The University of Georgia

Population Biology of Infectious Diseases

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Improving Malaria Transmission Risk Models

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Introduction

Current malaria transmission risk models predict that the relationship between malaria risk and temperature is both positive and linear. However, **mosquito and parasite traits responsible for malaria transmission display a non-linear trend with increasing temperature**[1]. This has resulted in an inconsistency with malaria's predicted incidence rates and disease actualization.

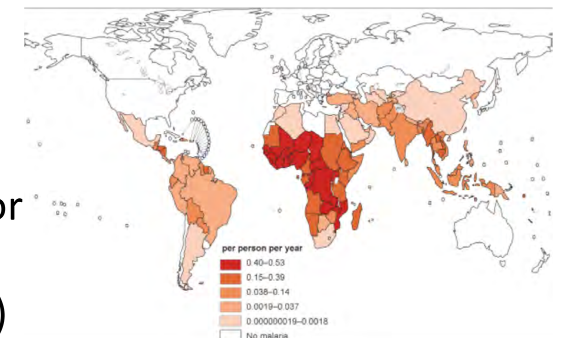


Figure 1. Global Malaria Incidence Rates[2]

Furthermore, this discrepancy can be linked to the lack of quality data across different temperatures for *Anopheles stephensi.* Past studies conducted;

- Used data substitutes (diff. species & pathogens) to generate thermal performance curves[1].
- Found the largest uncertainty in risk prediction was associated with bite rate (*a*), fecundity(*EFD*), and daily probability of mortality (μ). [3]

This experiment aims to enhance the data available for *A. stephensi* (an important vector of malaria) across relevant temperatures, and thus, improve the transmission risk model.

The R_0 equation is used to predict the number of resulting cases from a single infection. This experiment aims to improve the precision of the R_0 Equation using temperature-dependent functions for fecundity, mortality, and bite rate.

Basic reproductive number

$$R_0 = \sqrt{\frac{EFD\, p^{Ea} MDR\, a^2 bc e^{-\mu/PDR}}{N r \mu^3}}$$

Methods and Materials

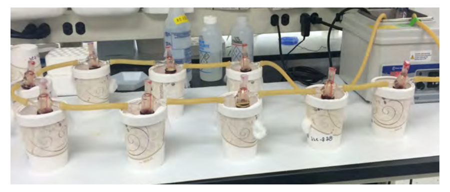
Life Table Study (N = 180)

Fecundity (Eggs per Female per Day)

Mortality (# of dead & when at different temperature treatments)

Bite Rate (# of occurrences mosquito takes a blood meal)

15- Minute Feeding Opportunity

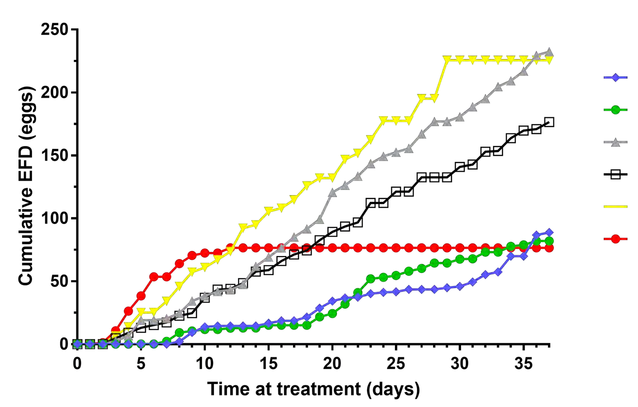


Results

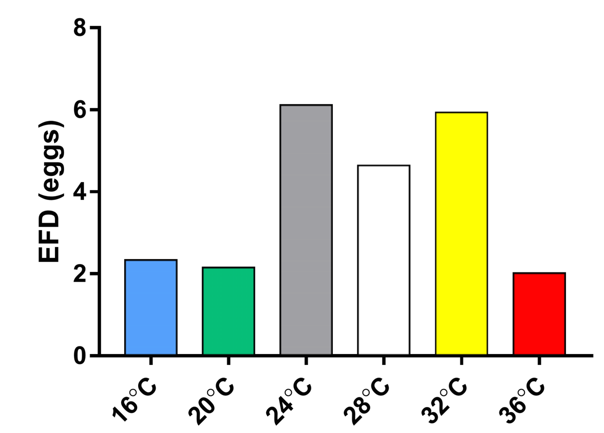
Fecundity

Eggs per female per day (*EFD*)

Mosquitoes at the mid temperatures (24°C, 28°C, and 32°C) had the highest EFD values.



Gross reproductive rate. Calculated as the # of eggs laid on day x divided by the total # mosquitoes alive on day x and compounded daily.

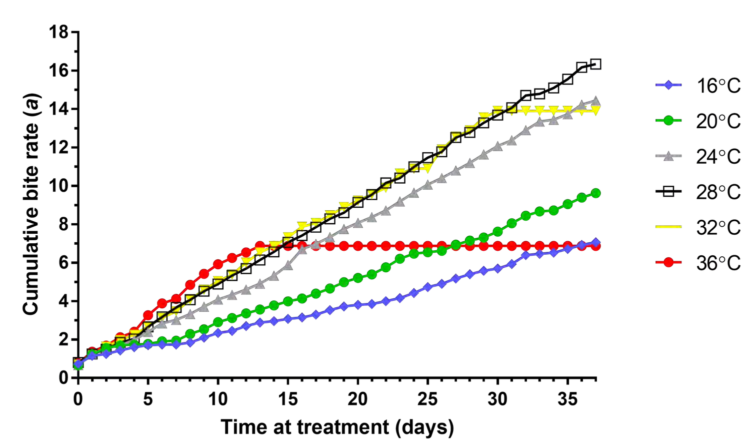


Eggs per female per day. Calculated as the # of eggs laid on day x divided by the total # mosquitoes alive on day x and averaged across all days.

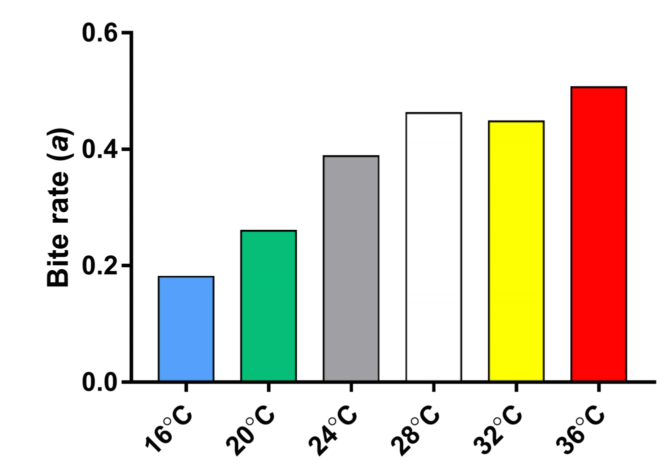
Bite Rate

Prop. of bloodmeals taken

Mosquitoes at higher temperatures have higher biting rates than those at lower temperatures.



Bite rate. Calculated as the # of mosquitoes that took a blood meal on day x divided by the total # of mosquitoes alive at temp on day x and compounded daily.

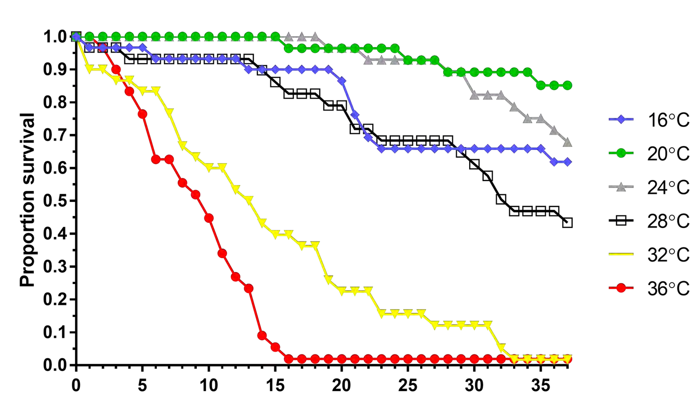


Bite rate. Calculated as the average of the # of feeds for an individual mosquito divided by the # of opportunities that mosquito had to feed.

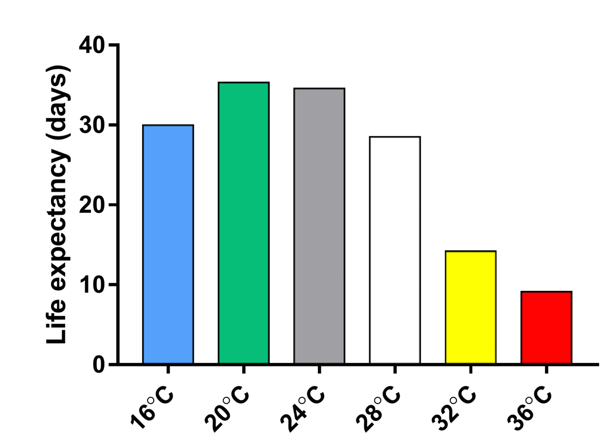
Mortality

Survivorship

Mosquitoes at higher temperatures have higher mortality rates than those at lower temperatures.



Daily proportion surviving. Calculated as 1- cumulative proportion dead. Cumulative proportion dead was calculated as the # mosquitoes dead divided by the total # alive.

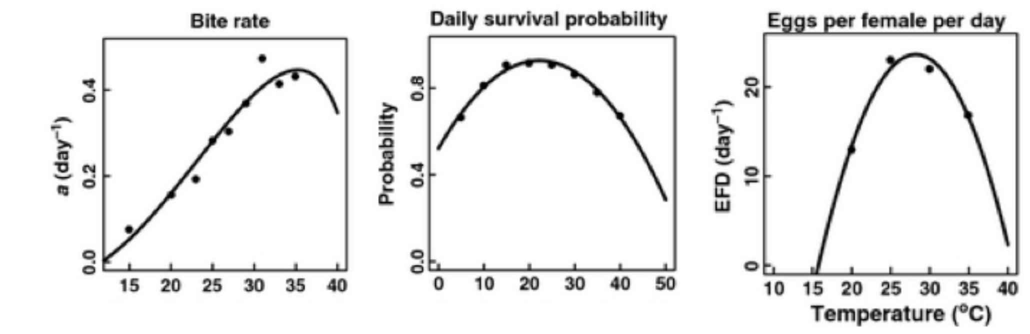


Life expectancy. Calculated as the total area under the daily proportion survival curve.

Discussion

This experiment demonstrates:

- Mortality, fecundity, and bite rate are all interconnected.
- Notably, longevity plummets as temperature increases



Non-linear rates of measurement (Mordecai et. al, 2013)

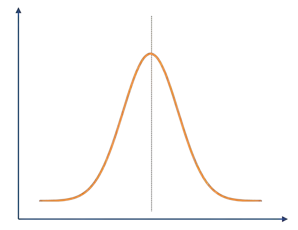
Mortality and bite rate play significant roles in the overall population size of the mosquito vector, because those with decreased longevity have a smaller time span to bite, lay eggs, and reproduce. This alters the density of mosquitoes to humans which is a factor in the transmission risk equation.

Conclusion: This experiment generated a robust data set comprising of important *A. stephensi* life history traits essential for generating improved malaria transmission risk models which incorporate a temperature-dependent mechanistic framework and essentially filling the knowledge gap there once was about *Anopheles spp.* mosquitoes.

Future Directions

1. Generate thermally-dependent function for three traits measured

$$R_{0\,(T)} = \sqrt{\frac{EFD_T\, p^{Ea} MDR\, a_T^2 bc e^{-\mu_T PDR}}{N r \mu_T^3}}$$



2. Apply model to the 'real' world
   - Better accuracy in determining risk of transmission in malaria-susceptible areas.

Acknowledgements

Many thanks to the Murdock Lab, the Population Biology of Infectious Diseases at the University of Georgia, the Odum School of Ecology, and The College of Veterinary Medicine.

Thank you to Howard University, my family, and friends.

Funding is provided by the National Science Foundation & the National Institute of Health.

NIH R01 1R01AI110793-01A1

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References

1. Mordecai et. al, 2013
2. World Health Organization
3. Johnson et. al, 2014

National Institutes of Health