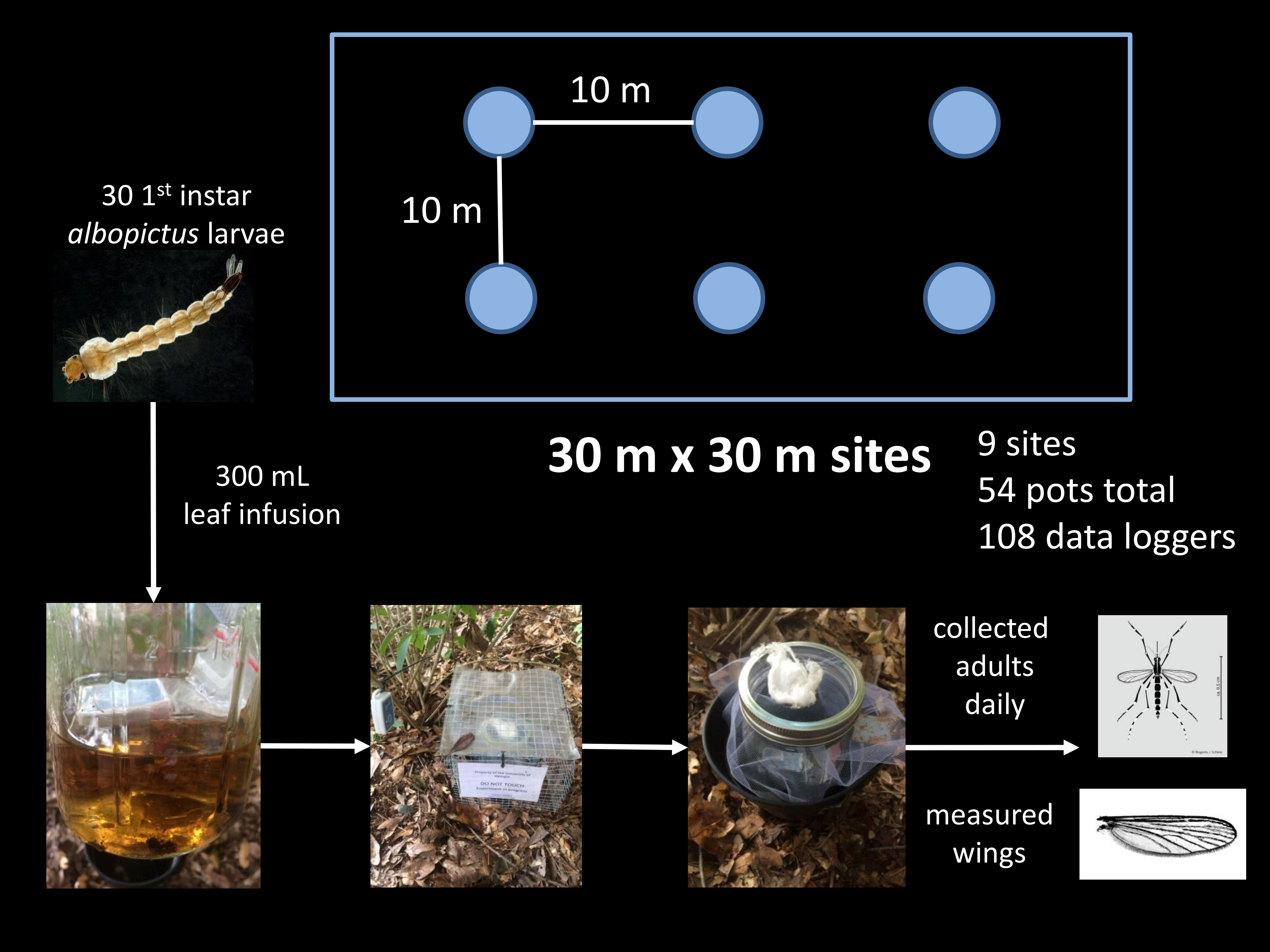
Heat signatures for urban and suburban sites in Atlanta, GA
NASA

http://narsal.uga.edu/glut/data-stats/georgia-impervious-surface-trends





urban
suburban
rural



10 m
10 m
30 1st instar
albopictus larvae
30 m x 30 m sites
9 sites
54 pots total
108 data loggers
300 mL
leaf infusion
collected
adults
daily
measured
wings

Overall objectives for the summer 2015 field season:

1. Does mosquito microclimate vary across human – modified landscapes?

2. Does variation in mosquito microclimate translate into variation in mosquito traits?

    - Rate of larval development (no. adults emerging / day)
    - Total no. emerged adults per pot
    - Size of emerging adults
    - Per capita growth rate (*r*)

Predict that **urban sites** will produce **fewer**, **smaller** mosquitoes at a **faster rate** than suburban and rural sites because they are **hotter**

Per capita growth rate

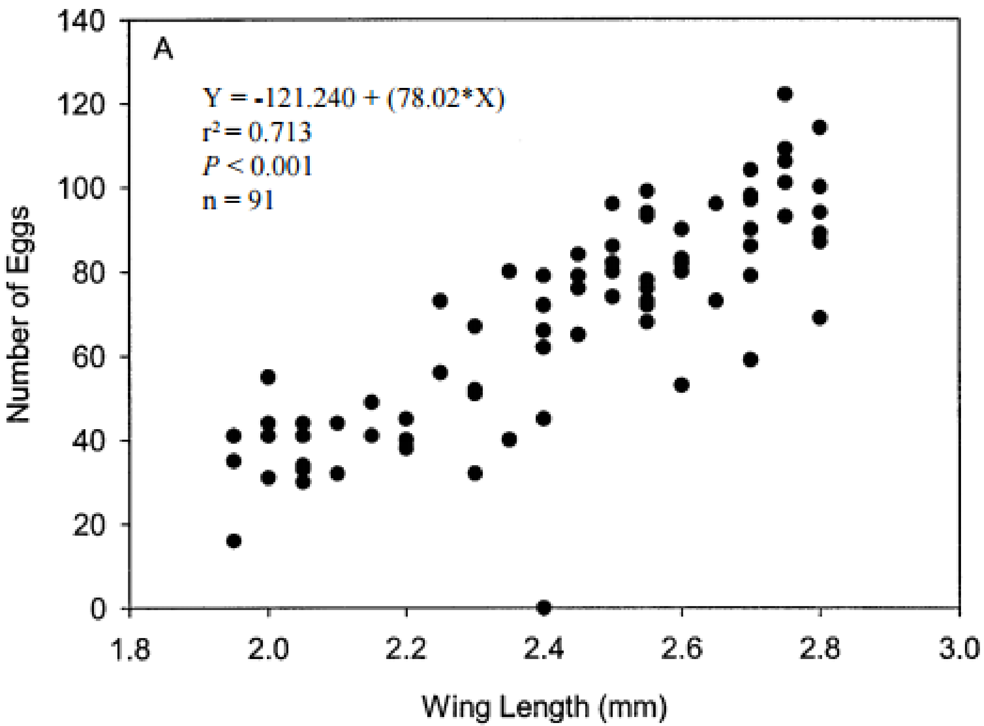
$$r = \frac{ln\left[\frac{1}{N_o}\sum A_x f(w_x)\right]}{D + \left[\frac{\sum x A_x f(w_x)}{\sum A_x f(w_x)}\right]}$$

N_o = initial no. of females (n = 15)

A_x = the no. of females emerging on day, *x*

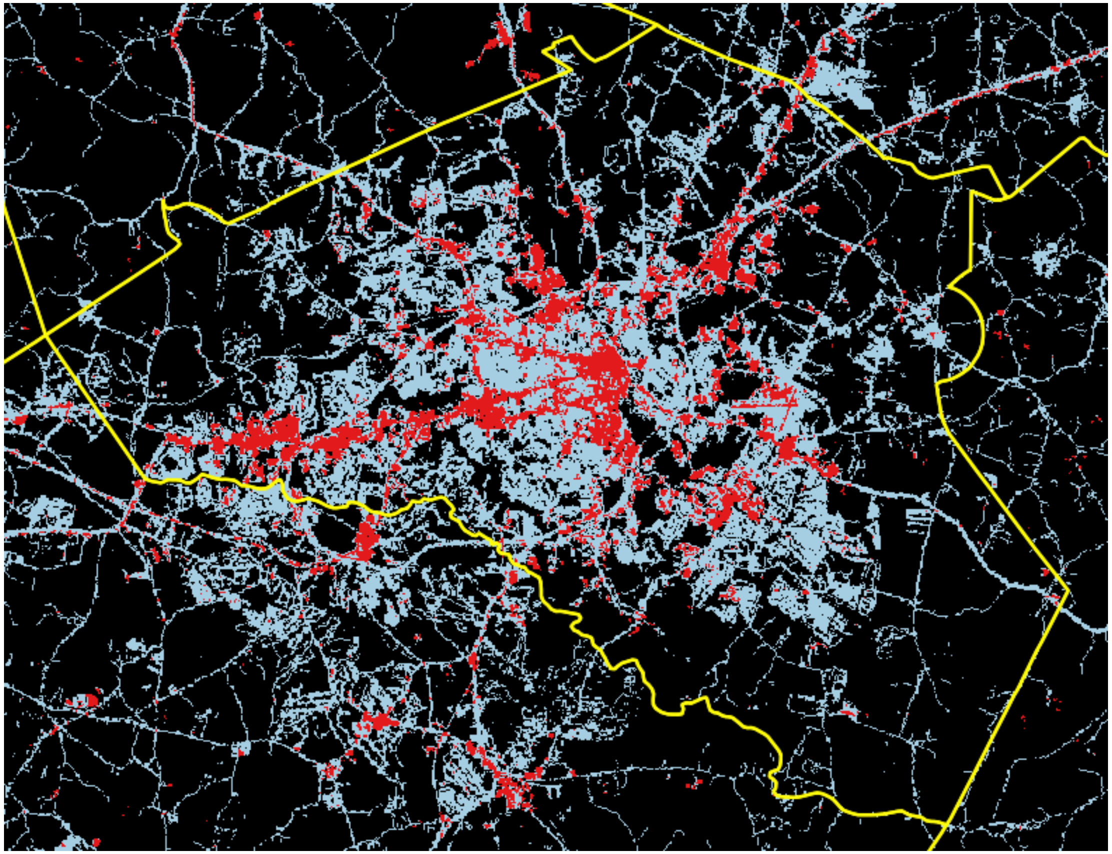
$f(w_x)$ = predicted no. offspring based on female wing size, *w*, on day, *x*

D = delay between female emergence and 1st oviposition (14 days; Lidvahl & Wiley 1992)

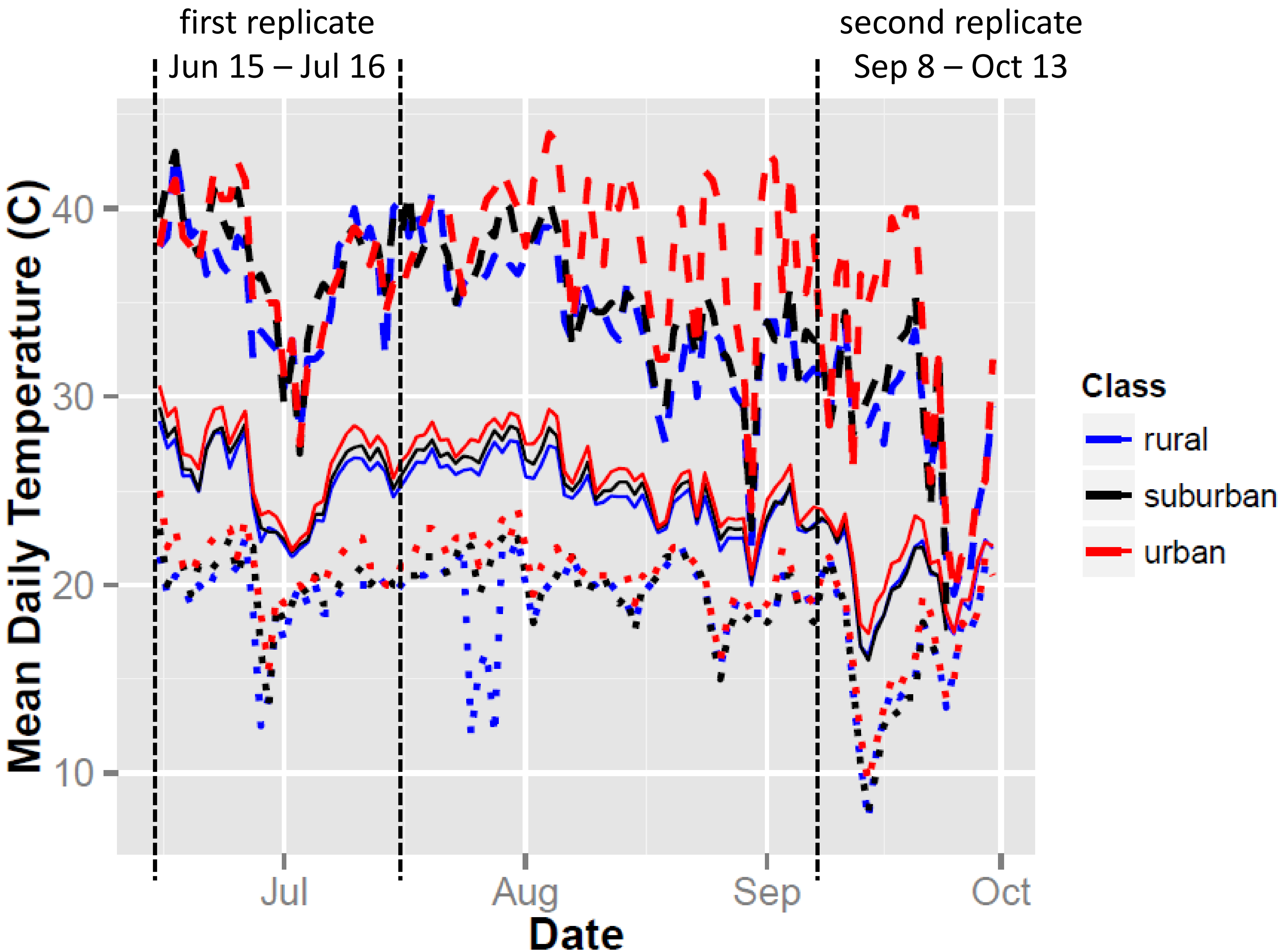


$f(w_x) = 78.02w_x - 121.24$;
r^2 = 0.713, N = 93, $p < 0.001$
Lounibos et. al. 2002

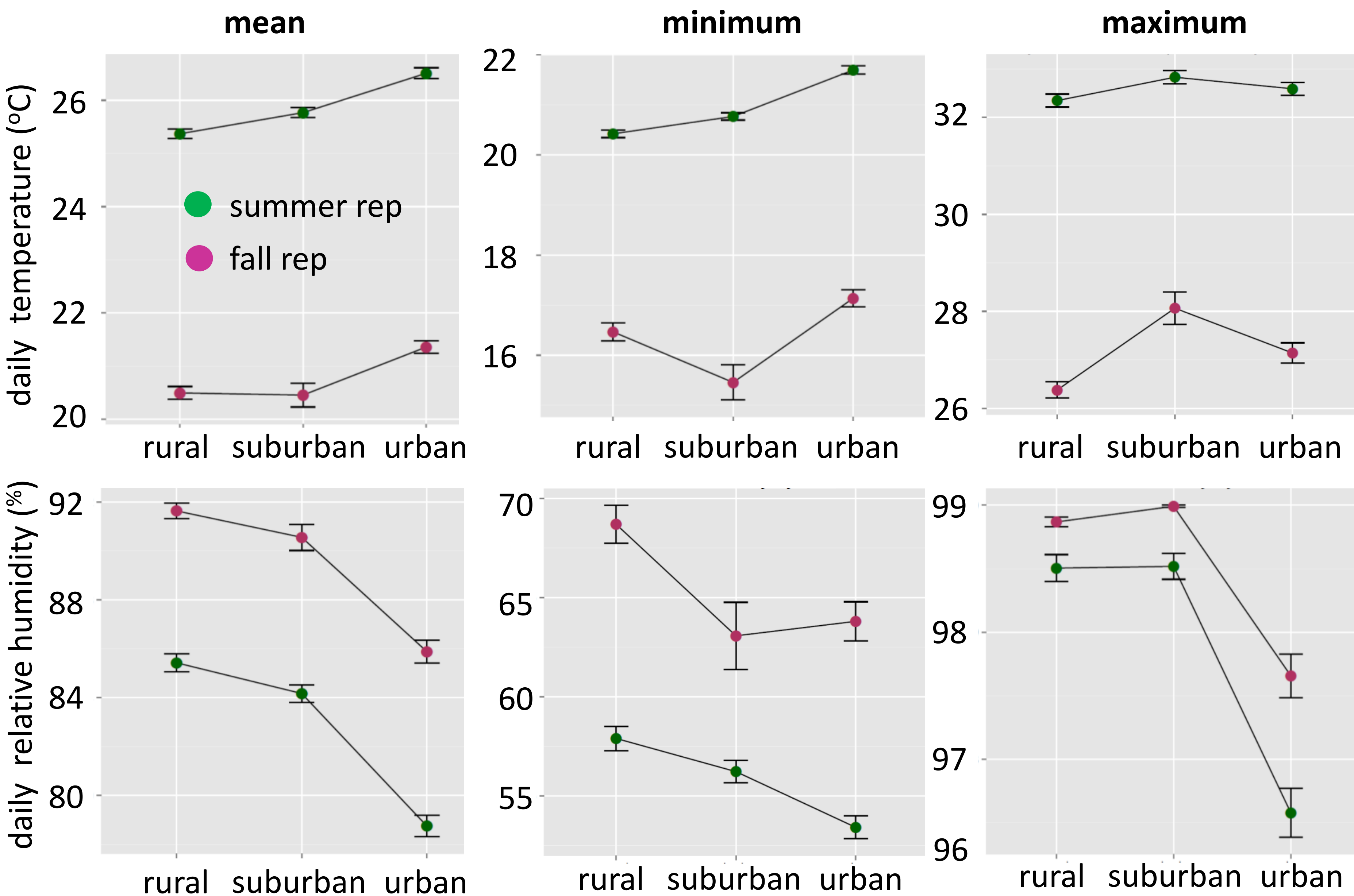
Does mosquito microclimate vary across urban, suburban, and rural sites?



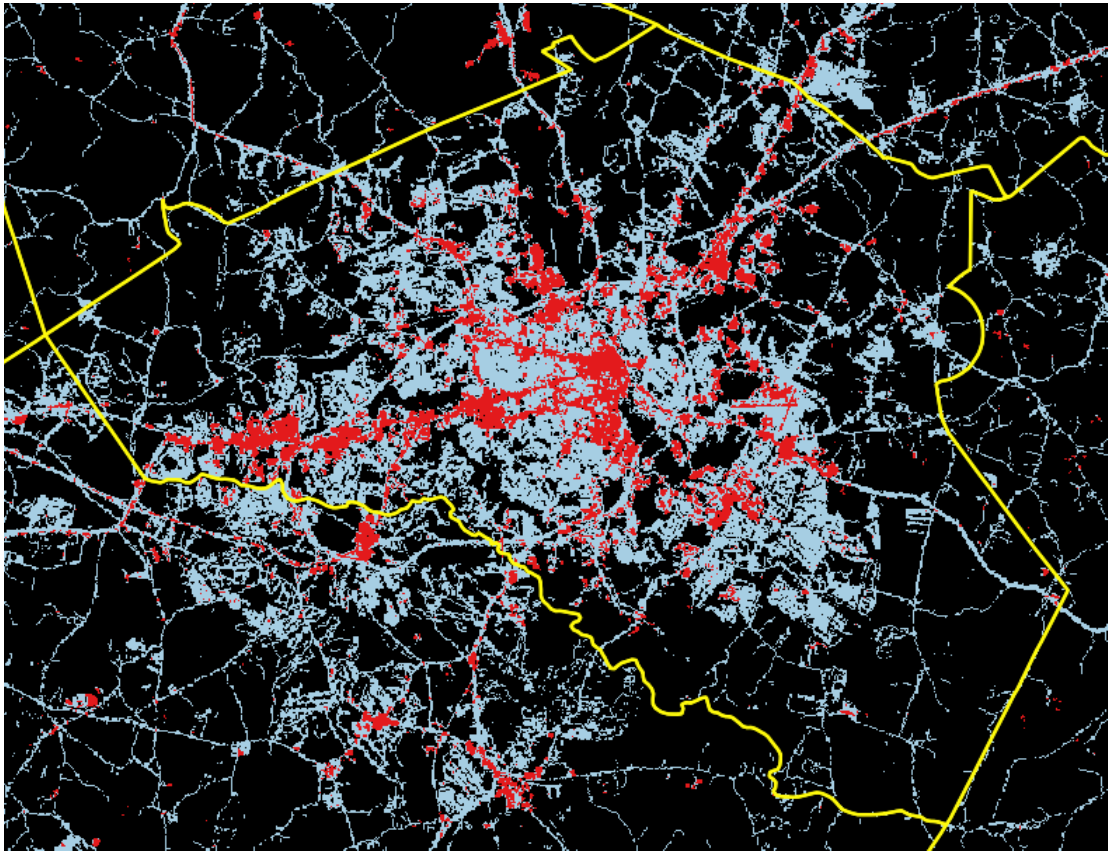
Mosquito microclimate varies across urban, suburban, & rural sites

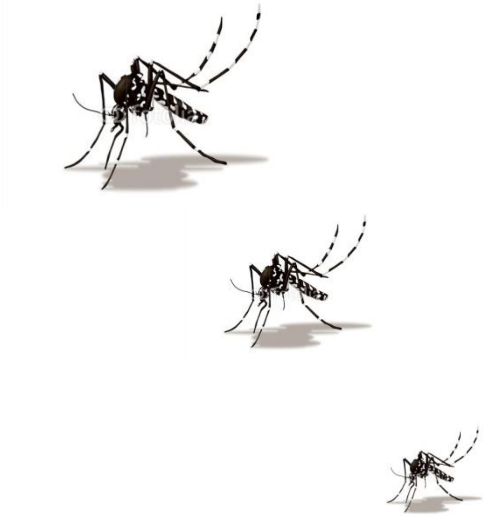


Urban sites experience on average higher temperatures and lower humidity

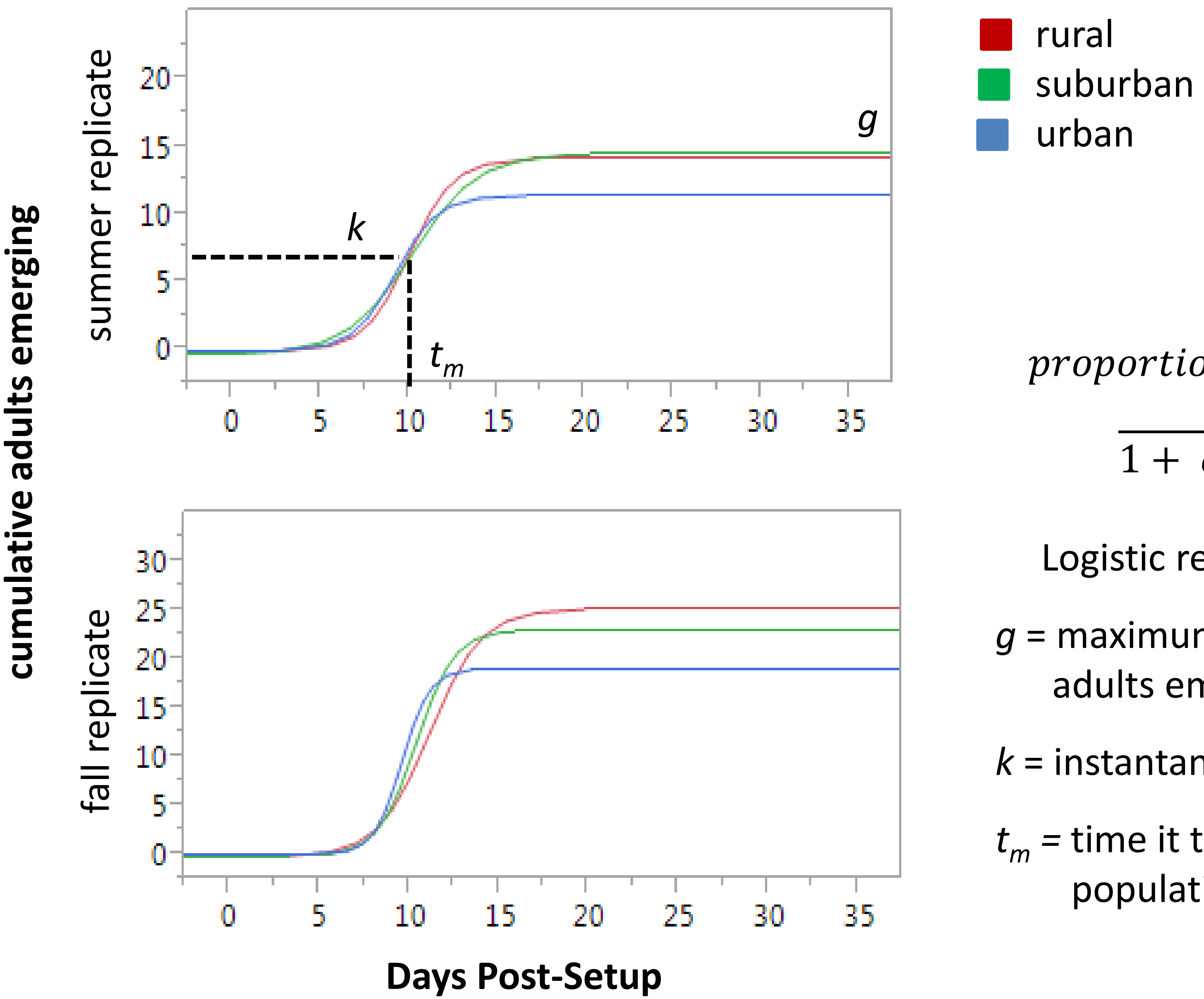


Does variation in mosquito microclimate translate into variation in mosquito traits?





Larval survival was lower in urban environments, and development rates were faster in urban environments in the fall



$$proportion\ emerged = \frac{g}{1 + e^{-k(x - t_m)}}$$

Logistic regression analysis:

g = maximum proportion of adults emerged

k = instantaneous rate of change

t_m = time it takes for 50% of the population to emerge

Bottom Lines

1. Microclimate varies significantly with land-use, with **urban** sites being on average **warmer**

2. Mosquito ecology appears to vary with land use, with **lower mosquito survival** and potentially **faster development** on **urban** sites

   This is likely due to increased temperatures on urban sites

3. **Urban** sites are also in general **less humid** – could have negative implications for adult survival

Work in Progress

1. Finish measuring wings from both replicates so that we can calculate per capita mosquito growth rates across sites

2. Are larval microclimates similar to adult microclimates?

3. If microclimate variation affects mosquito ecology, can we use local weather station data to predict relevant microclimate?

4. What are the implications for mosquito transmission potential?

Work in Progress

1. Finish measuring wings from both replicates so that we can calculate per capita mosquito growth rates across sites

2. Are larval microclimates similar to adult microclimates?

3. If microclimate variation affects mosquito ecology, can we use local weather station data to predict relevant microclimate?

4. What are the implications for mosquito transmission potential?

Work in Progress

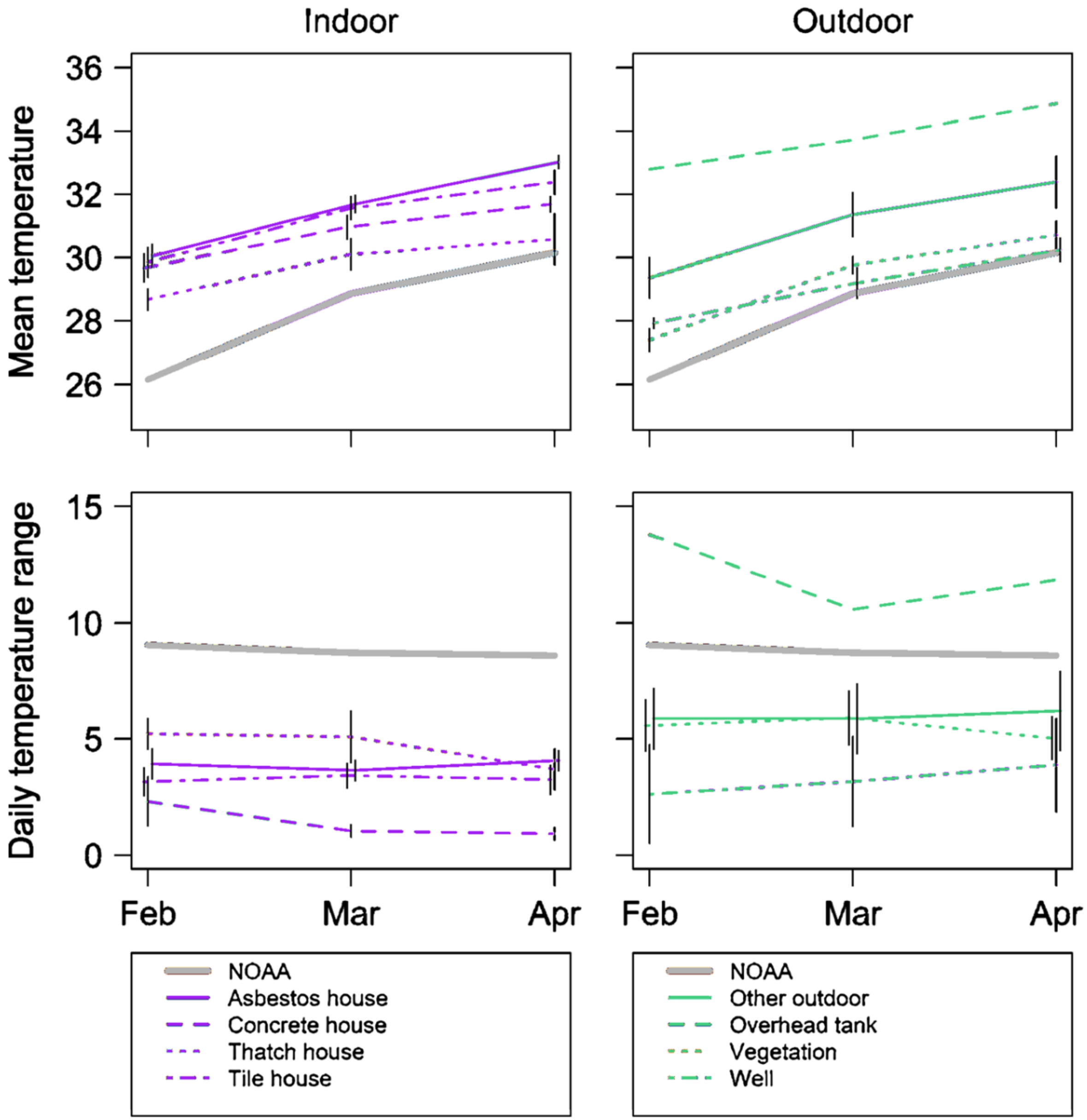
1. Finish measuring wings from both replicates so that we can calculate per capita mosquito growth rates across sites

2. Are larval microclimates similar to adult microclimates?

3. If microclimate variation affects mosquito ecology, can we use local weather station data to predict relevant microclimate?

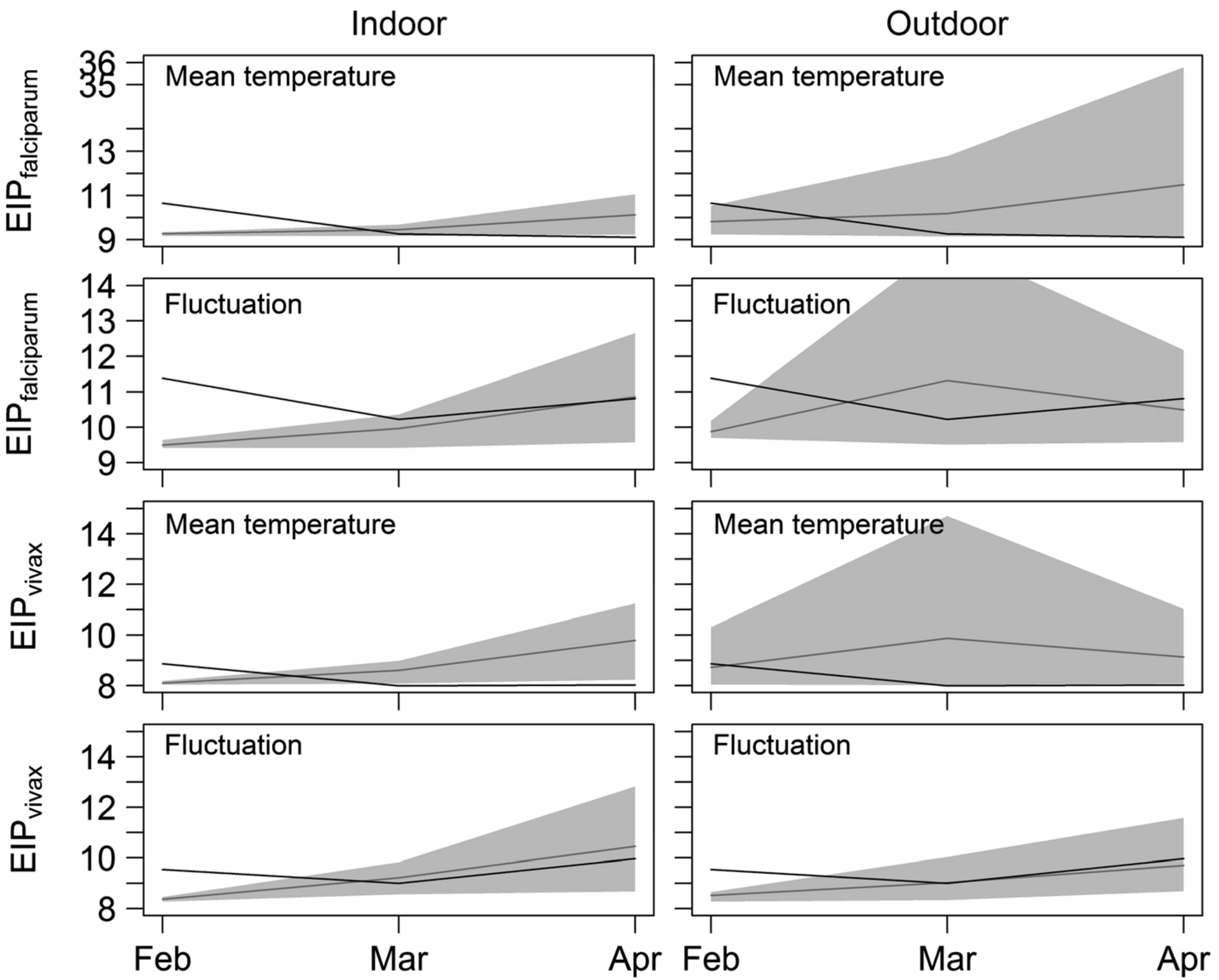
4. What are the implications for mosquito transmission potential?

Weather stations underestimate mean daily temperatures and overestimate diurnal temperature range for indoor resting mosquito vectors environments



Cator et al. 2013 Malaria Journal

Weather stations under predict the potential range in parasite extrinsic incubation periods for *Plasmodium falciparum* and *P. vivax*



Work in Progress

1. Finish measuring wings from both replicates so that we can calculate per capita mosquito growth rates across sites

2. Are larval microclimates similar to adult microclimates?

3. If microclimate variation affects mosquito ecology, can we use local weather station data to predict relevant microclimate?

4. What are the implications for mosquito transmission potential?

Estimating effects of microclimate on vectorial capacity

$$VC = \frac{ma^2 b e^{-\mu EIP}}{\mu}$$

the rate at which future infections arise from one infectious mosquito

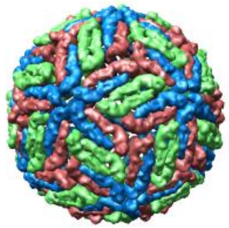
m = density of mosquitoes upon completion of EIP

b = vector competence

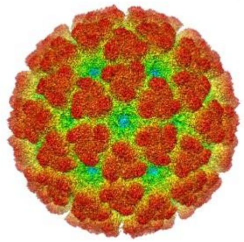
a = daily biting rate – from the literature

EIP = time it takes to reach average vector competence

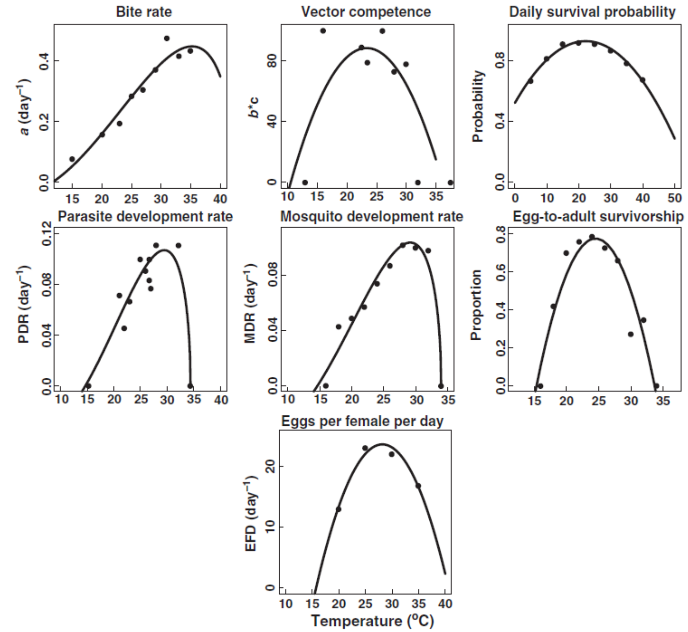
μ = daily probability of mosquito survival



dengue



chikungunya



$$VC = \frac{ma^2 \boldsymbol{b} e^{-\mu \boldsymbol{EIP}}}{\mu}$$

Fit the following functions to the raw data for values for each parameter obtained from our experiment and the literature

Briere's Equation: $X(T) = cT(T - T_o)(T_m - T)^{1/2}$

Quadratic Equation: $X(T) = qT^2 + rT + s$

Linear Equation: $X(T) = yT$

T = mean temperature	T_m = maximum temperature
T_o = minimum temperatures	$c, q, r, s,$ and y = constants

Estimating effects of microclimate on vectorial capacity

Fit all models using non-linear least squares and use AIC to choose among candidate models (adjusted for small sample sizes)

Build in temperature dependence using above relationships into vectorial capacity:

$$VC(T) = \frac{m(T)a(T)^2 b(T)e^{-\mu(T)EIP(T)}}{\mu(T)}$$

Collaborators

John Drake
UGA

Mark Brown
UGA

Anne Elliot
UGA

Funding

College of Veterinary Medicine

Population Biology of Infectious Diseases REU Program

The Mosquito Team

Cristina Huertas-Diaz, Blanka Tesla, Kerri Miazgowicz
Michelle Evans, Hannah Feltner, Jennifer Cyr
UGA

Taylor McClanahan
REU Program