Correlates of urban mosquito fitness: CSO streams and Culex oviposition choices

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West Nile Virus in Atlanta: Combined Sewer Overflow (CSO) study

Collaborators

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Atlanta Combined Sewer Overflow (CSO) study – ongoing (and growing!)

Am. J. Trop. Med. Hyg., 77(3), 2007, pp. 478–484

Combined Sewage Overflows (CSO) Are Major Urban Breeding Sites for *Culex quinquefasciatus* in Atlanta, Georgia

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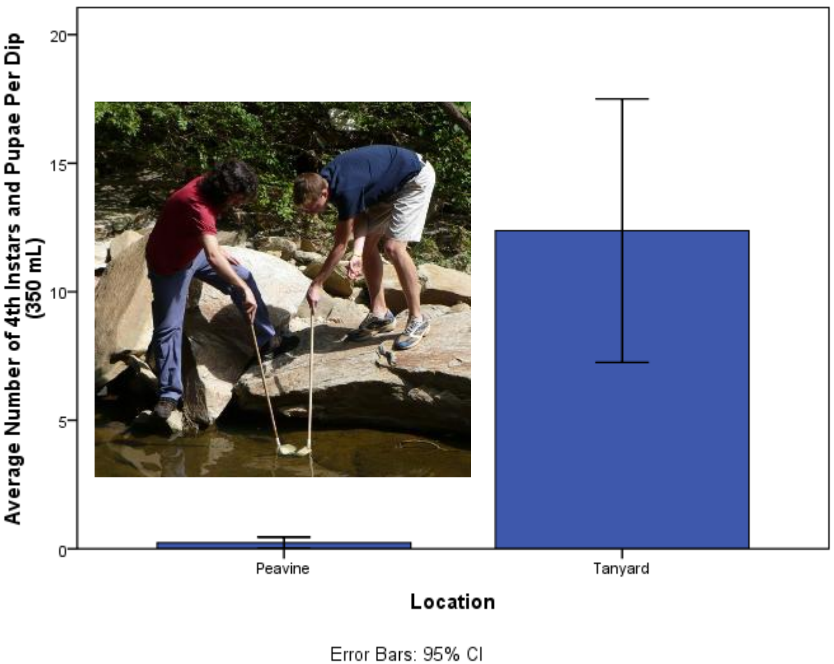


<u>Key questions</u>

Does the high mosquito productivity in CSO's translate in a higher WNV transmission risk?

Particularly,

→How does the CSO larval habitat affect *Culex* spp. fitness, and vector potential?

→ How do the basics of oviposition biology change in CSO streams, and how might this relationship affect fitness?

Descriptions of recent and current projects addressing these questions:
http://www.envs.emory.edu/research/WNV/index.htm

Determinants of Mosquito Fitness

- Adult survival
- Adult fecundity
- Juvenile survival
- Juvenile fecundity
  - Larval nutrition
  - Body size

Female oviposition choices

Affected by
•Nutrient availability
•Presence of microorganisms
•Presence of conspecifics

How does a CSO contribute to attactiveness?

This talk…

- Semi-natural experiments
  - Preferences for CSO versus non-CSO oviposition habitats
  - Egg rafts as an indicator of oviposition choice
  - Effect of oviposition habitat size on oviposition preference
- Further studies on fitness effects (preliminary data), if time permits!

Experiment 1: Preference for CSO versus an alternative oviposition site

Mosquito oviposition is not uniform across different media, so:

- Is there a preference for CSO water in comparison to non-CSO (tap) water?
- Do protein-rich nutrients enhance attraction?
- Can egg rafts be used as an indicator of oviposition choice, or is a trade-off invovled?

Preference for CSO versus non-CSO oviposition site: methods

Carried out on the bank of Tanyard creek, near one of the field sampling sites, using 10gal Rubbermaid containers (with 6 gallons of water each)

Experimental design: 2 x 2 factorial = 4 treatments

1. CSO water (collected 48 hours after a 9400 kGal overflow)
2. Tap water
3. Presence (+) of additional nutrient (24g of dogfood)
4. Absence of added nutrients

Tap	CSO	Tap+	CSO +
Tap	CSO	Tap+	CSO+
Tap	CSO	Tap +	CSO +

Data collection:

Counted and removed egg rafts after 3 days and after 6 days

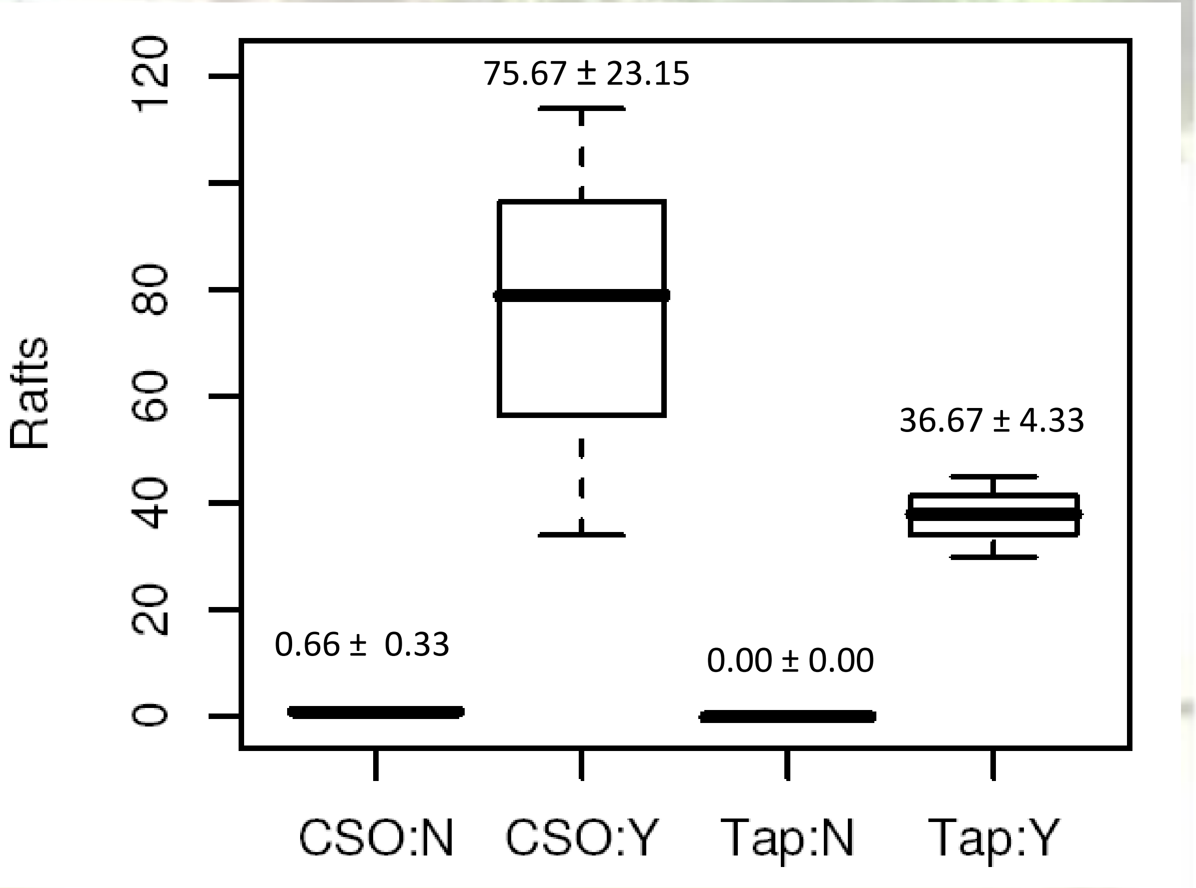
Individuals from 5 randomly chosen rafts per sampling period were allowed to hatch in the lab, identified at 4th instar as *Cx. quinquefasciatus*

Preference for CSO versus non-CSO oviposition site: results

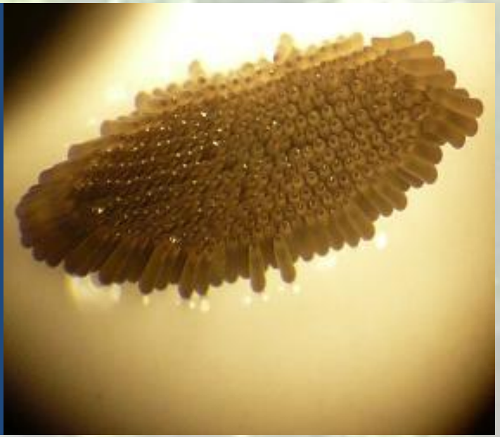
Results:

1. Females oviposit preferentially in containers with added nutrients

2. CSO containers with added nutrients are significantly more attractive than non-CSO habitats with added nutrients



Is the number of rafts a reliable indicator of number of eggs, or is there a trade-off in the number of eggs oviposited per raft in an "undesirable" habitat?



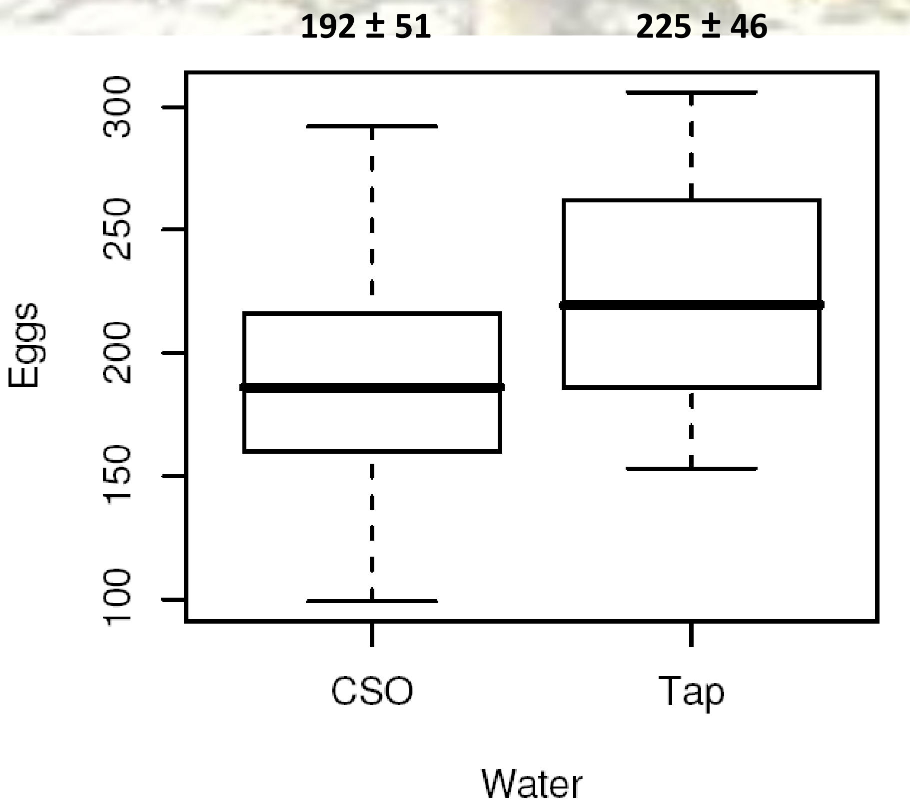
Methods

Counted eggs in15 egg rafts from CSO+ 14 egg rafts from tap+

Compared means with students *t*-test

Results

No significant difference between # eggs per raft in CSO versus tap (t=1.80, df=27, P>0.083)
number of eggs per raft can vary seasonally, so this result is only relevant
for rafts collected at the same time



Experiment 2: Spatial grain of oviposition preferences

- Is the influence of habitat quality on oviposition choices scale dependent?
- How does the attractiveness of each media vary in the presence vs absence of conspecifics?

Semi-natural study sites

Spatial Grain: methods

- 4 clusters of 10 5gal Rubbermaid containers with 3gal of water spaced >75m along a transect following the stream
- Experimental design: 2 factors by 2 levels controlling for the effect of cluster on oviposition preference
- Same 4 treatments as with the previous experiment
- total amount of CSO and tap as well as nutrients or no-nutrient treatments was consistent across clusters

Tap	Tap	Tap	Tap	Tap +
CSO	CSO +	CSO +	CSO +	CSO +

Tap	Tap	Tap	Tap +	Tap +
CSO	CSO	CSO +	CSO +	CSO +

Tap	Tap	Tap +	Tap +	Tap+
CSO	CSO	CSO	CSO +	CSO +

Tap	Tap +	Tap +	Tap +	Tap +
CSO	CSO	CSO	CSO	CSO +

Data collection:

•Counted egg rafts daily for 8-day periods

- 1st 8-day period (July 11-18): egg rafts were **kept** in the containers but sequestered to avoid double counting

-2nd 8-day period (July 19-26): egg rafts were **removed** daily

•25 larvae from CSO and tap treatments kept and identified at 4th instar

•In raft-removal period, 5 rafts kept and hatched

Spatial Grain: methods

Tap	Tap	Tap	Tap	Tap +
CSO	CSO +	CSO +	CSO +	CSO +
Tap	Tap	Tap	Tap +	Tap +
CSO	CSO	CSO +	CSO +	CSO +
Tap	Tap	Tap +	Tap +	Tap+
CSO	CSO	CSO	CSO +	CSO +
Tap	Tap +	Tap +	Tap +	Tap +
CSO	CSO	CSO	CSO	CSO +

Data analysis:

Number of rafts oviposited per container in the last 6 days of each trail were summed (no oviposition in the first 2 days of either trial)

Split-plot linear mixed effects model

- cluster and error as random factors
- interactions between nutrients, water quality, and number of replicates per cluster as fixed factors
- model parameters selected using backwards elimination, based on Akaike information criterion
- models were fit using a restricted maximum likelihood method

Spatial Grain: results when rafts are kept

Keeping or removing egg rafts had an effect on the relative importance of parameters selected for the models

Model selected for non-raft removal (1st period)

$$Rafts_{ijkl} = \mu + \alpha_i(number) + \beta_j(nutrients) + \alpha \times \beta_{ij}(number \times nutrients) + \sigma_k + \varepsilon_{ijkl} \quad [1]$$

where μ = mean number of rafts

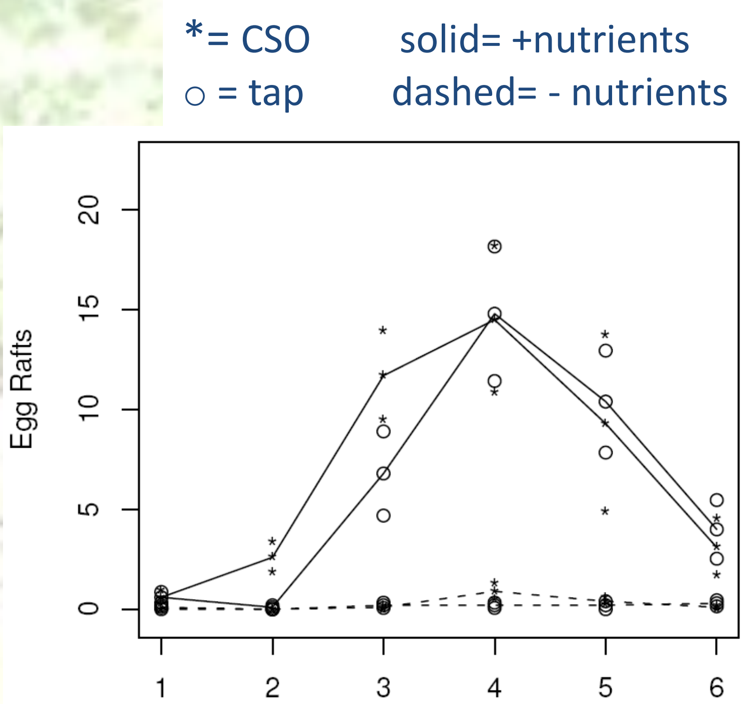
σ = cluster variability

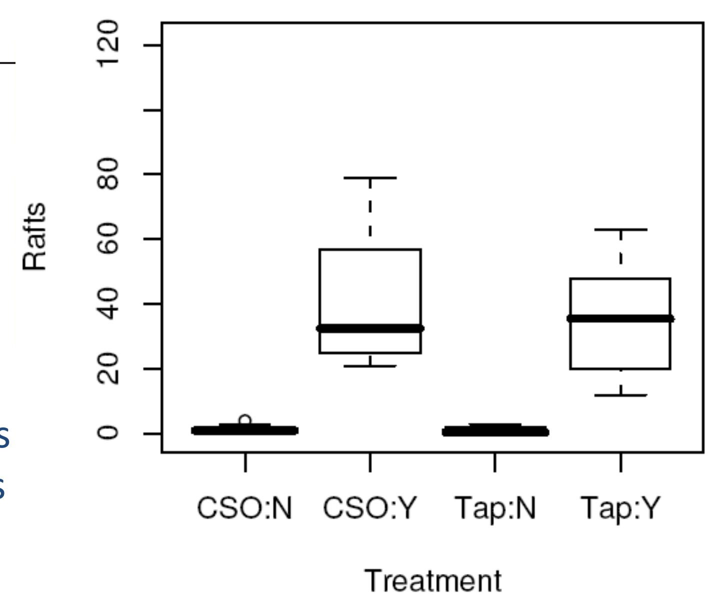
ε = individual container variability

Parameter	No raft removal	
	Estimate	95% CI
Tap ($\hat{\mu}$)	3.973	−14.594 to 22.446
No. containers ($\hat{\alpha}$)	−0.925	−6.367 to 4.705
CSO ($\hat{\gamma}$)	—	—
Nutrients ($\hat{\beta}$)	12.550	−11.699 to 36.522
Containers × nutrients ($\hat{\alpha} \times \hat{\beta}$)	8.300	0.692–15.977[a]
Water × nutrients ($\hat{\gamma} \times \hat{\beta}$)	—	—
Cluster variability VAR($\hat{\sigma}$)	10.982	—
Container variability VAR($\hat{\varepsilon}$)	140.124	—

Findings:

- there is some importance of the interaction between nutrients and quantity, that is more important in presence of conspecifics
- greatest variability is at the scale of the individual container





Spatial Grain: daily egg raft removal results

With raft removal (2nd period):

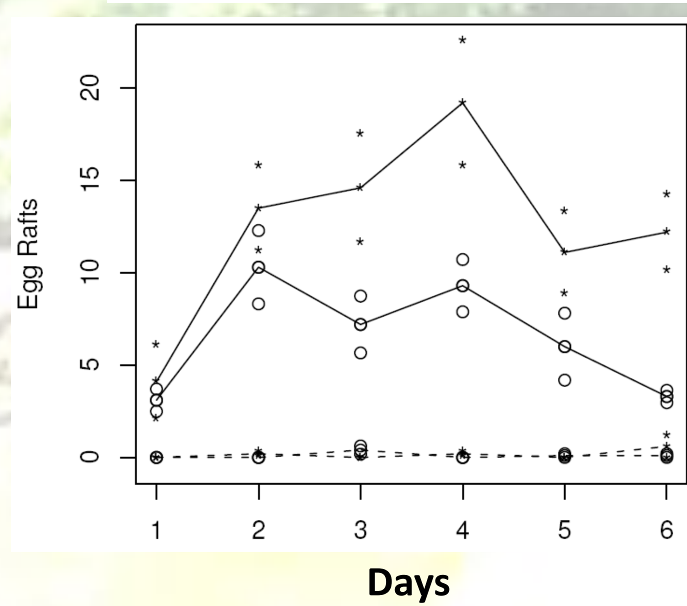
$$Rafts_{ijkl} = \mu + \beta_j(nutrients) + \gamma_i(water) + \gamma \times \beta_{ij}(water \times nutrients) + \sigma_k + \varepsilon_{ijkl} \quad [2]$$

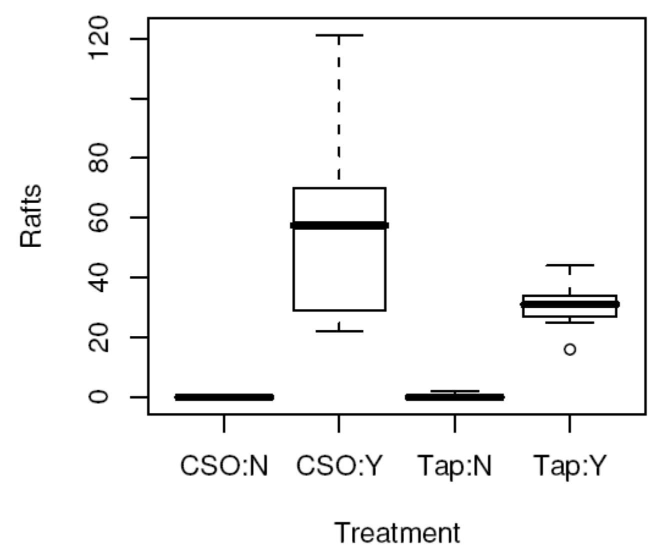
where μ = mean number of rafts
σ = cluster variability
ε = individual container variability

Parameter	Daily raft removal	
	Estimate	95% CI
Tap ($\hat{\mu}$)	1.019	−11.668 to 14.417
No. containers ($\hat{\alpha}$)	—	—
CSO ($\hat{\gamma}$)	−1.238	−15.458 to 12.909
Nutrients ($\hat{\beta}$)	29.462	15.643–44.006[a]
Containers × nutrients ($\hat{\alpha} \times \hat{\beta}$)	—	—
Water × nutrients ($\hat{\gamma} \times \hat{\beta}$)	27.176	6.337–47.586[a]
Cluster variability VAR($\hat{\sigma}$)	28.208	—
Container variability VAR($\hat{\varepsilon}$)	225.569	—

Findings:
- importance of water quantity is decrease, and now the water type and nutrients are most important
- greatest variability is again at the scale of the individual container

*= CSO solid= +nutrients
○ = tap dashed= - nutrients





Overall conclusions

- Nutrient availability was most important factor enhancing oviposition (consistent with other studies)
- Significant effect of interaction of nutrients and CSO water
- Largest variability in oviposition choice was at the level of individual containers
  - Local differences in oviposition medium are most important factor governing oviposition choices
- No trade off in number of eggs deposited in CSO versus tap

→ CSO nutrient pulses and flushing events may alter vector population dynamics by concentrating oviposition and production in CSO streams

→ Preference for CSO streams may confer overall fitness advantages, but may involve trade-offs at different life stages

BEHAVIOR, CHEMICAL ECOLOGY

Combined Sewage Overflow Enhances Oviposition of *Culex quinquefasciatus* (Diptera: Culicidae) in Urban Areas

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J. Med. Entomol. 46(2): 220–226 (2009)

Current and future studies

- Effect of CSO larval habitat on
  - Survival
  - Time to emergence
  - Body size
  - Sex ratio
- Density interactions of CSO vs non-CSO larval habitats
- Significant effect of interaction of nutrients and CSO - what's the mechanism?
    - bacterial communities and/or nutrient processing?
- Interactions with other stream inverts

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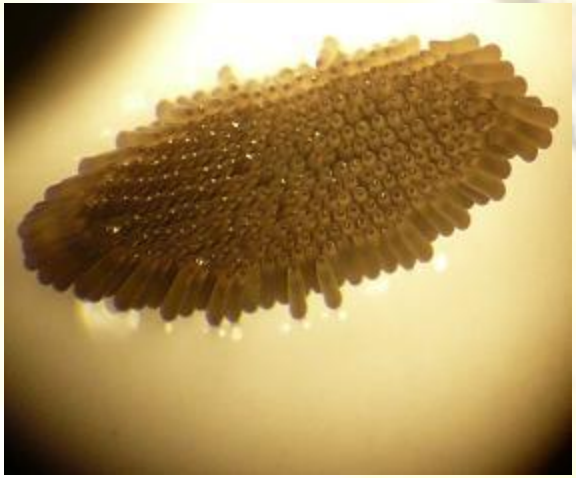


And thanks to GMCA for the opportunity to present this study!

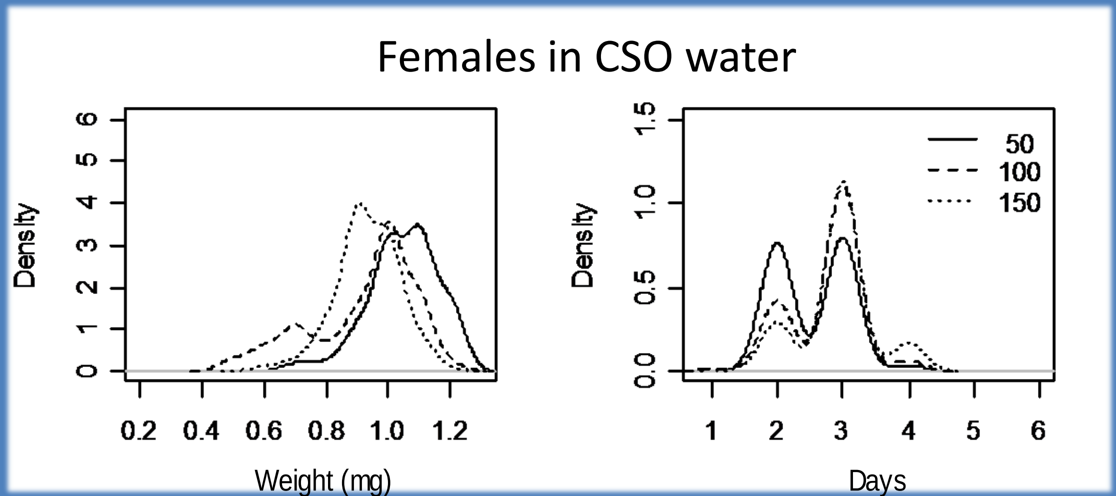
Effect of Density on CSO vs tap survival, sex ratio, and size

- Does development in the CSO larval habitat affect larvae survival, body size, or sex ratio?
- Does larval density affect “?

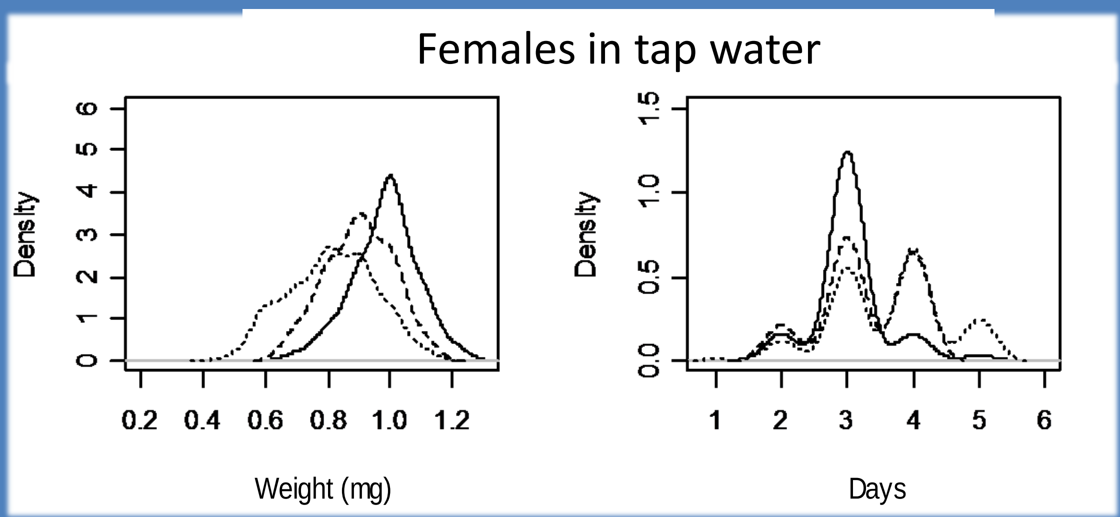
Density dependence: preliminary results

Effects of density on weight and time to emergence of:

CSO

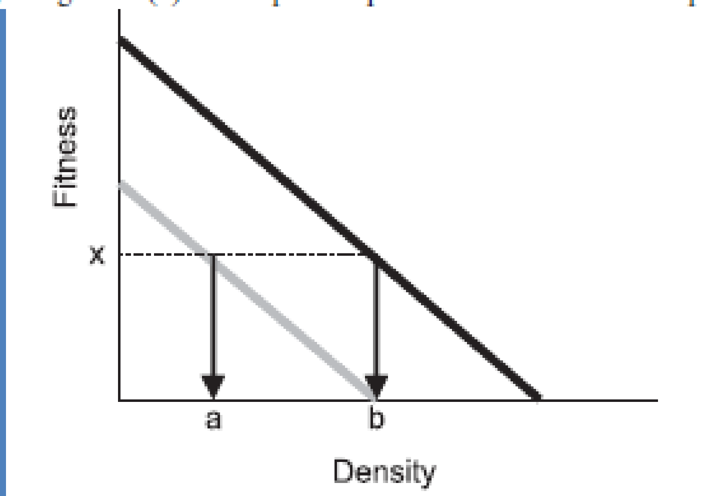


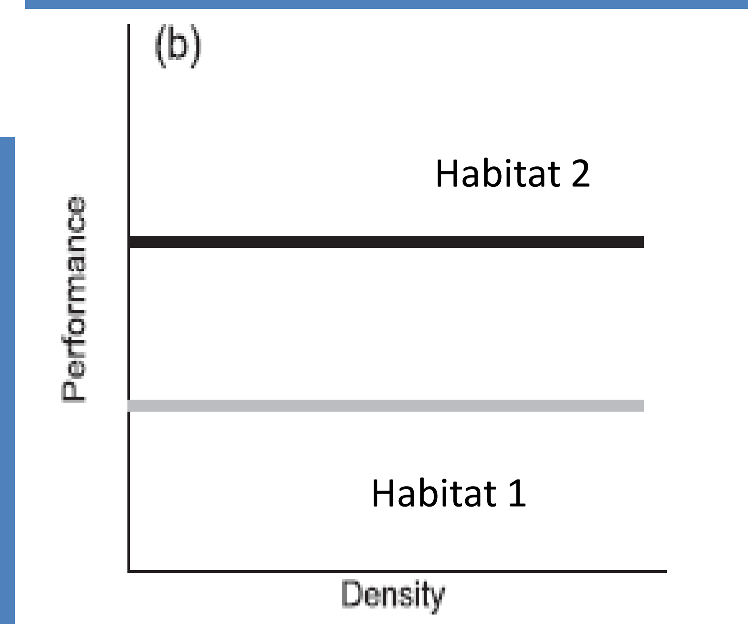
Tap



Ideal Free distribution and mosquito oviposition choice

Fig. 1. (a) Hypothetical example of ideal free distribution. In this example there should be a density of *a* in habitat 1 (grey line) and *b* in habitat 2 (black line) to achieve average fitness of *x* in both habitats. (b) Hypothetical example of the preference–performance hypothesis. Here there is no density dependence, and females should place all offspring in habitat 2 (black line) where offspring performance is always highest. (c) Example of performance relationships for





Habitat 1

Habitat 2

Ellis, A. M. 2008. Incorporating density dependence into the oviposition preference - offspring performance hypothesis. Journal of Animal Ecology **77**:247-256.