Behavioral Determinants of Parasite Transmission in a Wild Butterfly Host

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1. Introduction:

- Environmental transmission is common in infectious diseases, and especially important for insect pathogens
- Host behavior can determine the rate at which parasites are shed into the environment
- Infection can also alter host behavior with implications for shedding and uptake of free-living parasites
- The goal of this study was to examine how host behavior affects the transmission of a protozoan parasite in a butterfly host, and to explore the consequences for infection dynamics using a mathematical model

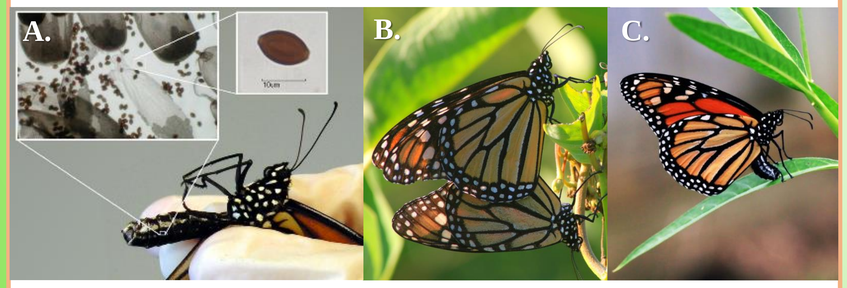
2. Research Questions:

a) **How do sex and infection status affect behavior and milkweed visitation rates in the wild?**
b) **How do milkweed visitation rate and the contamination of adult monarchs through spore transfer alter infection dynamics?**

- We investigated these questions with a combination of field observation and mathematical modeling

3. Study System:

- Monarch butterflies (*Danaus plexippus*) are commonly infected by a debilitating specialist parasite, the protozoan *Ophryocystis elektroscirrha* (OE)
- OE has two transmission modes: adults shed spores on to (1) eggs (vertical transmission) or to (2) milkweed leaves that are consumed by unrelated larvae (environmental transmission)
- Parasites develop internally and adult monarchs emerge with millions of dormant parasite spores
- Spores can be transferred between adults via mating and other contacts, potentially increasing spore deposition on milkweed



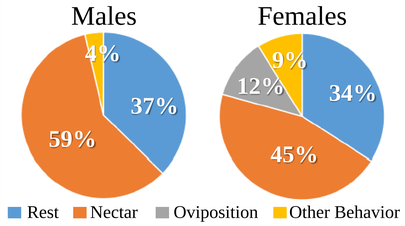
A. The parasite OE as viewed under a microscope. Infected adults can have millions of spores. B. Matings and other types of contact increase the potential for transmission between adults. C. Oviposition causes vertical transmission of the parasite.

4A. Field Observations:

- Wild monarchs were marked according to sex and infection status, and released into butterfly gardens at the Wormsloe Historic Site in Savannah, GA
- A total of 14 uninfected (6 males, 8 females) and 3 infected (1 male, 2 females) were observed for 30 minute increments at different times of day throughout 12 gardens over the course of 8 days
- The times spent engaged in the following behaviors was recorded: nectaring, flying, resting, ovipositing, and aggressive encounters
- To estimate rates of spore deposition on milkweed, the total number of milkweed stalks visited over 30 minute intervals was recorded

A. Photo of a butterfly garden at the Wormsloe Historic Site. B. Monarch #19 nectaring on tropical milkweed (*Asclepias curassavica*) during a 30 minute trial. C. Anna performing the observational studies in the field.

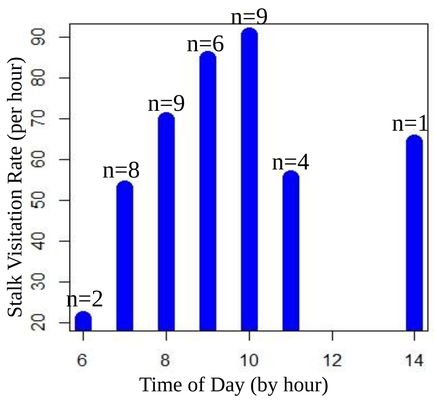
4B. Field Observation Results:



Using GLMs, sex but not infection status was found to have significant effects on activity budgets.

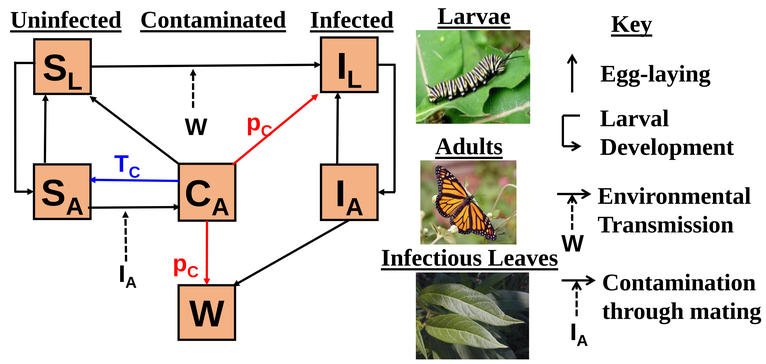
Variable	M	F
Resting		. ↓
Nectaring All Plants	. ↑	
Stalk Visitation	**↓	

0 '***' 0.001 '**' 0.01 '*' 0.05 '.'



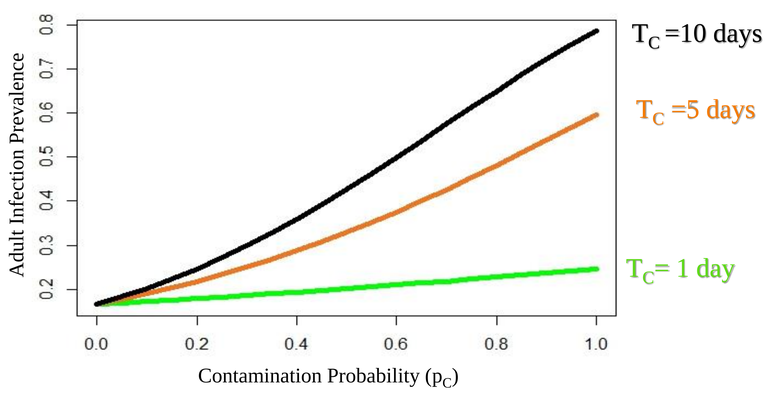
Hourly stalk visitation rate varied by time of day, with an overall mean of 69.66 stalks per hour across days

5A. Modeling



- We modified an existing differential equation model of monarch-OE dynamics to include adults contaminated with OE spores through mating (C_A)
- Contaminated adults shed spores onto milkweed, and infect their offspring, with probability p_C
- Contaminated adults retain spores for T_C days
- We varied the **contamination probability (p_C)** and the **duration of contamination (T_C)**, and investigated their effects on infection prevalence in adults after 100 days

5B. Modeling Results:



- Late-season OE prevalence varied between 16.5 and 78.6%, and increased with p_C and T_C
- This is consistent with the wide range of OE prevalence recorded in US monarchs (6-20% in the Midwest, up to 100% in tropical milkweed patches in the Southeast)

6. Conclusions:

- **Sex but not infection status accounted for variation in host behavior**
- **Milkweed visitation rates were higher than previously thought – these high visitation rates are critical for parasite persistence in the model**
- **Contaminated adults shedding low doses of spores onto leaves and eggs can dramatically increase prevalence, consistent with field estimates**

7. Acknowledgements:

We would like to thank the Population Biology of Infectious Diseases REU, the Odum School of Ecology, and the Wormsloe Foundation for supporting this project; Craig and Diana Barrows for their hospitality; the Altizer Lab, Stuart Sims and Reidar Crosswell for help with data collection.