Nectar type, relative humidity and the flight-fecundity tradeoff in a semi arid environment

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Manduca sexta / Datura wrightii system

- Nectaring by adults ==> pollination of plants
- Consumption by larvae ==> herbivory of plants

Motivation of physiology from ecology

Insects have large surface / volume ratio

very susceptible to desiccation

Does RH play a role in foraging decisions?

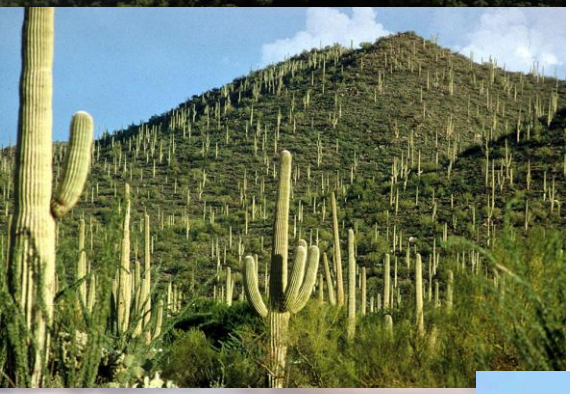
Host plants differ in nectar concentration

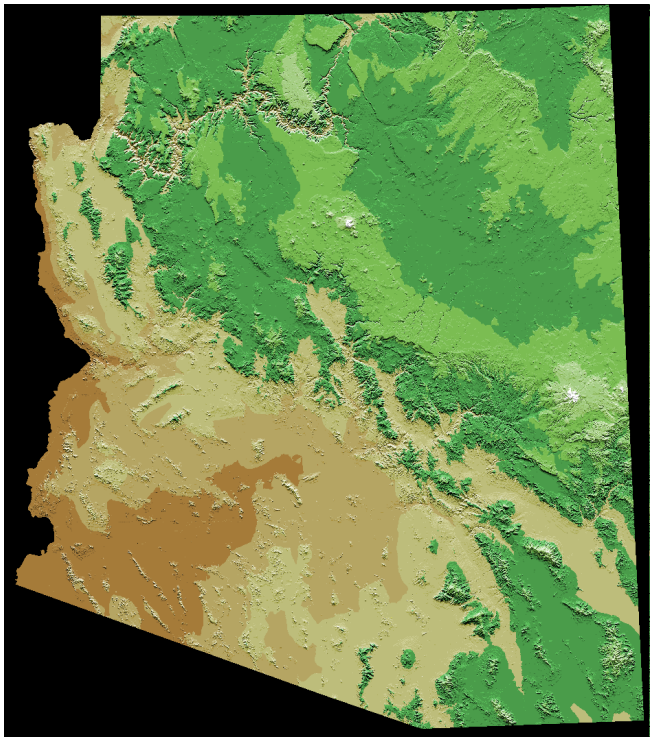
Does this make a difference?

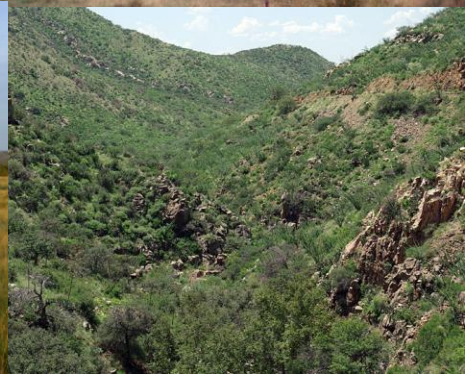
Resources are widely dispersed

Does this affect insect fitness?

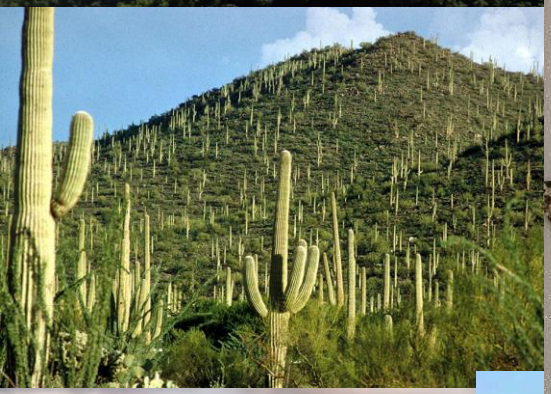
Southeastern Arizona has a high diversity of biomes and habitats





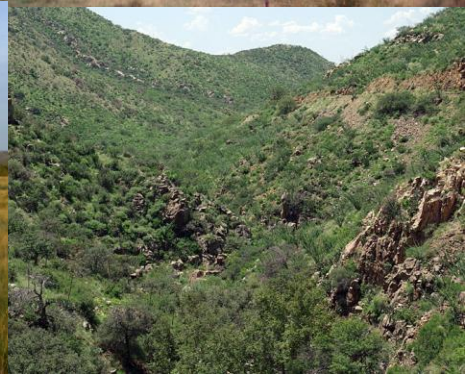


Large diversity and high abundances of hawkmoths (43 species)





Relative humidity increases dramatically with onset of monsoons

Relative Humidity %

90
80
70
60
50
40
30
20
10
0

3/10/01
4/19/01
5/29/01
7/8/01
8/17/01
9/26/01
11/5/01

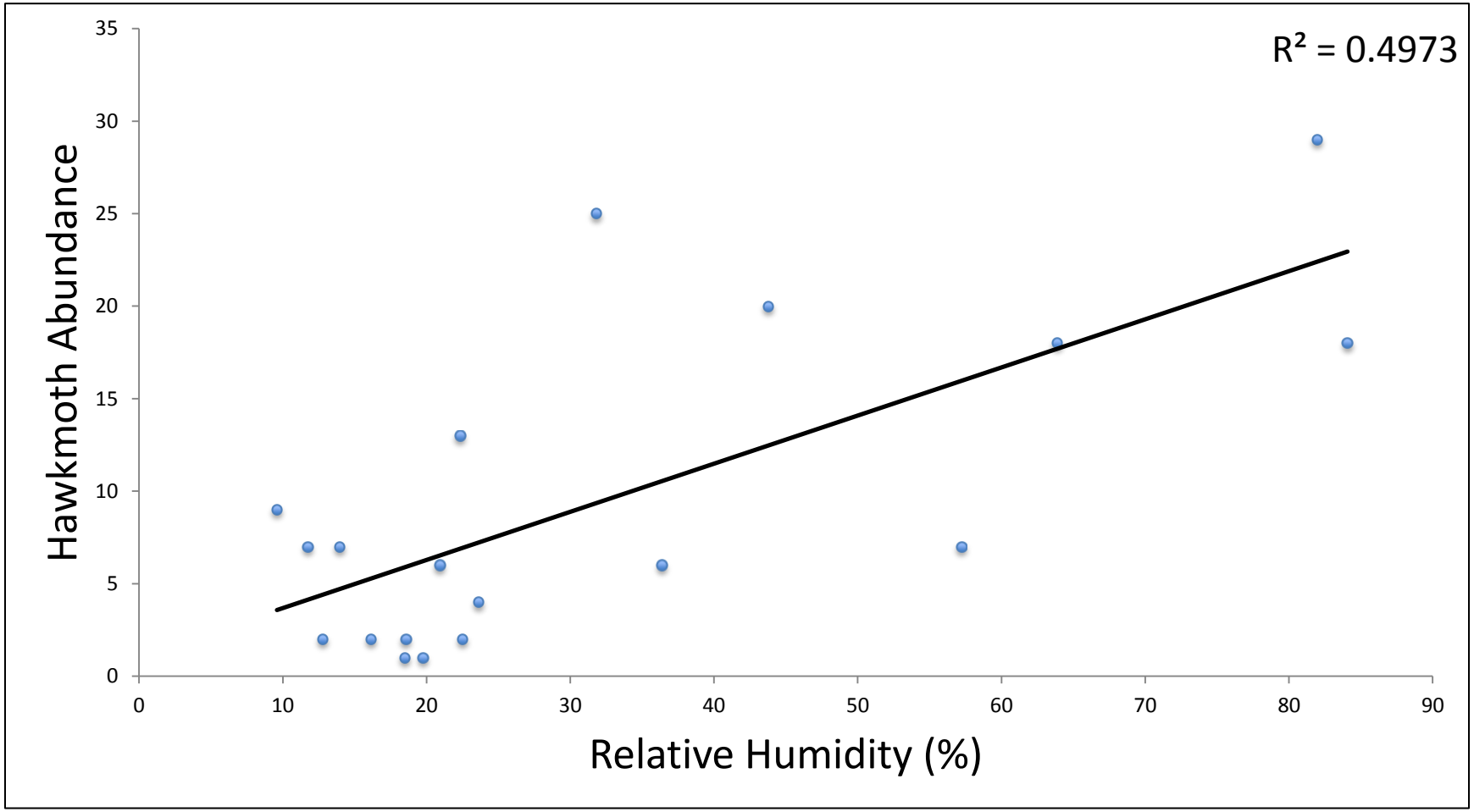
Date

Does relative humidity affect hawkmoth abundance?

Our study site at the SRER

Blacklighting for hawkmoths

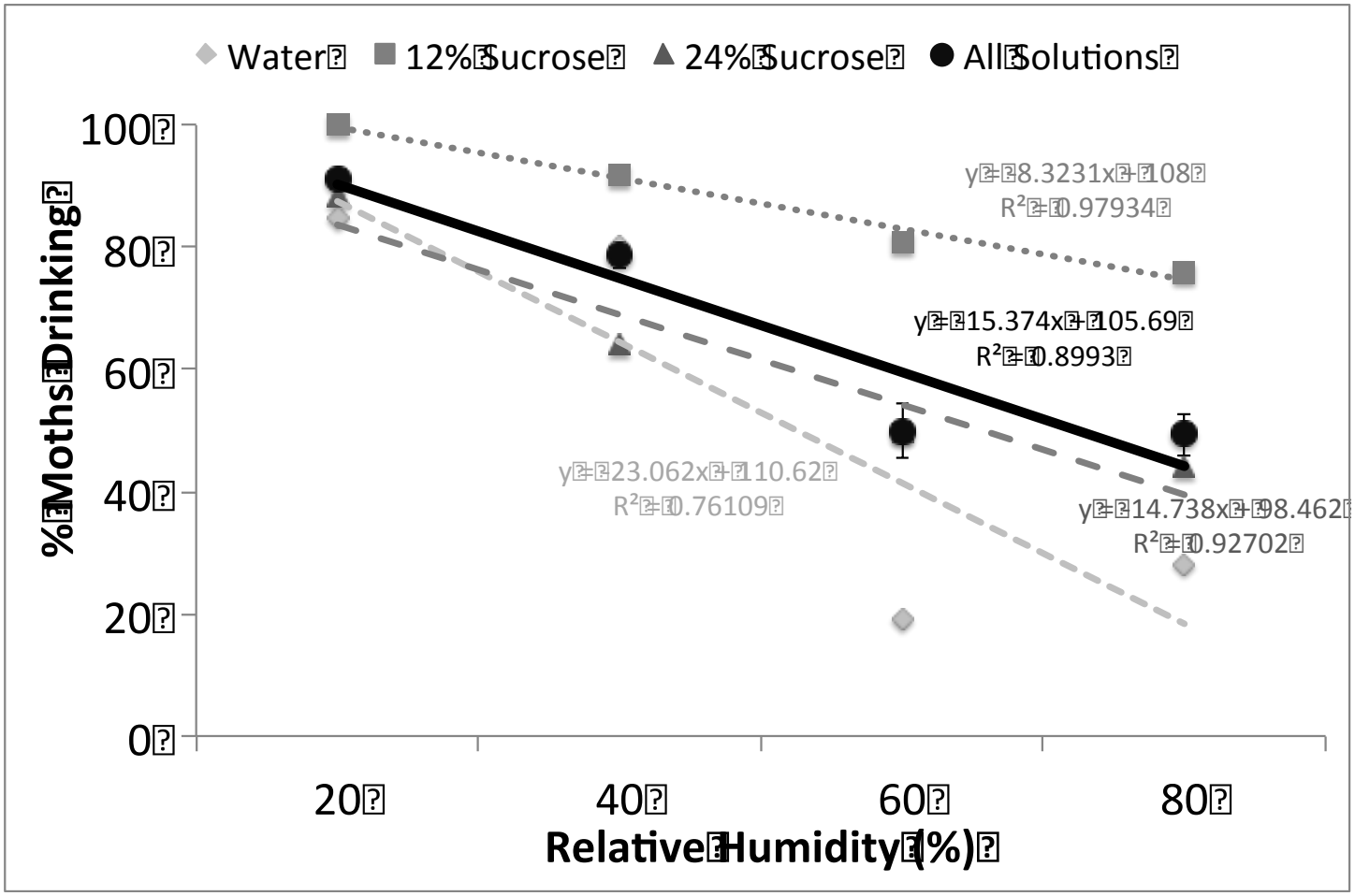
Hawkmoth abundance increases with relative humidity in a given site (2005)



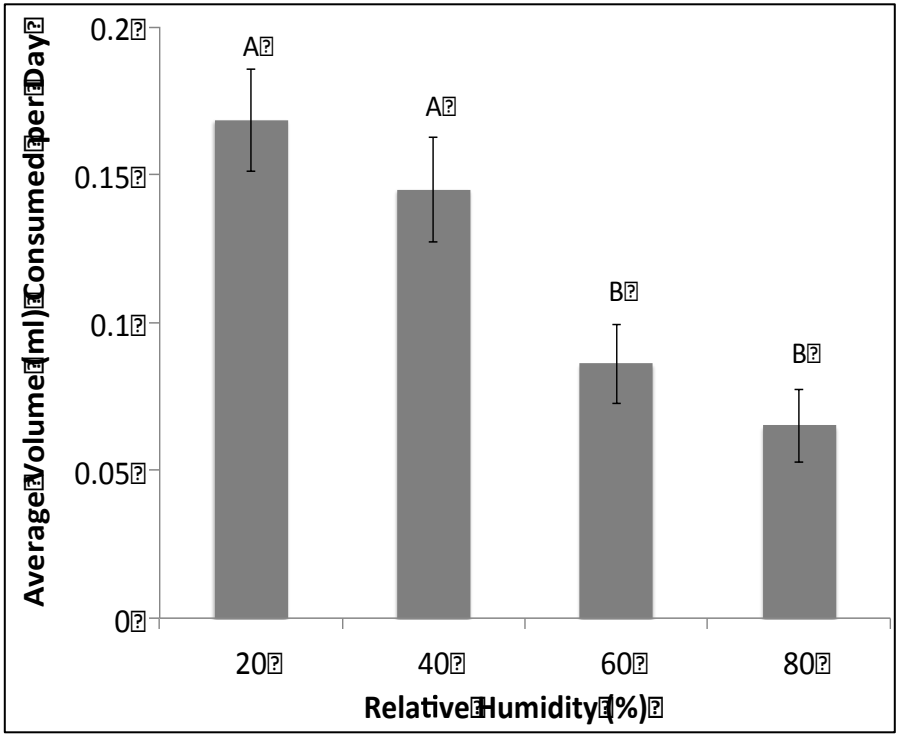
Manduca sexta:
the tobacco hornworm

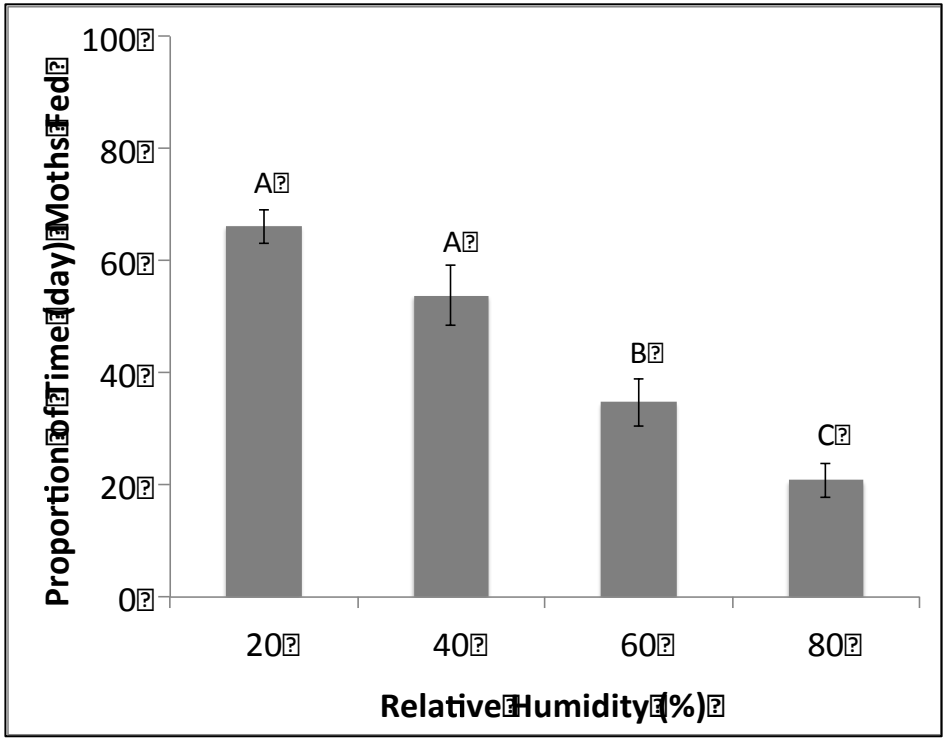
Does relative humidity affect moth foraging behavior?

Fewer moths drink nectar when humidity is higher

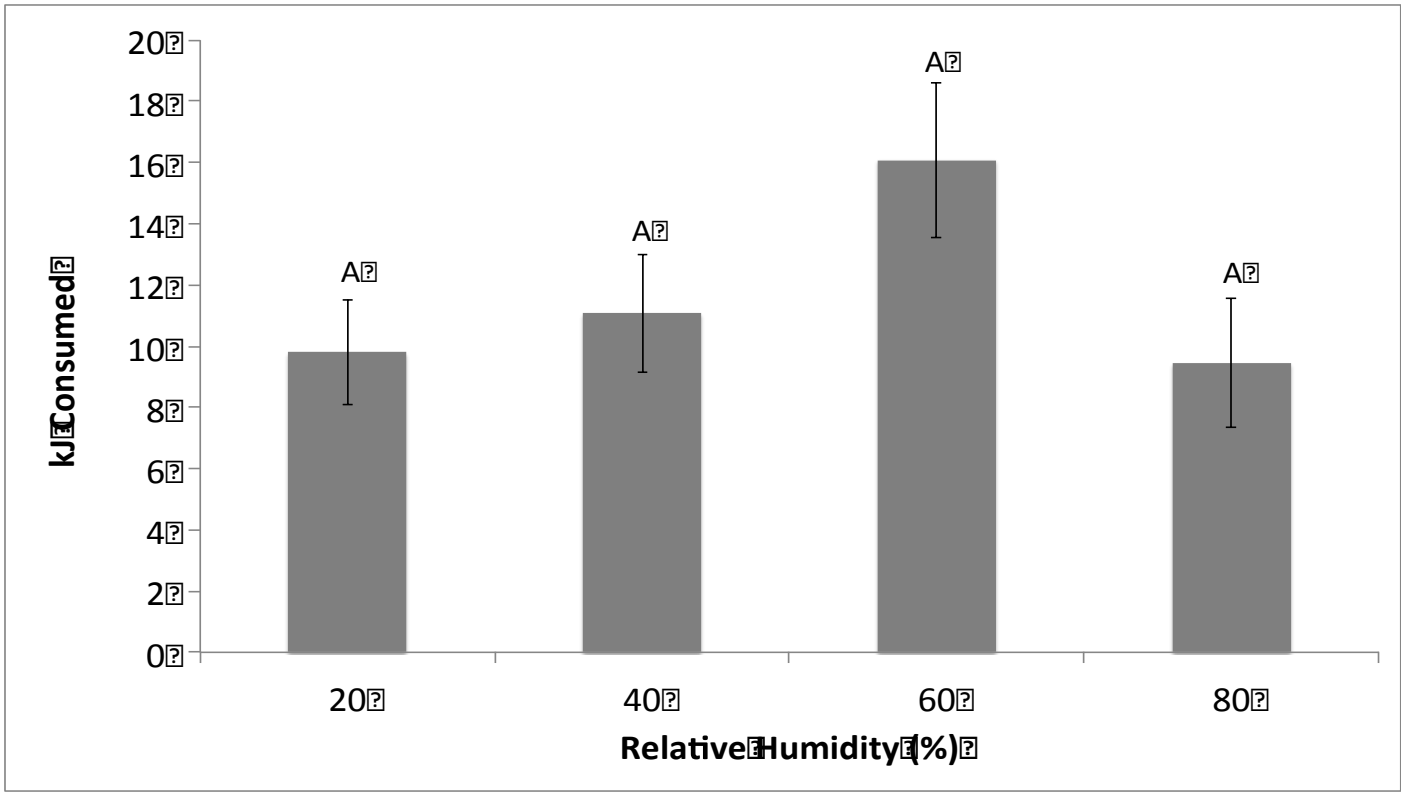


Moths drink less per day and feed fewer days at higher humidity





But, total energy consumed does not change with relative humidity



At high humidity, moths drink nectar primarily as a source of energy

At low humidity, water balance becomes as, or more, important than energy

How important is the main host plant in the diet of the adult moths?

Datura shows many signs of adaptation for hawkmoth pollination.

Flowers:

- open at night
- large tubular display
- highly reflective coloration
- strong, perfume-like odor

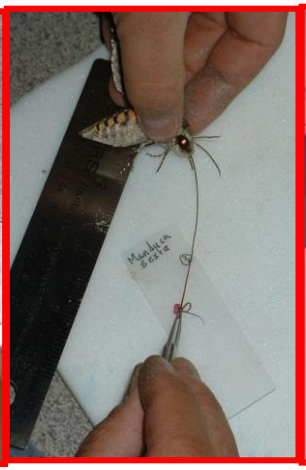
Huge reward

- 65 μl nectar/flower
- 25% sucrose

Prolonged flowering period (May-October)

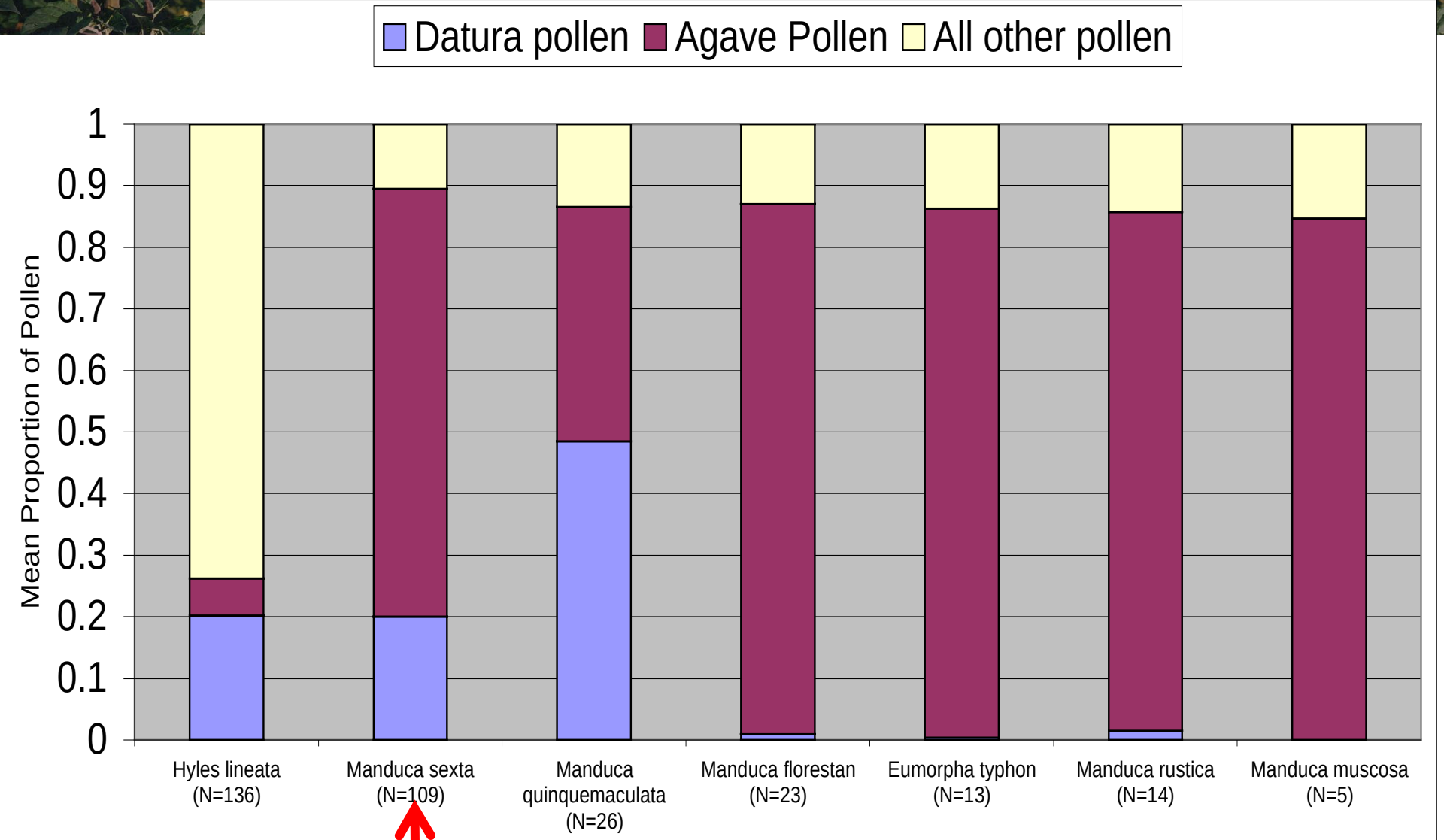






2004 Proboscis Pollen (n=326)



Riffell, Alarcón, Abrell, Davidowitz, Bronstein, Hildebrand: *PNAS 2008*
Alarcon, Davidowitz, Bronstein: *Ecol Entomol* 2008

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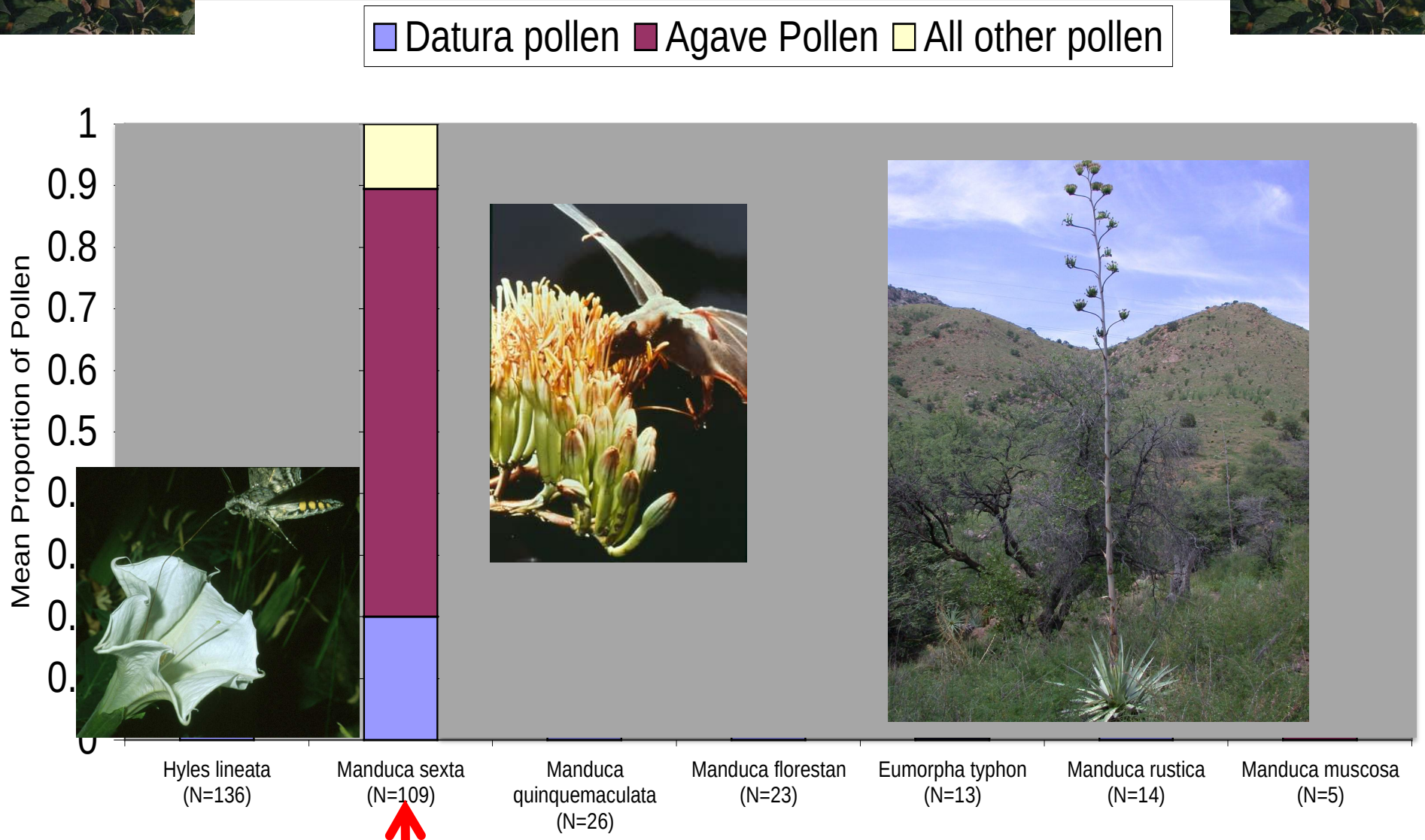

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Agave palmeri is a classic, well-studied bat-pollinated plant.

Datura *vs*. Agave as fuel source

Datura

24% sugar concentration

Sucrose based nectar

smaller volume (60ul)

More energy per volume (x3.6)

Lower osmotic load

Agave

12% sugar concentration

Hexose based nectar

greater volume (600ul)

Less energy per volume

Higher osmotic load

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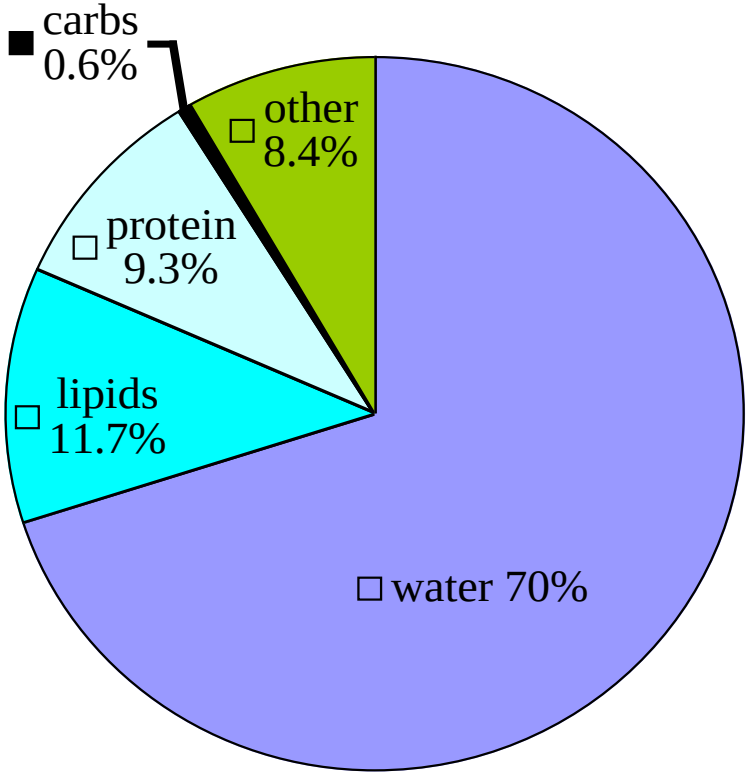
High metabolic cost due to excess water and low energy return

What are the relative costs and benefits of different nectars?

Moths fly long distances daily

~5 km

Eggs compete with flight for lipid and carbohydrate resources



M. Sexta egg: after Kawooya and Law, 1988

Moths use two main flight fuels

Carbohydrates: immediately available, short duration flights

Adult derived

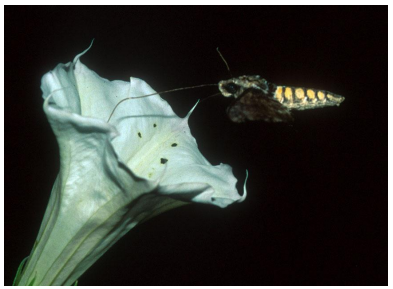
Lipids: 3.6 times more energetically efficient, used for long duration flights

Larva derived

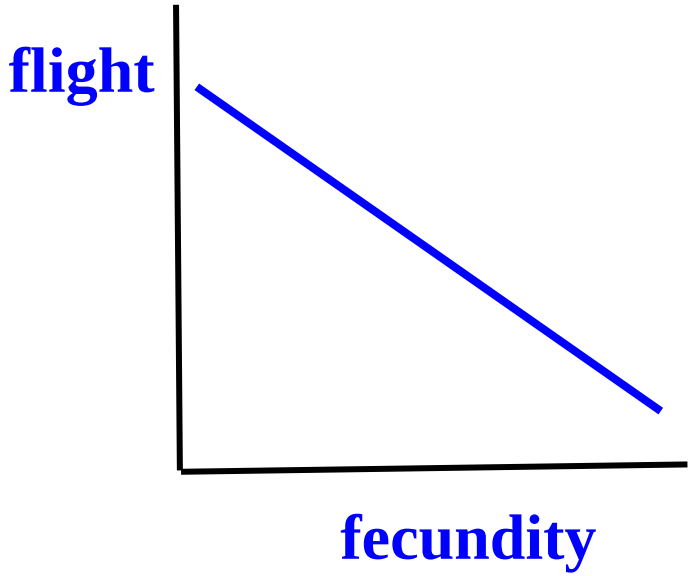
Manduca sexta system excellent model to examine flight-fecundity tradeoff

1. Eggs and flight compete for same resources (carbs, lipids)

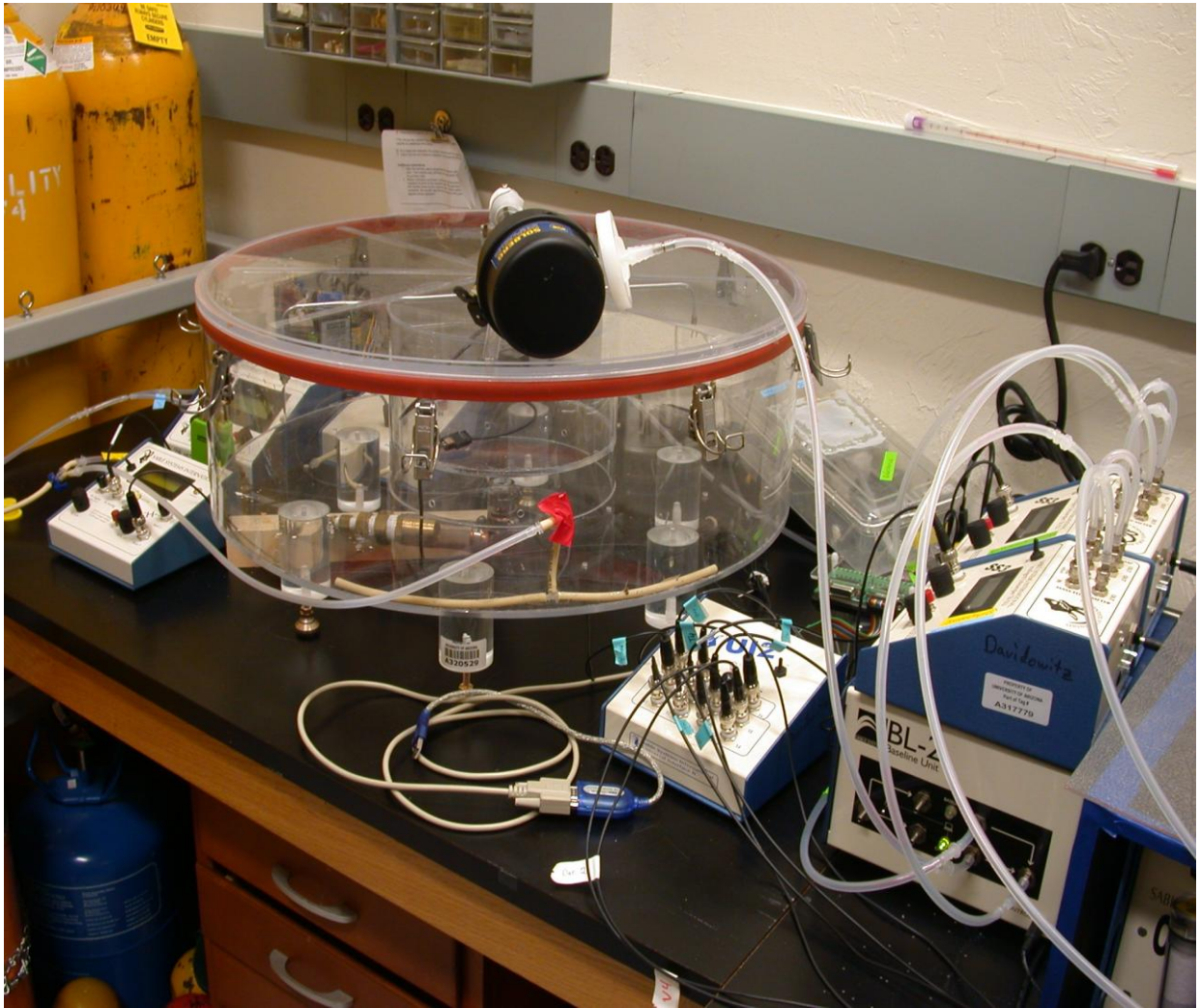
2. Moths apparently fly long distances (10km) nightly
3. Flight is VERY costly (hovering 100x)



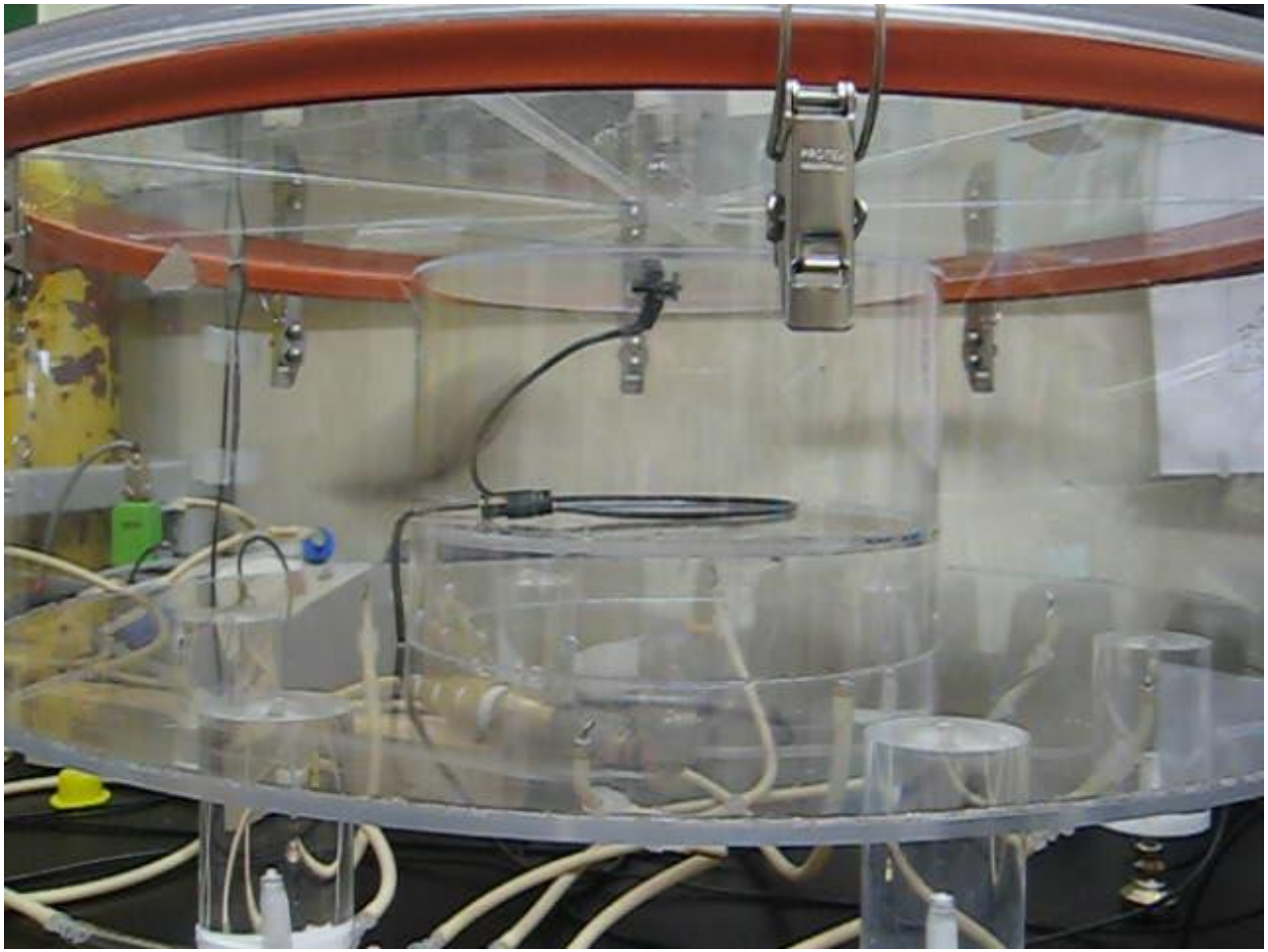
4. Females produce large numbers of eggs (≈ 250)



Flight mill / flow-through respirometry system



How far / fast / long is the moth flying?



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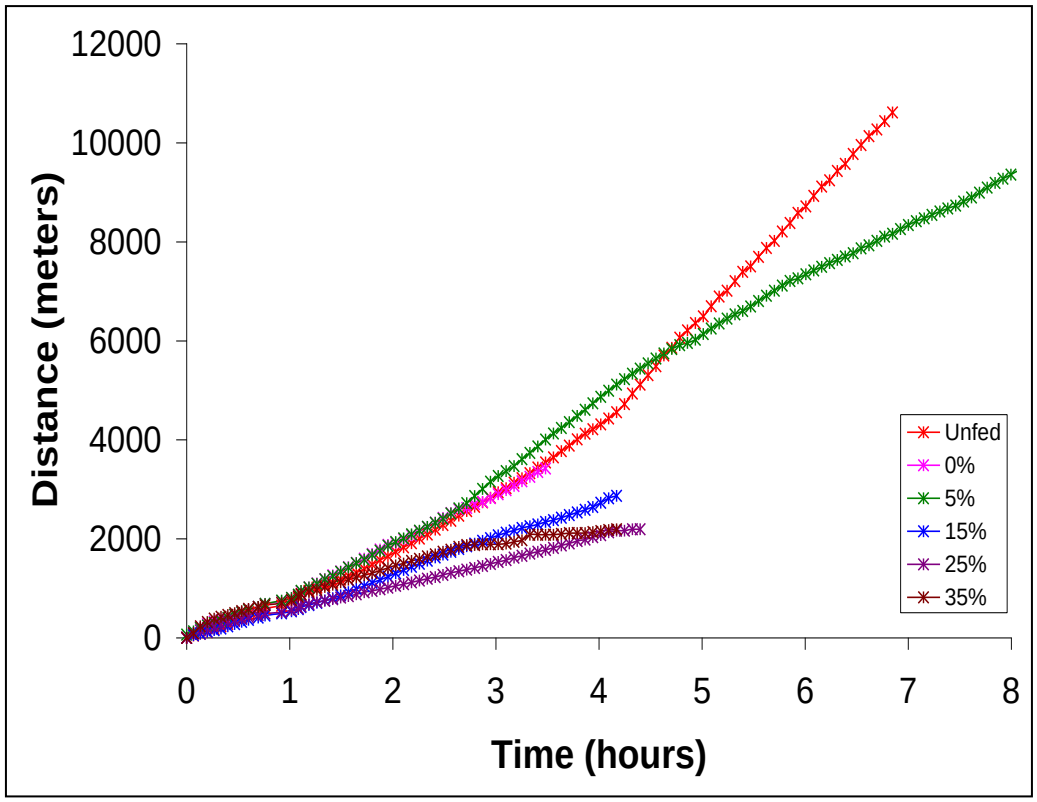
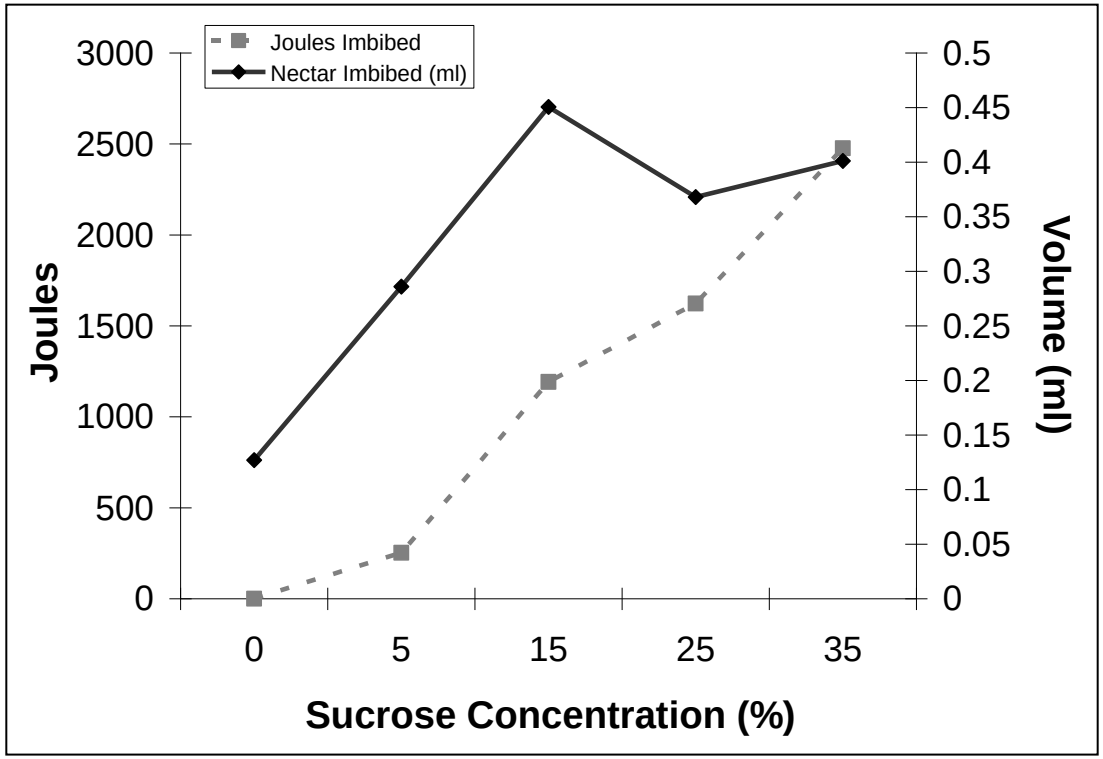
Moths fly farther when starved/very low concentrations of nectar (cut off 15%)



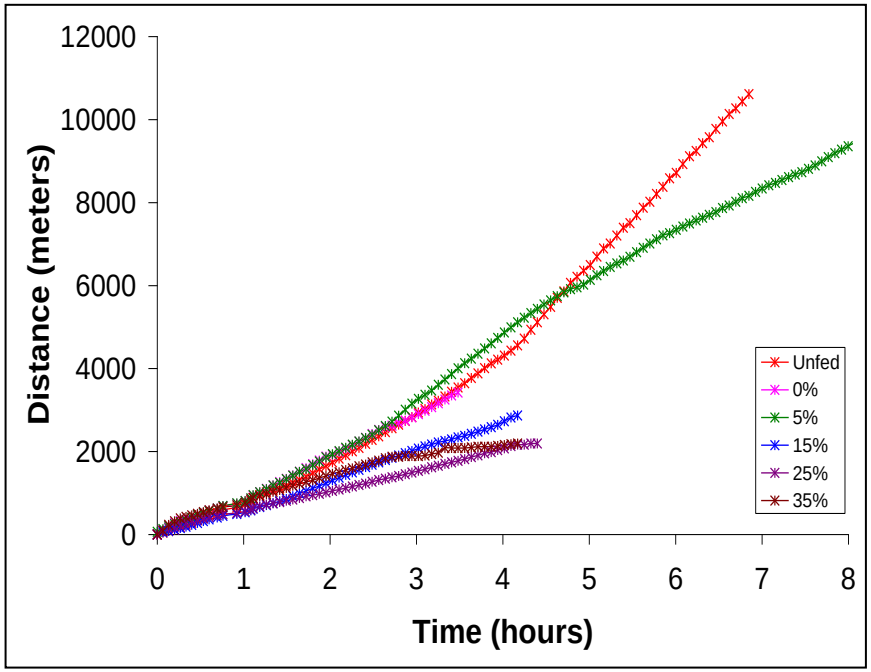
35%
25%
15%
5%
0%
Unfed

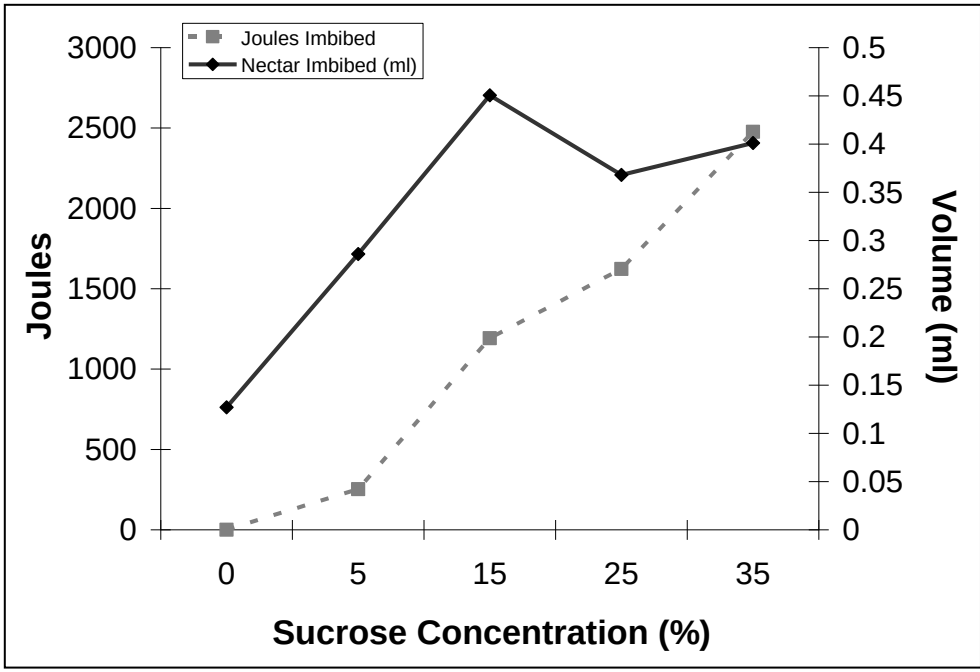
Amount of nectar imbibed increases with nectar concentration <15%

However, the amount of energy from nectar increases steadily with nectar concentration



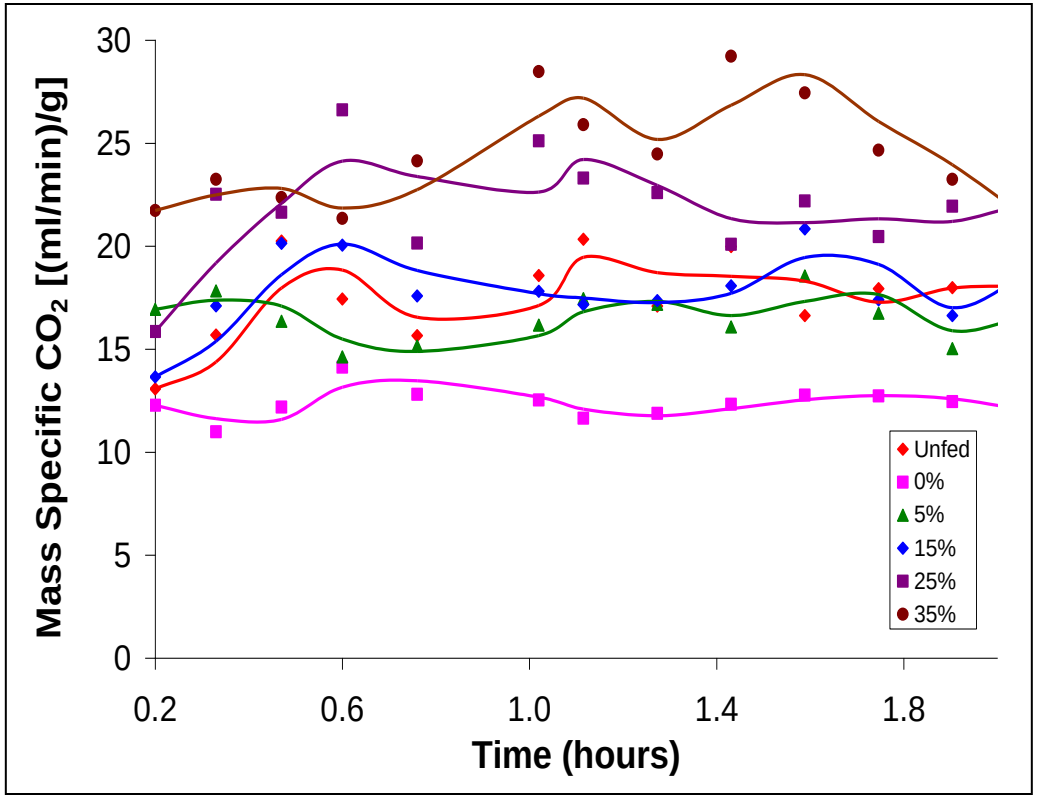
Much of the energy accumulated from nectar is allocated to processes other than flight (reproduction?)





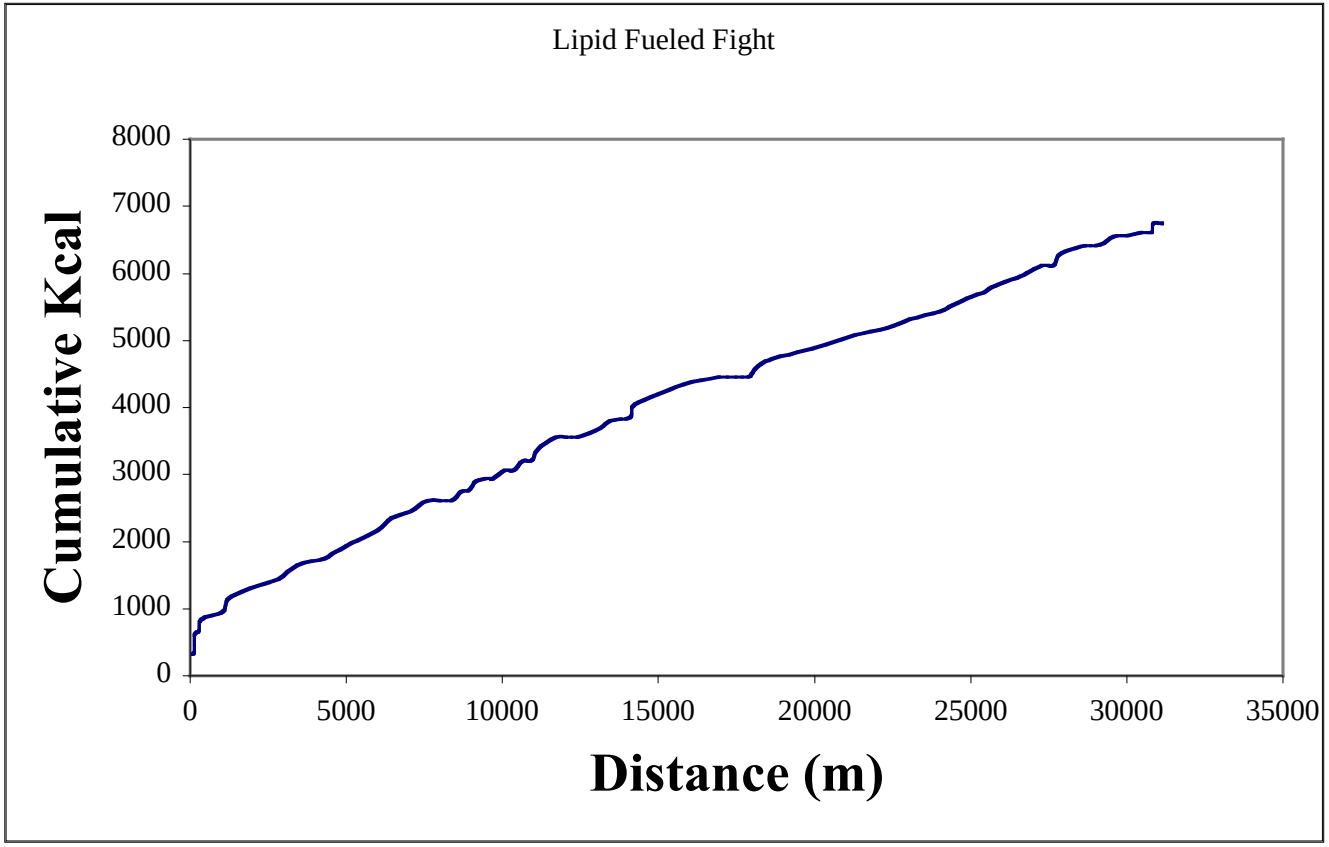

AIR
Davidowitz
BRUTE FORCE
SYSTEM
POWER SUPPLY

Metabolic cost of flight increases with nectar concentration



35%
25%
15%
Unfed
5%
0%

How many eggs does one km of flight cost?



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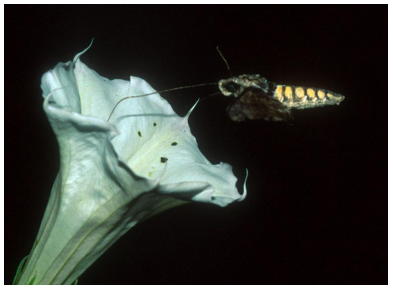
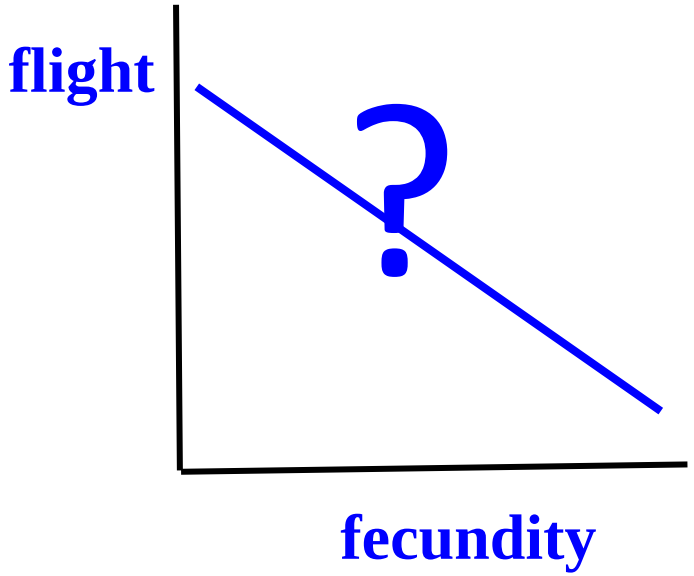
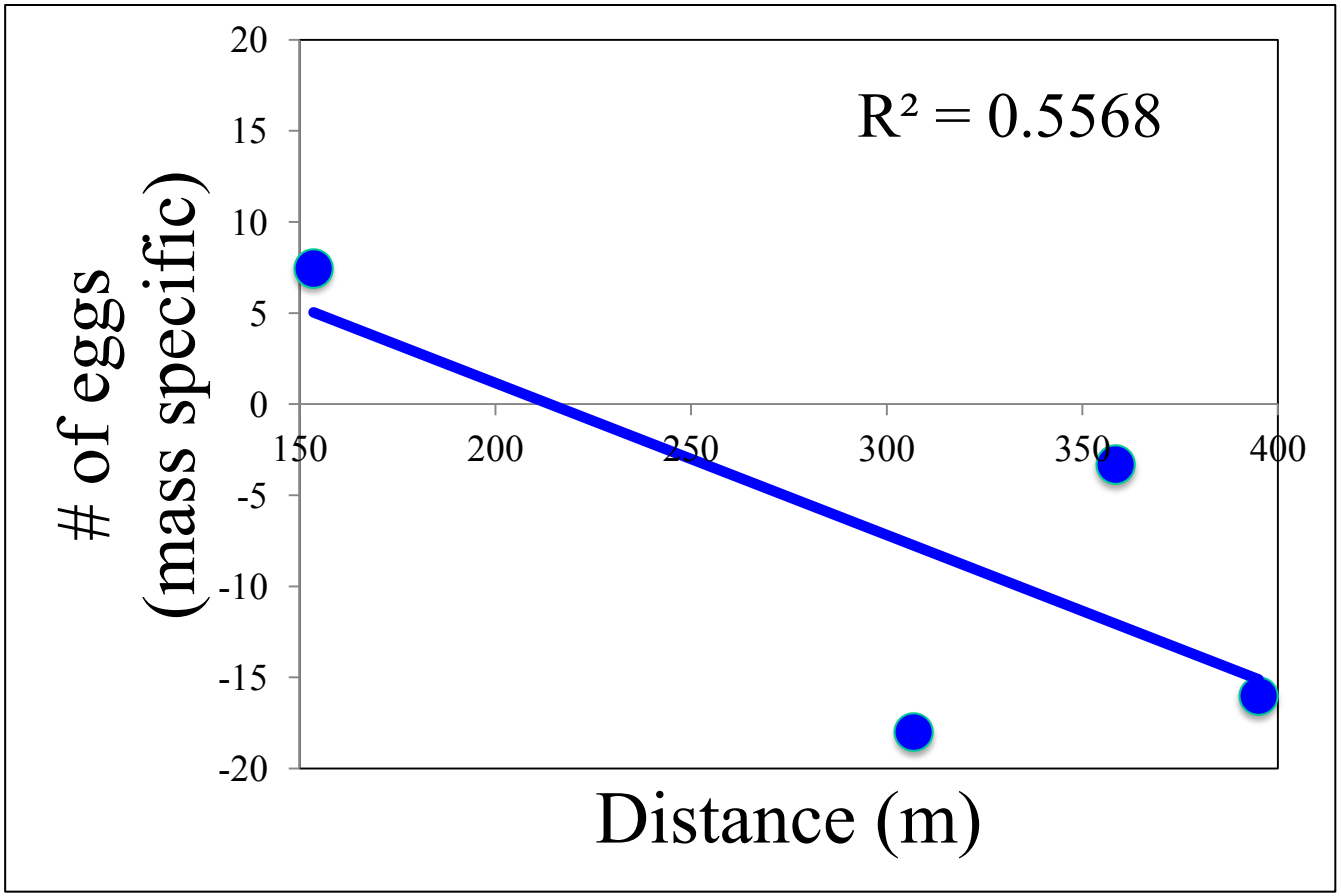




Preliminary data suggests a tradeoff after only a few hundred meters of flight



Summary

- Relative humidity affects hawkmoth abundance and foraging behavior, but not the overall energy budget

- Nectar concentration affects flight performance (metabolic rate and distance)

- Preliminary data suggests a tradeoff between flight and fecundity after only a few hundred meters of flight

Many Thanks To…

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