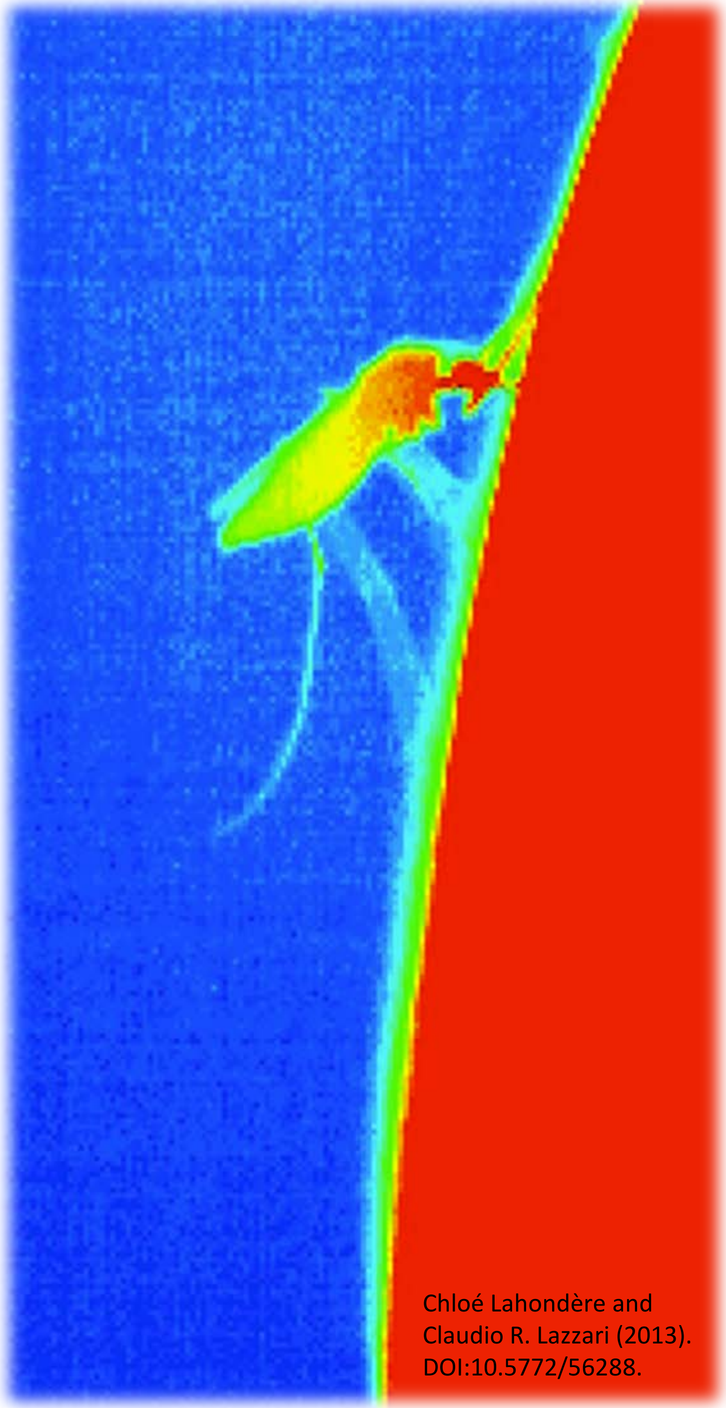

Chloé Lahondère and
Claudio R. Lazzari (2013).
DOI:10.5772/56288.

The Influence of Temperature on Mosquito Life History and Implications for Transmission

Georgia Mosquito Control Association Meeting

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Predictive models are an essential tool in mitigating vector-borne diseases

Current control methods include;

Vector control

- Indoor residual spraying (IRS)
- Insecticide treated bed-nets (ITNs)
- Larval source reduction
- Genetically modified mosquitoes

However...

- Lack of public health infrastructure
- Limited funding
- Insecticide resistance

…severely comprises the efficacy of these control measures

Predictive models help mitigate disease by;

Predictive models

- Identifying key mosquito/parasite traits to target with interventions
- Forecasting disease risk to direct limited funding
- Predicting how VBDs will alter in response to global changes

However...

…these models are only as accurate as the data they are derived from.

Generating predictive models are challenging as many factors influence vector-borne disease transmission

Factors

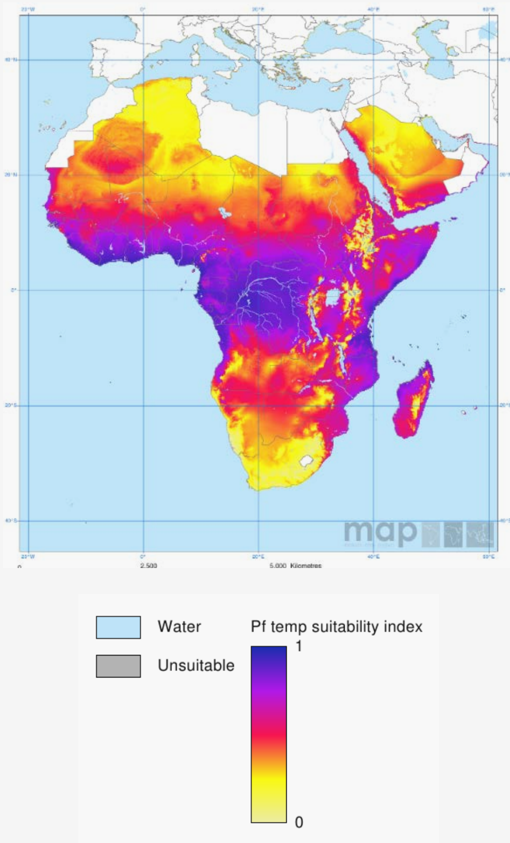
Components of vector-borne disease transmission

- Vector distribution
- Mosquito & pathogen biology
- Vector migration
- Transmission season
- Vector habitat
- Vector lifespan
- Exposure to vectors

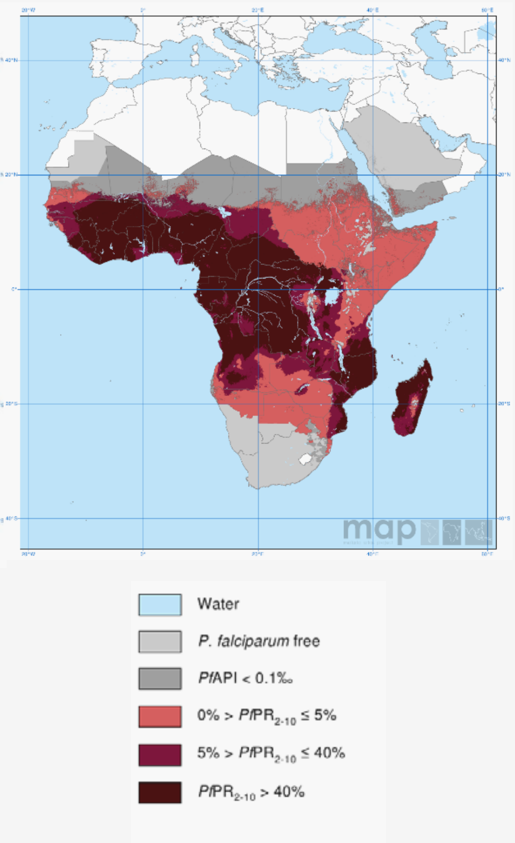
Temperature is a major factor in the transmission of vector-borne diseases

1. Correlated with disease distribution

Temperature suitability

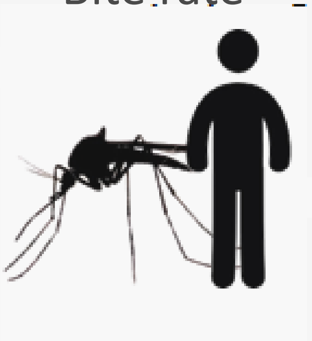


Endemicity



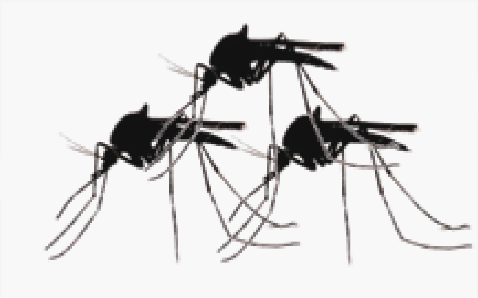
2. Profoundly affects mosquito physiology

Metabolism
Bite rate



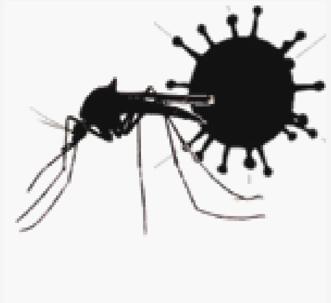
Contact rate

Rate of development
Mortality



Abundance

Susceptibility
Pathogen development

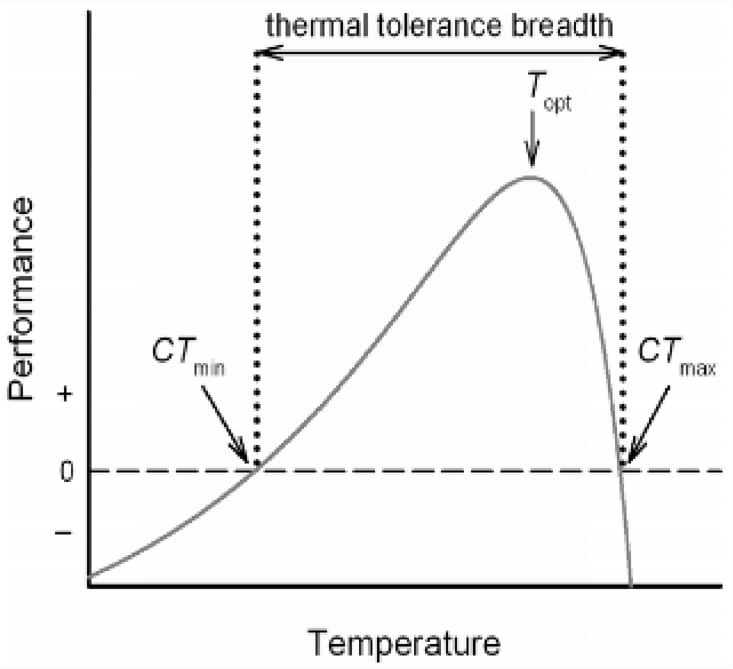


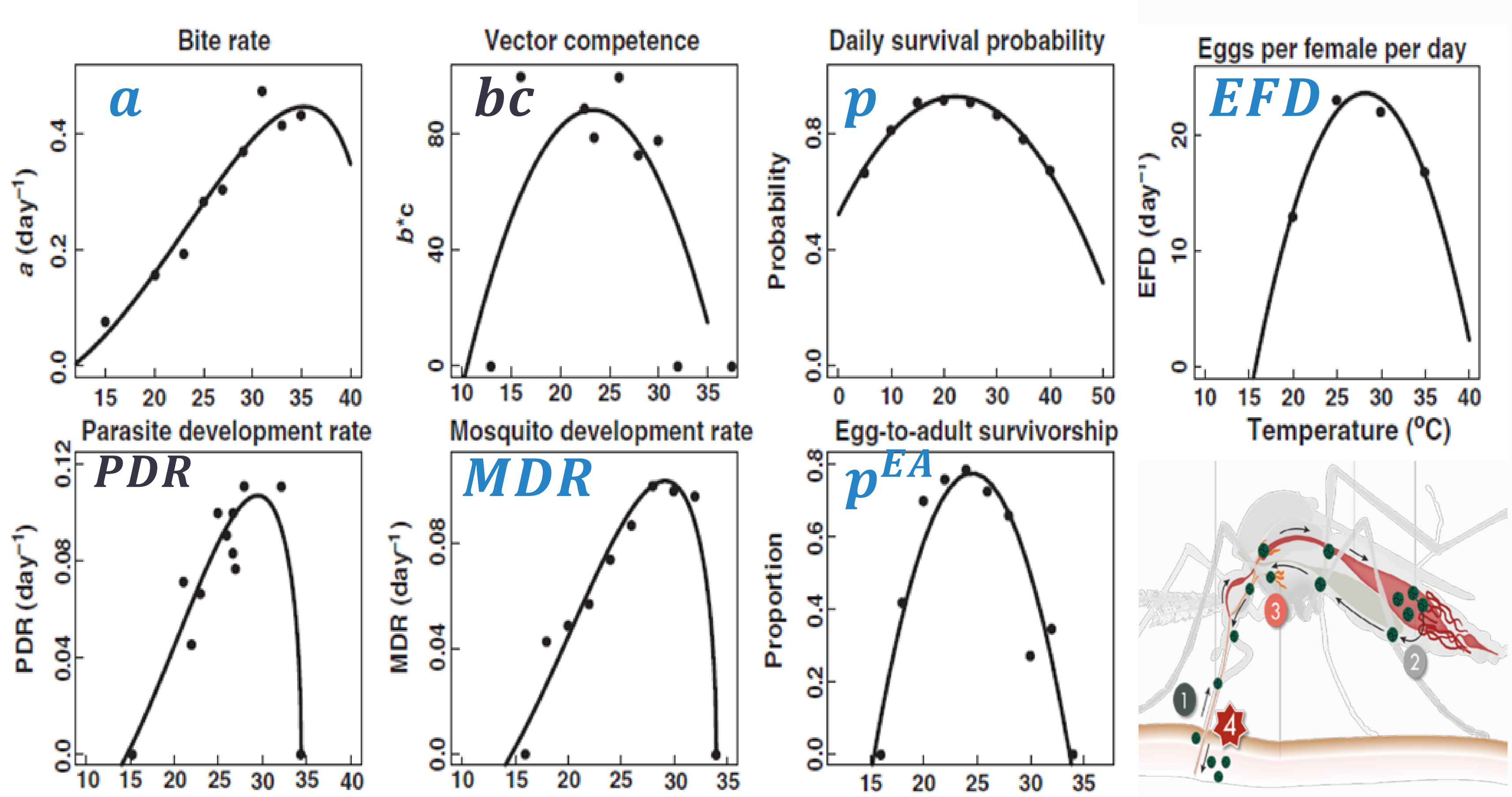
Vector competence

Temperature affects many traits that are involved in disease transmission

There is limited data on how temperature affects mosquito and pathogen biology

Thermal performance curve (TPC)





Key Features:

- Thermal optimum
- Curve shape (asymmetric)

Limitations:

- Mixed species
- Poorly characterized

Mordecai et. al. 2012. *Ecology Letters*.

These temperature-by-trait relationships have important implications for vector-borne diseases transmission

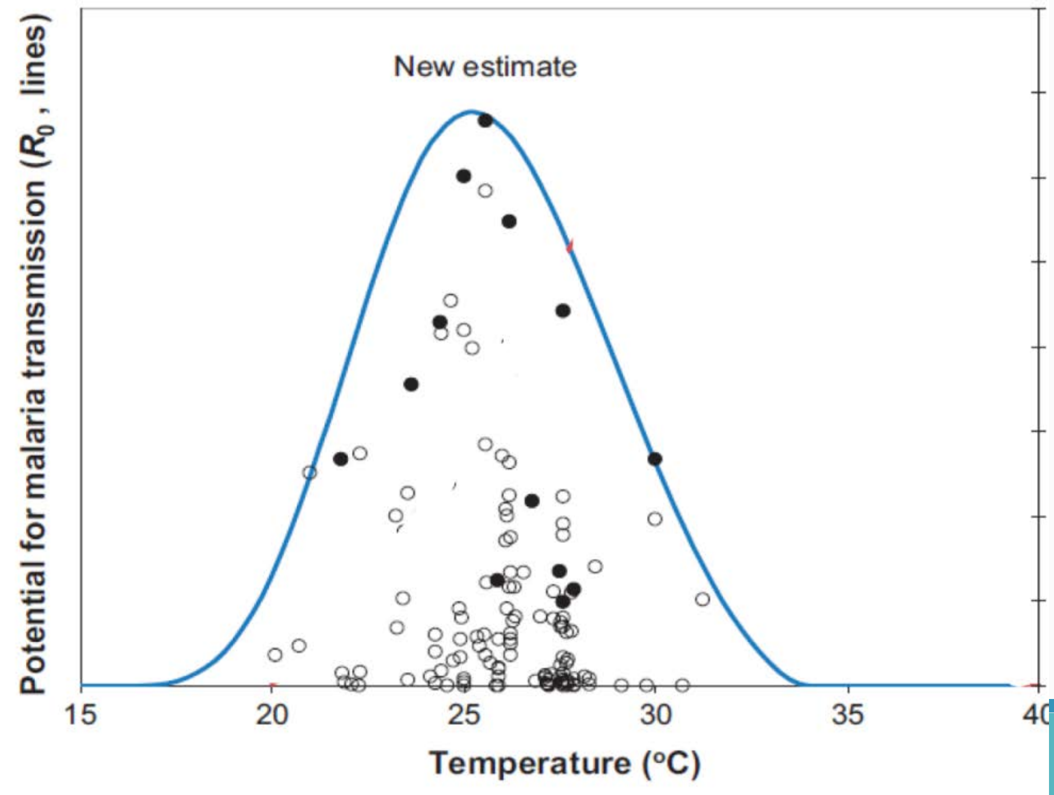
The basic reproductive number (R_0)

M = mosquito density
μ = daily probability of mosquito mortality
a = daily biting rate
b = probability of mosquito infection
EFD = eggs produced per female mosquito per day
$\mathcal{P}_{EA}$ = probability of egg to adult survival
PDR = parasite development rate
N = human density
r = human host recovery rate
c = probability of human infection

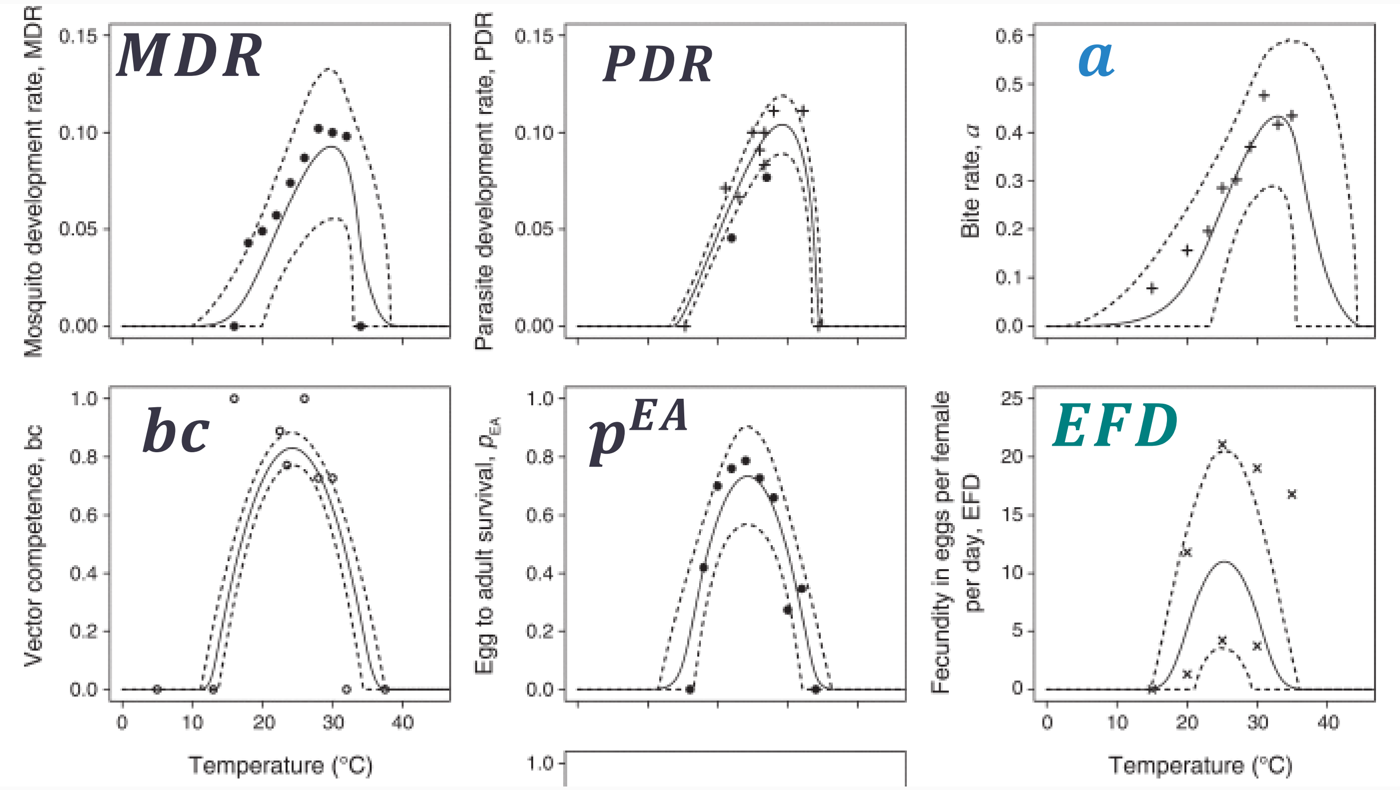
R_0 is primarily comprised of mosquito-specific traits

$$R_0 = \sqrt{\frac{Ma^2bce^{-\mu/PDR}}{Nr\mu}}$$

$$M = \frac{EFD\mathcal{P}_{EA}MDR}{\mu^2}$$



Previous research indicates that further characterization of specific parameters could aid in reducing uncertainty in R_0



μ

$$R_0 = \sqrt{\frac{Ma^2bce^{-\mu/PDR}}{Nr\mu}}$$

$$M = \frac{EFD\, p_{EA} MDR}{\mu^2}$$

More empirical data are required for the following parameters to resolve the:

Thermal optimum:

- Biting rate (a)
- Mortality rate (μ)
- Eggs / female per day (*EFD)*

Thermal extremes:

- Parasite development rate (*PDR*)

Study Aim: To generate a better understanding of how temperature impacts transmission dynamics

- Characterize *Anopheles stephensi* life history traits (EFD, a, μ)
  ****previous studies draw on a mixed-species approach of crude data****

Specific Aims:

1. Are these traits affected by temperature?
2. Do these traits change over the course of a mosquitoes' lifespan?
3. Is there an interaction between temperature and mosquito age?
4. **If these traits are affected by *age* and/or *temperature*, what are the implications for the transmission?**

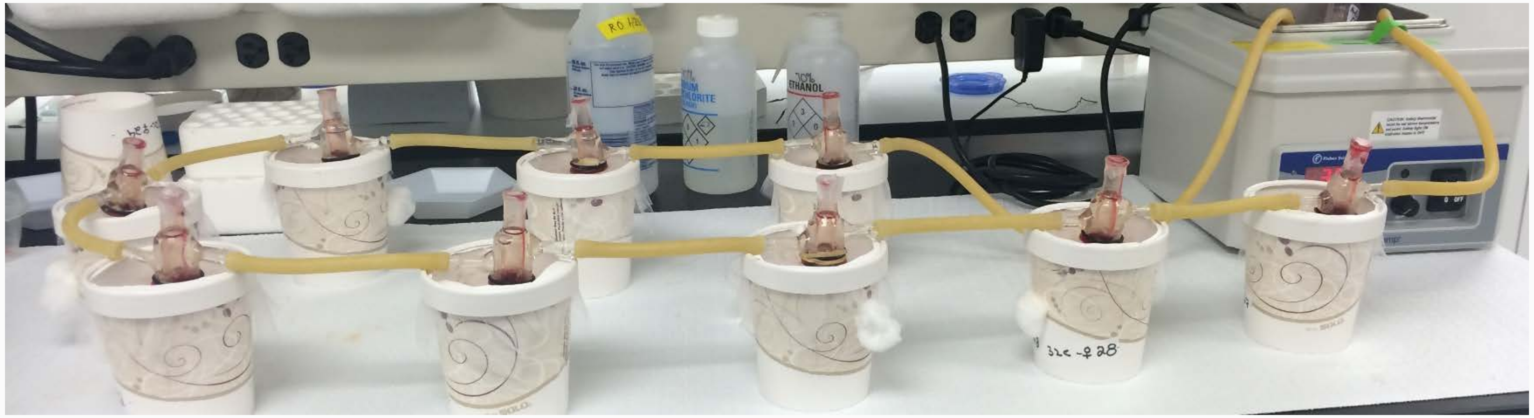
How does Temperature & Age integrate to affect mosquito-borne disease transmission in the *Anopheles*-Malaria system?

Followed 30 individual *An. stephensi* females in each temperature treatment till death

30 individuals x6 temperatures x 2 replicates (n = 360 total)

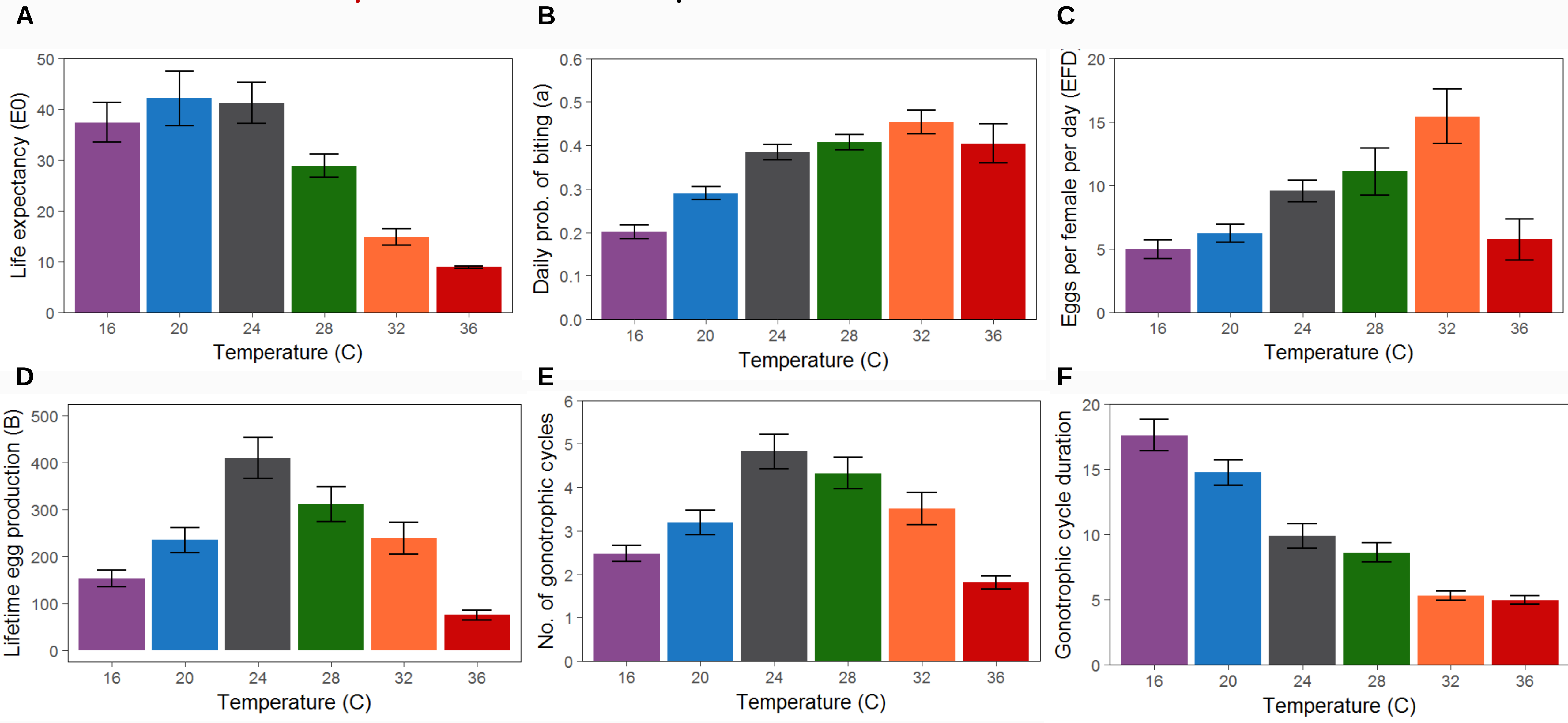
Daily individual measurements:

- no. of females that died per day (daily mortality probability, ***μ***)
- no. of females blood feeding per day (daily biting rate, ***a***)
- no. of eggs laid per day (eggs laid per female per day, ***EFD***)



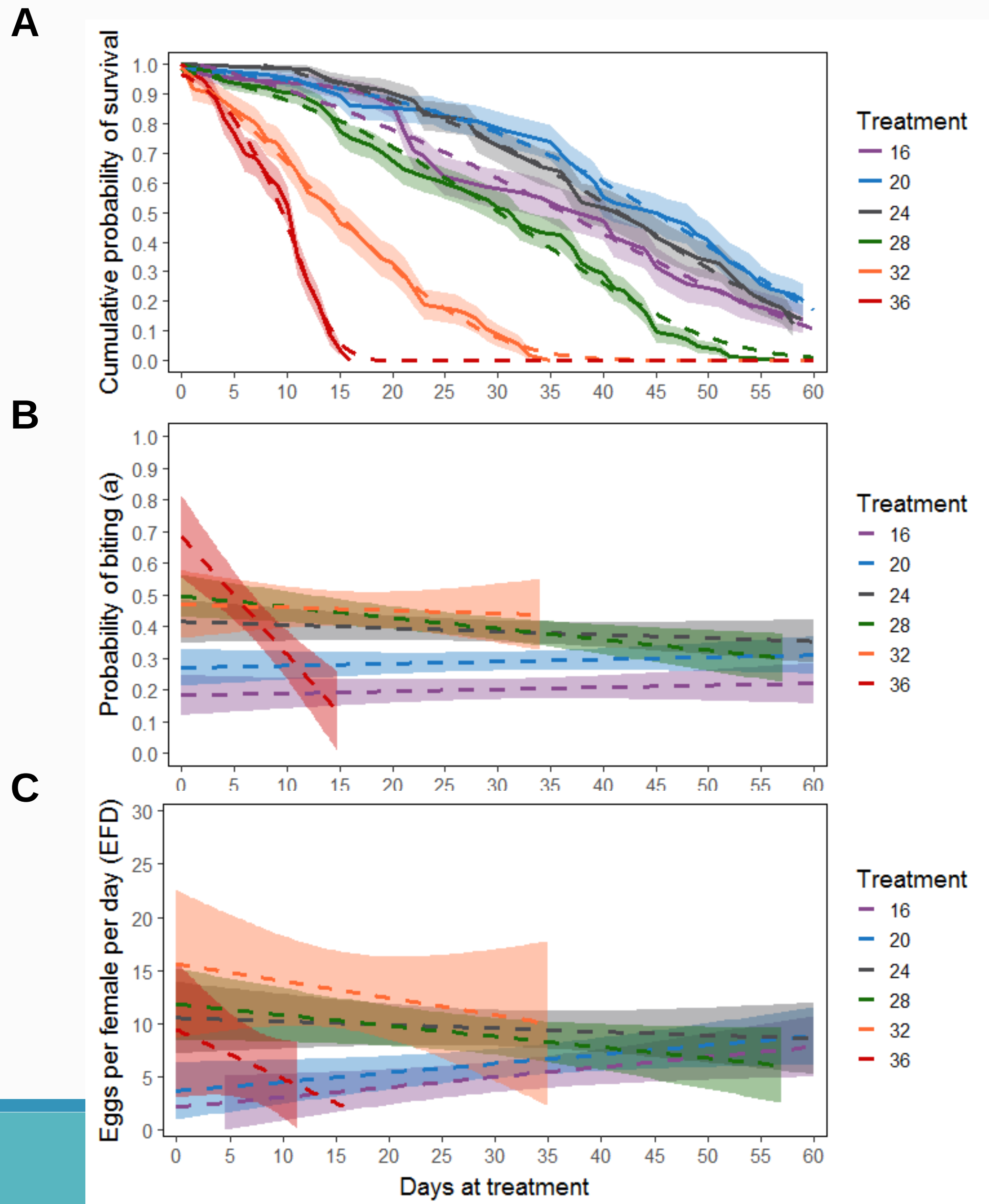
Anopheles stephensi were reared under standard laboratory conditions: 27°C, 80% RH, and a 12hr:12hr L:D photoperiod.

The effect of temperature on mosquito traits involved in transmission



These qualitatively different thermal responses complexly integrate to affect transmission

The effect of age on mosquito traits involved in transmission



Mortality increases with temperature and changes with age

Biting rates *decrease* with age at higher temperatures

Fecundity varies with age in relation to temperature

What are the implications of these temperature and age effects for transmission?

$$R_0 = \sqrt{\frac{M a^2 b c e^{-\mu/PDR}}{N r \mu}} \quad M = \frac{EFD\,\mathcal{P}_{EA}\,MDR}{\mu^2}$$

Shift in thermal optimal?
Shift in thermal breadth?

The basic reproductive number (R_0)

- M = mosquito density
- **μ = daily probability of mosquito mortality**
- **a = daily biting rate**
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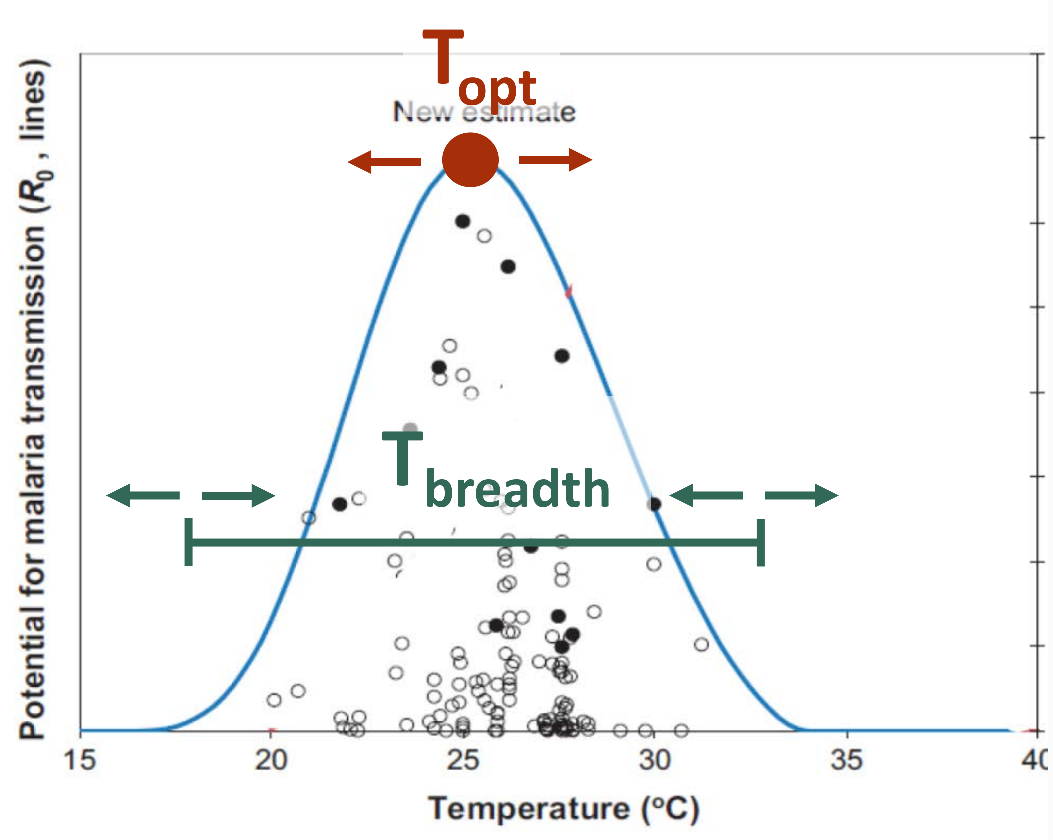


There are several ways we can evaluate the effects of temperature and age…

AGE-INDEPENDENT

Standard

$$R_0(T) = \left(\frac{a(T)^2 bc(T) e^{-\mu(T)/PDR(T)} EFD(T) p_{EA}(T) MDR(T)}{Nr\mu^3(T)} \right)$$

As in Mordecai et. al. 2012.

Reformulated

$$R_0(T) = \left(\frac{a(T)^2 bc(T) e^{-1/[E(T)PDR(T)]} p_{EA}(T) MDR(T) B(T) E(T)^2}{Nr} \right)$$

Replacing the assumption that *EFD*/μ = *B* (Lifetime egg production) with our observed data

AGE-DEPENDENT

Averaged Daily

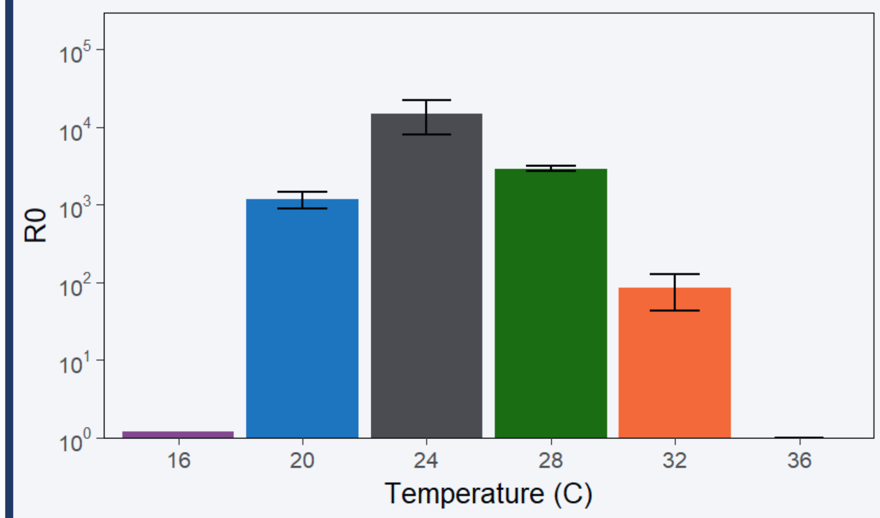
$$R_0(T) = \left(\frac{R_0(1) + R_0(2) + R_0(3) + R_0(4)\ldots}{N} \right)$$

The average of a day-specific R_0 with the measured day-specific traits (*EFD, u, a*)

The thermal performance curve for transmission potential is altered with the inclusion of age-specific trait performance

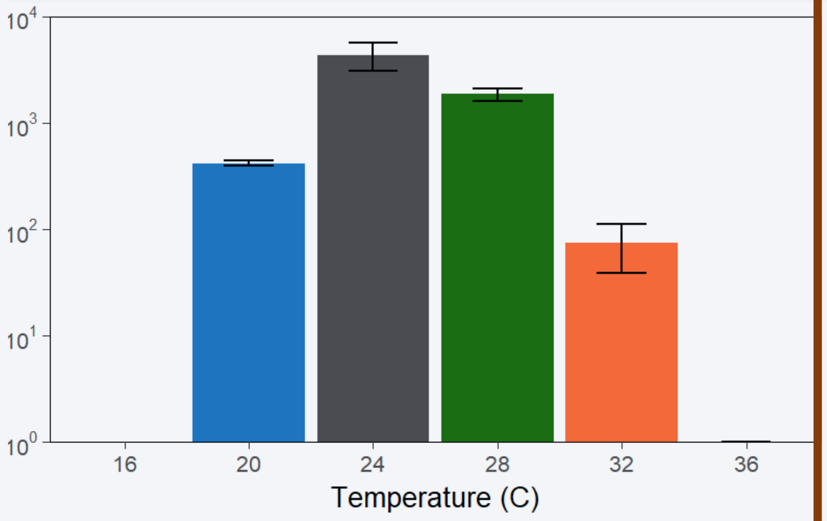
AGE-INDEPENDENT

Standard



$$R_0(T)=\left(\frac{a(T)^2 bc(T) e^{-\mu(T)/PDR(T)} EFD(T) p_{EA}(T) MDR(T)}{Nr\mu^3(T)}\right)$$

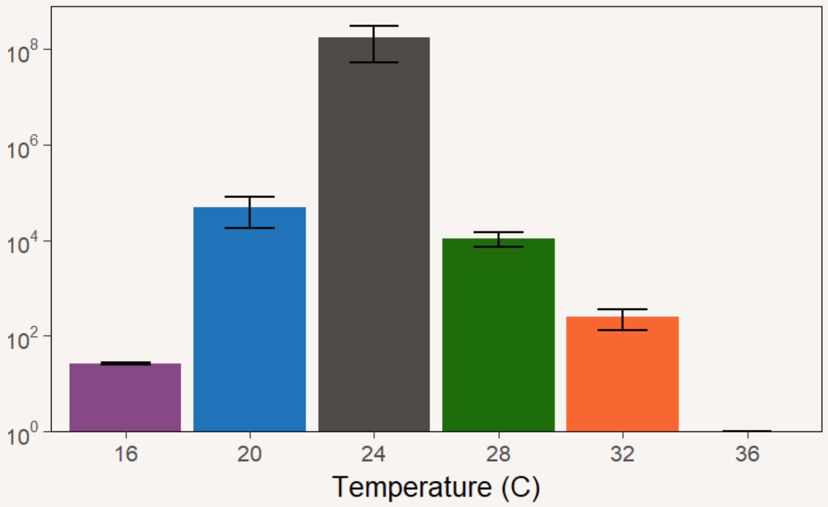
Reformulated



$$R_0(T)=\left(\frac{a(T)^2 bc(T) e^{-1/[E(T)PDR(T)]} p_{EA}(T) MDR(T) B(T) E(T)^2}{Nr}\right)$$

AGE-DEPENDENT

Averaged Daily



$$R_0(T)=\left(\frac{R_0(1)+R_0(2)+R_0(3)+R_0(4)...}{N}\right)$$

<u>Specific Aim 1:</u> Characterize the thermal performance for *Anopheles stephensi* life history traits relevant to malaria transmission

Results:

- *Temperature strongly influences An. stephensi life history traits.*
- *The non-linear relationship is unique to each trait.*

Implications:

- *The thermal performance curve for each life history trait integrates to complexly affect transmission.*
- *Many models rely on a mixed species approach for parameterization (lack of data).*
  - *-how different are these responses between mosquito species?*
- *(Future) How does individual variation in trait performance vary across temperature, implications?*

<u>Specific Aim 2:</u> Evaluate the effects of temperature and age on malaria transmission dynamics

Results:

- *The standard R_0 closely resembles the reformulated R_0.*
- *The averaged daily R_0 and standard R_0 have different thermal performance curve shapes.*

Implications:

- *Mosquito population age-structures may modify trait performance across temperatures and play an important role in transmission dynamics.*

R_0 is a powerful tool in the application and evaluation of interventions, however if current methods fail to capture important aspects of transmission, our ability to effectively reduce vector-borne disease is hindered.

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